Institutional Arrangements for Resource Recovery and Reuse in the Wastewater Sector

by

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Abstract

As populations grow and urban centres expand, meeting water demand and wastewater management requirements will become increasingly difficult. Goal 6 of the Sustainable Development Goals is to: '*Ensure availability and sustainable management of water and sanitation for all*'. Part of the approach to achieving this will be reusing wastewater and will require a greater understanding of the institutional arrangements that support or obstruct reuse. This research was designed to achieve this and aimed to develop a set of factors that investors could use to assess the institutional feasibility of reuse in a given setting. The methodology combined a case study approach, focusing on wastewater systems in Bangalore, India and Hanoi, Vietnam, with triangle analysis to assess: the content of policies and laws; the structures (formal and informal) to implement laws and reuse projects; and the culture around acceptance and engagement in reuse. The reuse practices observed in Bangalore were treatment and use within apartments, centralized treatment and sale to industries, use in agriculture after natural attenuation, groundwater recharge and lake regeneration. In Hanoi the only reuse was indirect use from rivers feeding fish ponds and fields, although formal treatment and use is planned. Critically, both cities have environmental and water resources policies and laws that advocate reuse, as well as related local legislation. However, support for reuse is not reciprocated in industrial, agricultural or fisheries law, the result being that reuse does not always take place as planned. Legislation is required along the whole sanitation chain to the point of wastewater use. Structures to implement reuse are also vital. In Bangalore the water board has initiated reuse projects and established the New Initiatives Division but resources are a limiting factor. Effective institutions include expertise, manpower and financing mechanisms, which are lacking in both cities. The environment agency is also engaged in reuse though legislation on recycling in residential and commercial complexes but guidance for users is inadequate, expectations are perceived to be excessive and monitoring is almost impossible. The driver for reuse is increasingly the benefits observed by users. In the case of apartments this is a reliable water source and reduced costs of water supply. As a result, a private sector in wastewater treatment is becoming established. The active civil society and strong, independent media are instrumental in providing information to potential users and holding authorities to account in Bangalore. Their absence in Hanoi is notable. In summary, institutional elements to be considered are: supportive legislation across all sectors; details of acceptable reuse, deterrents and inducements; budget allocation; structures to enable reuse; strong civil society, NGOs, courts, media and universities providing evidence of suitability and safety; donors and finance mechanisms; and stakeholders willing to use the products. Encumbrances are inconsistent or uncoordinated legislation, lack of cooperation and insufficient benefit sharing or perceptions of benefits along the reuse chain.

Key words

Institutions; stakeholders; triangle analysis; wastewater use; recycling; water reuse; stakeholders; policies; legislation; Bangalore; Hanoi.

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Acronyms and Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
AED	Agency for Enterprise Development
AHFD	Animal Husbandry and Fisheries Department
BBMP	Bruhat Bangalore Mahanagar Palike (Greater Bangalore Municipal Corporation)
BDA	Bangalore Development Authority
BMA	Bangalore Metropolitan Area
BMR	Bangalore Metropolitan Region
BWSSB	Bangalore Water Supply and Sewerage Board
CBO	Community-based organization
CAG	Comptroller and Auditor General of India
CCW	Coalition for Clean Water
CDD Society	Consortium for DEWATS Dissemination Society
CFE	Consent for establishment
CFO	Consent for operation
CGWB	Central Ground Water Board
CII	Confederation of Indian Industry
CIWEM	Chartered Institute of Water and Environmental Management
CMIE	Centre for Monitoring Indian Economy Pvt. Ltd.
COC	Chemicals of Concern
COI	Census Organization of India
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
CREDAI	Confederation of Real Estate Developers' Associations of India
CSE	Centre for Science and the Environment
CSO	Civil Society Organization
CTW	Constructed treatment wetland
CWSS	Cauvery Water Supply Scheme
DAC	Department of Agriculture and Co-operation
DADF	Department of Animal Husbandry Dairying and Fisheries
DAHF	Department of Animal Husbandry and Fisheries
DAP	Diammonium phosphate
DARE	Department of Agricultural Research and Education
DFEE	Department of Forest, Ecology and Environment
DFID	Department for International Development
DFS	Design for Service
DMA	Directorate of Municipal Administration
DOC	Department of Construction
DONRE	Department of Natural Resources and Environment
DPR	Direct Potable Reuse
DST	Department of Science and Technology
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
EC	European Commission
EDC	Endocrine disrupting compound
EKW	East Kolkata Wetlands

EKWMA	East Kolkata Wetlands management Authority
EMPRI	Environmental Management and Policy Research Institute
EPFs	Environmental Protection Funds
ETP	Effluent treatment plant
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCO	Fertilizer Control Order
FD	Fisheries Department
GOI	Government of India
GOK	Government of Karnataka
DOH	Department of Health
HACCP	Hazard Analysis and Critical Control Point
HCMC	Ho Chi Minh City
HUDCO	Housing and Urban Development Corporation Limited
IFAD	International Fund for Agricultural Development
INGO	International Non-governmental Organization
IPR	Indirect Potable Reuse
IWRM	Integrated Water Management
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KCPF	Karnataka Co-Operative Poultry Federation Limited
KFD	Karnataka Forestry Department
KMF	Karnataka Milk Federation
KSPCB	Karnataka State Pollution Control Board
KSDA	Karnataka State Department of Agriculture
KUIDFC	Karnataka Urban Infrastructure Development and Finance Corporation
KUWSDB	Karnataka Urban Water Supply and Drainage Board
LDA	Lake Development Authority
LOC	Law on Construction
LOEP	Law on Environmental Protection
LOWR	Law on Water Resources
LPLD	Law on Promulgation of Legal Documents
MARD	Ministry of Agriculture and Development
MDWS	Ministry of Drinking Water and Sanitation
MID	Minor Irrigation Department
MLD	Million Litres per Day
MOA	Ministry of Agriculture
MOC	Ministry of Construction
MOEF	Ministry of Environment and Forests
MoEFCC	Ministry of Environment, Forest and Climate Change
MOH	Ministry of Health
MOIT	Ministry of Industry and Trade
MOJ	Ministry of Justice
MONRE	Ministry of Natural Resources and Environment

MOST	Ministry of Science and Technology
MOUD	Ministry of Urban Development
MOWR	Ministry of Water Resources
MPI	Ministry of Planning and Investment
MPN	Most probable number
NEP	National Environment Policy
NFDB	National Fisheries Development Board
NGO	Non-governmental organization
NUSP	National Urban Sanitation Policy
NWP	National Water Policy
O&M	Operation and maintenance
PAH	Polycyclic aromatic hydrocarbons
PC	People's Committees
PhAC	Pharmaceutically Active Compound
PHED	public health engineering departments
PPP	Public Private Partnership
QMRA	Quantitative Microbial Risk Assessment
RMC	Recommended maximum concentration
RRR	Resource Recovery and Reuse
RSC	Residual Sodium Carbonate
SADCO	Sewerage and Drainage Company
Sandec	Department of Water and Sanitation in Developing Countries
SAR	Sodium Adsorption Ratio
SAT	Soil aquifer treatment
SDC	Swiss Agency for Development and Cooperation
SDGs	Sustainable Development Goals
SLEIAAK	State Level Environmental Impact Assessment Authority, Karnataka
SME	Small and medium scale enterprises
SOE	State owned enterprises
SPCB	State Pollution Control Board
SSWM	Sustainable Sanitation and Water Management
STP	Sewage Treatment Plant
SuSanA	Sustainable Sanitation Alliance
TAC	Technical Assistance Centres
TIA	Technical Infrastructure Agency
TCN	Branch standard
TCNV	Vietnamese standard
TC	Manufacturer/Base standard
TCV	Local standard
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TTP	Tertiary treatment plant
UASB	Upward flow anaerobic sludge blanket
ULB	Urban Local Body
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund

URENCOs	Urban Environmental Companies
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
VEA	Vietnam Environment Administration
VFF	Vietnam Fatherland Front
VUFO-NGO	Vietnam Union of Friendship Organisations-NGO Resource Centre
VUSTA	Vietnam Union of Science and Technology Associations
VWU	Vietnam Women's Union
WASA	Water and Sanitation Agency
WEDC	Water Engineering and Development Centre
WHO	World Health Organization of the United Nations
WGUIWSS	Working Group on Urban and Industrial Water Supply and Sanitation
WQAA	Water Quality Assessment Authority
WRD	Water Resources Department
WSP	Waste stabilization pond
WSS	Water supply and sanitation
WW	Wastewater
WWC	World Water Council
WWT	Wastewater treatment
WWTP	Wastewater treatment plant
WWTU	Wastewater treatment and use
YMSK	Yele Mallappa Shetty Kere

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1 Introduction

1.1 Chapter Outline

This chapter introduces the thesis, explaining the background to the study and the reasons why it is important to identify institutional arrangements around wastewater use. It describes the water supply and sanitation context that prevails globally but most particularly in parts of Asia and Africa, where access to water supply and sanitation is poor, and incidents of water related disease are high. The chapter presents the research question, defines the scope of the study and explains how the research will contribute to knowledge. It concludes with an outline of the composition of the thesis.

1.2 The Research Context

This study is set in the context of diminishing water resources, due to growth in demand, increasing water pollution, and inadequate access to sanitation. The current trajectory and existing modes of sanitation are not expected to lead to any significant breakthrough in the near future. However, wastewater use could be an important component of an integrated water resources management (IWRM) approach that provides greater access to water for various users and improves sanitation. As such, reuse could contribute significantly to a number of the Sustainable Development Goals (SDGs), especially elements of Goal 6 on ensuring 'availability and sustainable management of water and sanitation for all' (UN, 2013).

1.2.1 Population Growth and Water Resources

The growth in water and sanitation demand is driven by the increase in the global population and changes in lifestyle. The global population is rising by approximately 1.2 percent per annum and the total global population is expected to reach 9 billion by 2030 (Winpenny et al., 2010). Much of this growth will be in urban areas of developing countries, which are among the least able to cope. In Africa and Asia the urban populations are expected to double between 2000 and 2030; and by 2030 the towns and cities of the developing world will make up 81 percent of the global urban population (UNFPA, 2007; UNESCO, 2009). Trying to provide water for this burgeoning population to drink, grow and process food, and manufacture goods is a difficult task that will only get harder. Urbanization, improvements in living standards and changing behaviour are all increasing demand for water. One fifth of the world's population - 1.2 billion people - live in areas of water scarcity, and this is projected to increase to 3 billion by 2025 (Corcoran et al., 2010).

Water pollution adds to this stress. Around 80-90 percent of domestic water is not consumed and returns to the environment as wastewater, as does 90-95 percent of industrial process water and 10-50 percent of irrigation water (UNESCO, 2009). Based on existing trajectories, by 2050 almost half the available fresh water may not be available due to pollution. Figure 1-1 shows projections both for increasing demand for water and reductions in the availability of water as sources become polluted. If managed correctly however, this wastewater could become a resource rather than a pollutant. Urban areas offer great potential for this because of numbers of wastewater producers in a concentrated area, which makes collection and treatment more cost effective.

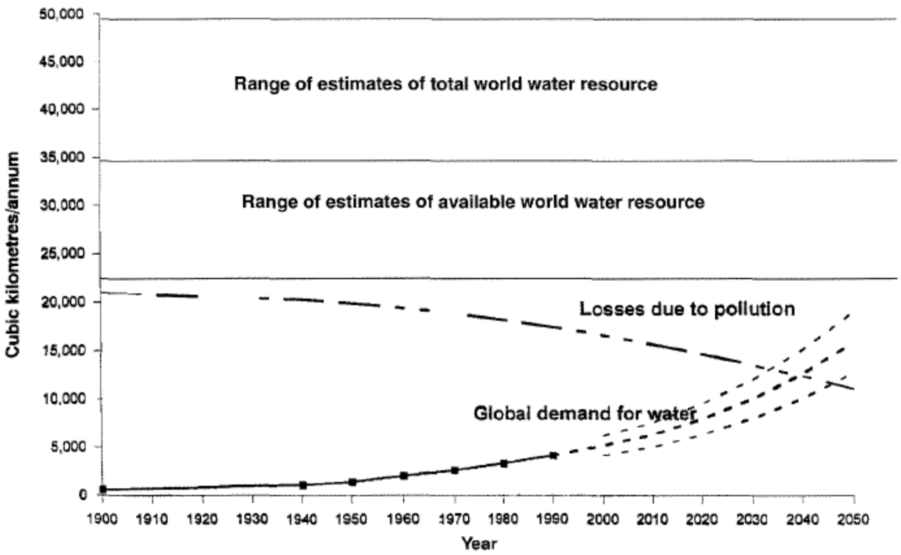


Figure 1-1. Scenarios for world water resources and demands
Source: Rodda (2001)

1.2.2 Domestic Water Supply and Sanitation

The growing demand for domestic water is reflected in the most recent figures from the United Nations Children's Fund (UNICEF) and World Health Organization (WHO) Joint Monitoring Programme (JMP) for Water Supply and Sanitation (WSS), which show that over 2.5 billion people gained access to improved water sources between 1990 and 2015 (UNICEF and WHO 2015a). This is significant progress but produces new conditions that must be managed if the full benefits of improved WSS are to be felt. Furthermore, 663 million individuals still lack access to an improved source of drinking water (UNICEF and WHO, 2015a). In terms of sanitation, although 2 billion people gained access to improved facilities between 1990 and 2015 a further 2.4 billion people remain unserved (WHO and UNICEF, 2015). Most of these people are in Asia and sub-Saharan Africa (Figure 1-2).

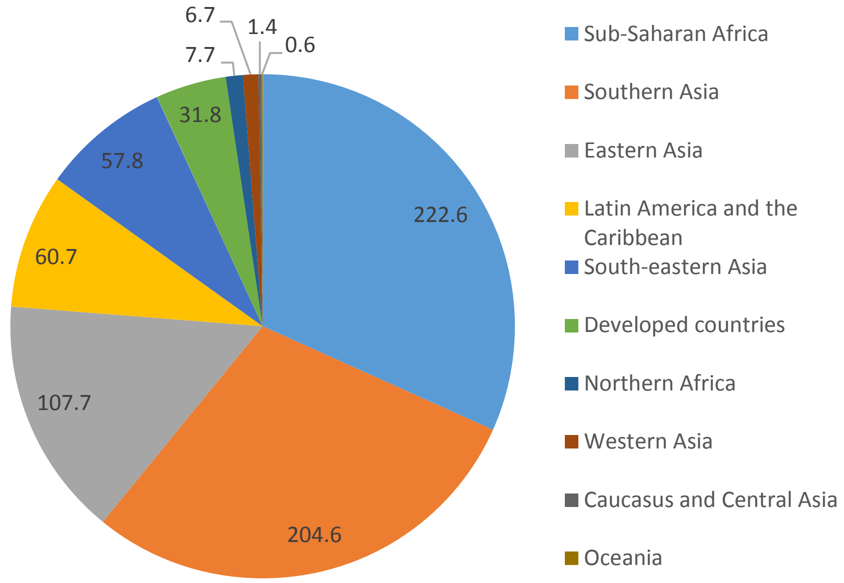


Figure 1-2. Regional distribution of people without improved sanitation facilities in 2015 (population in millions)
Source: Developed from WHO and UNICEF (2015)

It should also be noted that 'improved sanitation facilities' does not take account of collection, treatment or hygienic management of facilities nor does it cover domestic grey water. In many cities in developing countries grey and black water, and urban runoff, enter open water bodies, drains and canals, often to be used downstream. Worldwide, two thirds of the sewage from urban areas is pumped untreated into lakes, rivers, and coastal waters; in developing countries this figure climbs to 90 percent (ADB, 2008; Corcoran et al., 2010). Even where sewers do exist much domestic wastewater remains untreated (Table 1-1).

The combination of adequate sanitation facilities and proper wastewater disposal is critical because microbial contamination from domestic wastewater has a significant effect on human health (UNESCO, 2009; Corcoran et al., 2010). A measure of this contamination is the number of water disease related deaths per 100,000 inhabitants. This figure is less than 15 in most developed countries but is 30-100 across almost all of South Asia, rising to 100-200 in certain parts of Asia. In most of Africa, figures range from 200-400 and exceed 400 in some countries (Corcoran et al., 2010).

Table 1-1. Wastewater generation and treatment in Asia

Country	Volume of wastewater generated (km^3 yr^{-1})		Volume of wastewater treated (km^3 yr^{-1})		Percentage of wastewater treated[1]
	Reporting year	Volume	Reporting year	Volume	%
Bangladesh	2000	0.725	ND	ND	-
Bhutan	2000	0.004	ND	ND	-
Cambodia	2000	1.184	1994	0.0002	-
China	2006	53.700	2004	22.100	-
India	1996	25.410	2004	2.555	-
Japan	2007	28.500	2008	14.250	-
Laos	2000	0.546	ND	ND	-
Malaysia	1995	2.690	1995	0.398	14.80
Maldives	2000	0.004	ND	ND	-
Mongolia	2002	0.126	2002	0.083	65.87
Myanmar	2000	0.017	ND	ND	-
Nepal	2006	0.135	2006	0.006	4.44
Pakistan	2000	12.330	2000	0.145	1.18
Philippines	1993	0.074	1993	0.010	13.51
Republic of Korea	1996	7.947	1996	4.180	52.60
Singapore	2000	0.470	ND	ND	-
Sri Lanka	2000	0.950	ND	ND	-
Thailand	2007	2.191	2007	0.523	23.87
Viet Nam	2003	1.100	2003	0.250	22.73
Kazakhstan	1993	1.833	1993	0.274	14.95
Kyrgyzstan	2006	0.701	2006	0.148	21.11
Tajikistan	1999	0.026	1998	0.061	-
Turkmenistan	2000	1.181	1994	0.025	-
Uzbekistan	2001	2.200	2001	2.069	94.05

Source: Sato et al. (pers. comm., 2011); in Evans et al. (2012)
[1]Only calculated for countries where generation and treatment figures are for the same year.
Note: “ND” indicates that data are not available for that year.

1.3 Justification for the research

Evidently there is a need for a new approach to wastewater management and water supply, especially in growing cities. The disparity between the quantities of wastewater generated and treated (Table 1-1) gives considerable scope for the introduction of reuse systems as a solution. Where sewers exist and where a high percentage of the urban populations is connected to them (Table 1-2) end of pipe treatment and reuse could aid in cost recovery and provide a substantial quantity of water for various uses. In cities where sewerage is lacking, reuse could provide an incentive for collection and treatment or stimulate new models such as on-site or condominium collection and treatment (Laugesen and Fryd, 2010) or application to land.

Table 1-2. Development of connections to sewer systems in urban areas (regional averages)

Region	Connected urban population (%)	
	1988-1994	**2003-2006**
European Union, North America, Australia		87-92
MENA	72	83
South Asia	31	31
Southeast Asia	3	3
China	38	56
Russia, Georgia, Kazakhstan, Kyrgyzstan, Uzbekistan	82	83
Latin America and the Caribbean	56	64
Sub-Saharan Africa	26	19

Source: Evans et al. (2012)

If wastewater reuse could be introduced or expanded it could provide the following benefits:

- Protect receiving water bodies and the people who depend on them.
- Create value that can support the sanitation chain, including operation and maintenance (O&M) costs and potential capital investment (Rao et al., 2015).
- Provide an alternative water source to water users and city residents.
- Provide additional benefits to local communities (e.g. food or fuel, if used for agriculture or aquaculture, or jobs if used in industry).

It is important that reuse systems should not contribute to inequity or unduly disrupt existing livelihoods patterns or environmental conditions. For example, an unacceptable system would be one that took untreated wastewater currently used by farmers, treated it and sold the higher quality effluent to new users without making provision for the farmers.

1.4 The Research Question

The research was therefore designed to answer the question: ***What institutional arrangements support or hinder wastewater reuse*?** This question was designed to meet the aim of identifying '***a set of key institutional factors that are necessary for wastewater reuse and that can be used by stakeholders to: determine whether the institutional context is conducive to wastewater reuse and identify barriers that need to be removed to facilitate reuse*'.** This would enable investors to decide where to develop wastewater reuse and in what form.

The study was based on a case study methodology, examining the phenomena of institutional arrangements surrounding wastewater use within a city.

1.5 Contribution to Knowledge

1.5.1 Institutional Aspects of Wastewater Use

Research around wastewater use has largely focused on investigating traditional practices, health effects and agricultural impacts, as well as developing new technologies. By contrast there has been much less work to understand the formal and informal institutional arrangements that surround reuse. Elements of institutional arrangements are included within a variety of studies on health, agricultural practices, technology trials, and country water and sanitation studies, or they cover elements of institutional arrangements, such as policy, stakeholders or practices, but not a holistic analysis. Research that unpicks the necessary institutional conditions for the success of wastewater use covering formal policy reviews, informal institutions and stakeholder analysis are much less available in published literature.

Globally wastewater reuse is a limited phenomenon (with notable exceptions) (FAO, 2015). The reason is multifaceted and includes access to appropriate technologies, lack of expertise, and financial and cultural aspects but surrounding all of these are institutional dimensions. For example, access to technologies is influenced, among other things, by import tariffs and trade agreements; financial barriers are as much due to absolute lack of funds as inadequate credit arrangements or relationships with lenders; and expertise can be increased through investment in education and research organizations. This study was designed to provide insight into these factors and furnish stakeholders, such as governments, donors and private sector organizations, with practical information about institutional arrangements that can be developed or altered to encourage reuse.

1.5.2 Sustainable Development Goals

Increasing wastewater reuse is vital if the world is to meet its water and sanitation needs. The recently developed SDGs have as their sixth goal, to '*Ensure availability and sustainable management of water and sanitation for all'* (UN, 2015). The reuse of wastewater would contribute to both elements of this goal in several ways. Firstly it would contribute directly to achieving component 6.3 which relates to the improvement of water quality through reduced pollution, halving the proportion of untreated wastewater and increasing recycling and safe reuse globally. Reuse would support access to sanitation as set out in component 6.2 and increase water availability within cities, thus contributing to component 6.1 on access to safe and affordable drinking water for all and to 6.4 on reducing the number of people suffering from water scarcity. Reuse could also benefit the wider environment by protecting and restoring water-related ecosystems (component 6.6) (UN, 2015).

Understanding institutional barriers to reuse and identifying supportive institutional arrangements could also support efforts to achieve:

- SDG 2 on ending hunger, achieving food security and improving nutrition because wastewater is often used in urban and peri-urban agriculture;
- SDG 3 on ensuring healthy lives because better wastewater management and treatment will reduce water-borne and water related diseases (3.3) as well as reducing the number of deaths and illnesses due to water and soil pollution (3.9); and
- SDG 9 on infrastructure and sustainable industrialization, because industries can benefit from reliable supplies of good quality treated wastewater and because reuse technology development is in itself a growth industry (UN, 2015).

1.5.3 Institutional Analysis Methods

The research also contributes to knowledge in another respect. As already stated, there is little published material on institutional analysis of wastewater reuse and there is a similar inadequacy of available documentation on the process of conducting an institutional analysis that spans several policy sectors as well as encompassing a huge range of stakeholders, as is the case for wastewater reuse. Hence, the final element of the study is to evaluate the institutional analysis process and the efficacy of a feasibility study for investment in reuse based on the factors identified in the project. It also assesses the extent to which such an analysis is possible through desk review only.

1.6 Scope of the Study

This study focuses on understanding the institutional and organizational arrangements that support the start-up and continued operation of wastewater reuse systems that make use of domestic wastewater. The study considers domestic wastewater only but with acknowledgement that it is not uncommon for wastewater from domestic and small-scale industrial premises to be mixed. Domestic wastewater is the focus because the intention is to find solutions that could contribute to improved domestic sanitation and because, although domestic wastewater contains pathogens that need to be destroyed, it contains fewer chemicals than industrial effluent. These chemicals generate diverse risks, require different treatment and are governed by more stringent legislation. To consider industrial and agricultural wastewater would substantially extend the legislation and stakeholders to be included.

The study is concerned only with urban areas but considers all forms of wastewater use within the city boundary (e.g. in agriculture, within apartments, and using various treatment systems).

The research encompasses formal and informal institutional arrangements. This includes: existing policies and laws, as well as the organizations that are established to implement or enforce them; and the behaviours and beliefs of stakeholders in the wastewater chain, including water users, suppliers and nearby communities.

There are many more factors that contribute to the successful establishment and sustained functioning of wastewater reuse systems including the market, competition and financial viability. All these are essential components but are not be investigated in this study.

1.6.1 Terminology

It is important to note that there are a number of terms employed to describe the use of wastewater. They are often used loosely and interchangeably but some distinctions can be made. Wastewater use or reuse usually refer to the use of untreated wastewater, although some experts feel that wastewater reuse is a misnomer as it is the water, not the wastewater, being reused and therefore prefer the term water reuse. However, water reuse can imply that the water has been treated. Other terms are discussed in the literature review. In general in this study the terms 'wastewater reuse[1]' or 'resource recovery and reuse' (RRR) are used to describe the use of wastewater in general, treated or untreated. Where it is obvious that the wastewater has not been treated the term 'wastewater use' may be used or where it has definitely been treated the term 'water reuse' may be used. The term RRR refers to the recovery of all resources contained within wastewater (water, nutrients and energy) but in this study the focus is on water.

1.7 Composition of the Thesis

The thesis begins in **Chapter 1** with an introduction to the study, the main components of the work and how the research will contribute to knowledge. **Chapter 2** comprises a review of the literature on wastewater reuse and institutional analysis. It mainly concentrates on developing countries, setting the context of water supply and wastewater management, population pressure and other

[1] Technically this is inaccurate terminology but it helps to distinguish between treated (water reuse) and untreated (wastewater use).

factors contributing to a rise in water demand, wastewater generation and the need for integrated solutions to urban water management. It emphasises the body of work conducted on wastewater use in agriculture, and the implications for livelihoods and health. It covers the major developments in wastewater reuse policies, principally the WHO Guidelines and the United States Environmental Protection Agency (USEPA) guidelines, and gives examples of some national policies. The second half of the chapter is dedicated to a literature review of stakeholder, policy and institutional analysis. **Chapter 3** provides a detailed explanation of the research question and aims, as well as the research and analysis methods. The first step in the research is a mapping of wastewater reuse projects across the globe. This is presented in summary in **Chapter 4** where each reuse example is described in approximately half a page including a brief description of the RRR system, the stakeholders and any distinctive institutional arrangements. The mapping leads onto the case study of Bangalore, India in **Chapter 5**. This is a detailed case study that describes the WSS context of the city, reuse examples that were studied as part of the research, an analysis of the stakeholders involved in the sector and the institutions that govern their interactions. A similar methodology is used for a second city, Hanoi, in **Chapter 6,** but in this case the majority of the information is based on secondary sources and policy documents. The institutional arrangements for both cities are presented in **Chapter 7: The Discussion,** which provides a summary of the institutional arrangements for reuse, a comparison of the findings in each city and a set of indicators for institutional support for wastewater use developed from the case studies. The report concludes in **Chapter 8** with a summary of the reuse systems, stakeholders and instructional arrangements in the case study cities; a review of the institutional factors that contribute to or hinder reuse; assessment of their utility for investors seeking to determine the feasibility of reuse in other cities; and recommendations for further study.

2 Literature Review

2.1 Chapter Outline

The background to this study is that there is a growing demand for water, especially in urban areas of developing countries, but that supply is unable to keep pace. Similarly, sanitation provision and wastewater treatment (WWT) are woefully inadequate in many parts of the world. As a consequence wastewater is abundant and its use is growing. In some cases reuse practices are informal or unplanned and often involve little or no treatment. They may be highly beneficial to livelihoods and the economy but may pose risks to human or environmental health. In other cases they may be planned and formal, usually, but not always, involving treatment. Increasingly, wastewater RRR is seen as an essential component in efforts to extend potable water supplies, enhance food security, optimize industrial and recreational water use, and adapt to climate change (Wichelns et al., 2015).

This chapter, sets out the argument for why wastewater reuse is important for: meeting water demand, conserving precious resources, protecting water bodies, and contributing to healthy and productive lives. It makes the case that water demand is growing, particularly in developing country cities where populations are expanding and urbanization is taking place at a pace never before experienced. To demonstrate this, the chapter provides key statistics on population growth, urbanization and WSS coverage. It also outlines other reasons for wastewater RRR such as environmental protection and as an alternative treatment.

The chapter then discusses the forms of wastewater reuse that are taking place throughout the world. It includes both formal and informal reuse, using treated, partially treated and untreated wastewater. The risks and benefits of these practices are reflected on, including socio-economic, environmental and health risks, as well as mitigation measures. The chapter does not go into detail on each reuse type or specific cases (this is covered in Chapter 4).

Literature on attitudes and perceptions to wastewater reuse is also examined, including what drives people to engage in wastewater reuse and what is required to ensure support for reuse projects.

Internationally there has been a huge body of work on the development of guidelines for wastewater reuse. Most notable of these are the guidelines coordinated by the WHO. In addition there are national guidelines and regulations that have taken on international significance or are often referenced by other countries for example the USEPA and United States Agency for International Development (USAID). The chapter discusses the main components of these guidelines, the opinions of other researchers and practitioners and how they may contribute to (or hinder) the development of national policies and processes.

The chapter concludes with a section on institutional arrangements and methodologies for analysing institutional arrangements.

2.2 Literature Review Strategy

The literature review was undertaken using a number of databases: Loughborough University Catalogue Plus, Google Scholar, Science Direct and Wiley Online Library. The broad term of ‘wastewater’ was used to see the breadth of the field of literature and to enable consideration of further search terms. This was modified to combinations such as ‘wastewater and reuse’, ‘wastewater and policy’, ‘wastewater and institutions’. In some cases where results were limited (for example ‘wastewater and policy’ only gave 13 hits on Science Direct) more simple terms were used such as policy or institutions, in an attempt to broaden the field before honing in on the water and reuse sectors. Once key journals had been identified these were searched over a 10 year period for other relevant documents.

A number of important books and reports were identified, especially in the field of wastewater reuse in agriculture. For example reports by the WHO, USEPA, the Food and Agriculture Organization of the United Nations (FAO) and IWMI. These were used as a resource in themselves and to find major authors in the sector.

Another approach was to search the websites of organizations known to work in the field and which would be publishing or storing relevant documents, such as the Swiss Federal Institute of Aquatic Science and Technology (EAWAG), the Water Engineering and Development Centre (WEDC), the Sustainable Sanitation Alliance (SuSanA), IRC, IWMI, the World Water Council (WWC), the Asian Development Bank (ADB), the World Bank and the African Development Bank (AfDB).

All documents were stored in Mendeley where documents are searchable by author, title and content. An Excel spreadsheet was kept to document major searches and organization websites.

2.3 Why is Wastewater Use Taking Place?

The combination of rising water demand and limits to freshwater availability is possibly the most widely reported reason for wastewater reuse (USEPA and USAID, 2012; Lautze et al., 2014; Srinivasan and Reddy, 2009), although it may be one of many. Factors that contribute to this are population growth, urbanization and changes in living standards (Hanjra et al., 2012; Scheierling et al., 2010; Carr, 2005). These same factors increase the quantity of wastewater generated, which itself contributes to wastewater use (Raschid-Sally and Jayakody, 2008; Scheierling et al., 2010) especially where infrastructure does not exist to contain or treat it.

It is increasingly difficult to find and utilize new sources of water to meet demand (Niemczynowicz, 1999) and there are progressively more calls to make use of wastewater so that it becomes part of the solution rather than the problem. Miller (2006) believes that '*Water reuse represents a viable, long-term solution to the challenges presented by growing municipal, industrial, and agricultural demands for water*', while Angelakis and Durham (2008) broadly state that '*Water reuse is a water scarcity solution.'*

Water demand is not the only driver, for example, Scheierling et al. (2010) list '*increasing water stress, in part due to climate change; increasing urbanization and growing wastewater flows*' as the main drivers for wastewater use in agriculture but add to this the fact that '*more urban households [are] engaged in agricultural activities'*. USEPA and USAID (2012) and Lautze et al. (2014) make the distinction between drivers for water reuse and wastewater use, with the former being due to water demand and the desire to capture the economic benefits of wastewater flows, and the latter as a result of insufficient WWT leading to wastewater entering the environment and being used in resource constrained settings. Drivers can vary depending on location, existing infrastructure, the quality of the wastewater and the use to which the water is being put.

There are many other factors that some authors term drivers, such as economic and health benefits, but it is difficult to determine whether these are indeed drivers or the benefits associated with wastewater use. Hanjra et al. (2012) use a useful term, grouping these components into 'backdrop'. The view taken in this chapter is that there are four main, interconnected drivers, the importance of which varies by location due to hydrological and economic resources, and populations:

- Water demand and supply.
- Water pollution and protection.

- Wastewater generation and management.
- Wastewater treatment.

2.3.1 Urban Growth and Water Demand

Today, 54 percent of the world's population lives in urban areas, and projections are for this to reach 66 percent by 2050 adding 2.5 billion people to towns and cities and surpassing 6 billion by 2040. Close to 90 percent of this increase will be in Asia and Africa; and by 2050, 53 percent of the world's urban population will live in Asia compared to 14 percent in Europe (UNDESA, 2014). The size of cities is also growing. In 1990 there were 10 'megacities' (> 10 million people), now there are 28, mostly in the global south. In 2014, just over 300 million people lived in 43 'large cities' (5-10 million inhabitants) but by 2030 there will be a further 20 (UNDESA, 2014).

In addition to the growing demand from urban consumers for potable water and to meet a variety of municipal needs such as street cleaning, firefighting, construction and commercial requirements, changes in diet are exacerbating the pressure on water resources (USEPA and USAID, 2012; Wichelns et al., 2015). Urban residents are eating more dairy and meat than before, which require more water to produce than traditional plant-based diets. The production of 1 kg of animal protein requires about 100 times more water than the production of 1 kg of grain protein (Pimentel and Pimentel, 2003). Livestock directly consumes only 1.3 percent of the total water used in agriculture but it may take 13 kg of grain and 30 kg of hay, which require large quantities of water, to produce 1 kg of fresh beef (Pimentel and Pimentel, 2003).

The growth in population, combined with higher living standards, changes in lifestyles and eating habits, and economic growth are all affecting water demand (Amerasinghe and Smaktin, 2014). In some areas this is resulting in water stress and scarcity[2]. In North Africa, the proportion of renewable water resources withdrawn in 2008 has exceeded sustainable limits, while Western Asia, Central Asia and the Caucasus, and Southern Asia are approaching water stress (Figure 2-1).

The Comprehensive Assessment of Water Management in Agriculture, which '*defines water scarcity from the perspective of individual water users who lack secure access to safe and affordable water to consistently satisfy their needs for food production, drinking, washing, or livelihoods*', identified about 2.8 billion people, more than 40 percent of the world's population, as living in river basins

[2] Water scarcity exists where the annual availability of internal renewable freshwater is 1,000 m^3 or less per person. Water stress exists where the annual availability of internal renewable freshwater is between 1,000 and 1,667 m^3 per person (Rijsberman, 2006).

where water scarcity is an issue (Molden et al., 2007). This figure is composed of those who live in areas of economic water scarcity (1.6 billion), where human, institutional and financial capital limit access to water; and physical water scarcity (1.2 billion) where water resources development has exceeded sustainable limits (Molden et al., 2007). Water scarcity, in both its forms, is a key driver of wastewater reuse (Carr and Potter, 2013).

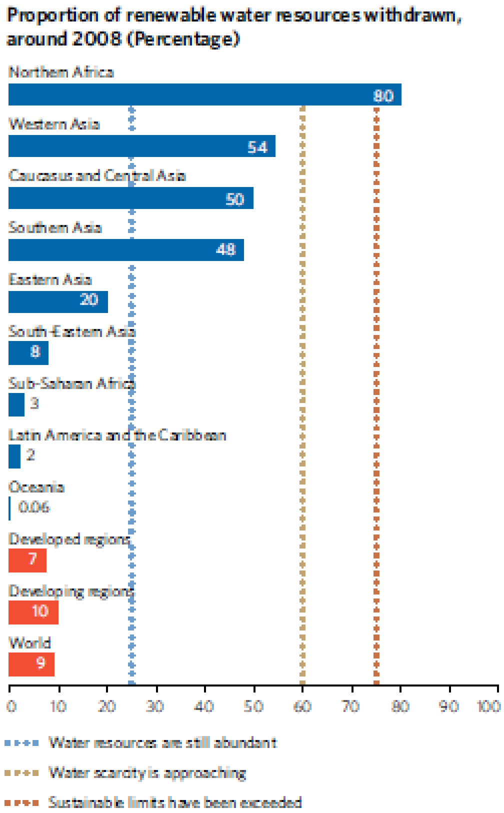


Figure 2-1. Proportion of renewable water resources withdrawn in 2008 (Percentage)
Source: UN (2014)

2.3.2 Water Demand

Amarasinghe and Smaktin (2014) report, based on FAO AQUASTAT data, that water withdrawals in the domestic sector rose by 4 percent between 1995 and 2010, while they declined in the agriculture and industrial sector by 3 percent and 1 percent respectively. However, their research also shows that '*a large number of low- and middle-income countries, … have very low domestic withdrawals at present. With economic growth and urbanization, these countries demand more access to domestic water supply*' and securing water for this sector is often a policy priority. Global water withdrawals are projected to total 4,794 km^3 in 2025, a 23 percent increase from 1995 but with a 28 percent increase in developing countries (Rosegrant and Cai, 2002). The per capita water use in developing countries is expected to rise from 73 litres/day in 1995 to 102 litres/day in 2025 (Rosegrant and Cai, 2002).

Rosegrant and Cai (2002) also project a 79 percent increase in industrial water demand, a 92 percent increase in domestic water demand and a 13.6 percent increase in irrigation in developing countries between 1995 and 2025.

In summary, '*water demand is projected to grow rapidly for domestic and industrial uses, and relatively slowly for agriculture. The developing world is projected to have much higher growth in total water demand than the developed world, and about 93 percent of the additional demand will occur in developing countries'* (Rosegrant and Cai, 2002).

2.3.3 The Cost of Providing Water

How this demand can be met is the question that many governments are asking because worldwide per capita freshwater availability is projected to decline by 50 percent from 1997 to 2025 (Hinrichsen, 1998; cited in Qadir et al., 2003). Although the total quantity of water consumed by urban populations is only a small fraction of total water used (with agriculture being by far the largest consumer), delivery of sufficient water of adequate quality constitutes a logistical and economic problem (Niemczynowicz, 1999) which can be increasingly costly the more difficult the water is to extract, the further it has to be transported or the poorer the initial quality. In some countries, water reuse is therefore being seen as an alternative to major infrastructure projects including costly inter-basin transfers (Scott et al., 2004). Miller (2006) reports on several surveys that have shown that reclaimed water costs compare favourably with those of alternative sources in the United States of America (USA).

The economic validity of source substitution with wastewater depends on the location, the use, the quality, the marginal costs of new-sources of high quality water, and the costs of WWT and disposal (USEPA and USAID, 2004). In countries where WWT is still nascent and the costs are difficult to meet, reuse can provide cost recovery incentives and reduce the burden of sewage charges on urban dwellers (Mekala et al., 2008).

2.3.4 Wastewater Generation and Sanitation Infrastructure

Urban water use is known to result in significant wastewater generation because around 80 percent of the water supplied to urban homes is not consumed but is utilized, contaminated and disposed of

(Tchobanoglous and Schroeder, 1985). In a study of wastewater use in 53 cities, Raschid-Sally and Jayakody (2008) identified increasing water demand, return flows and inadequate treatment resulting in pollution of water bodies and traditional irrigation sources, as a key driver of [unplanned] wastewater use. Several other authors have also emphasised the limited capacities of the cities to treat their wastewater as the main factor in pollution of water sources, including irrigation water (Drechsel and Evans, 2010; Jimenez et al., 2010; USEPA and USAID, 2012; Lautze et al., 2014; Raschid-Sally et al., 2005).

Worldwide, two-thirds of the sewage from urban areas is pumped untreated into lakes, rivers, and coastal waters; this figure climbs to 90 percent in developing countries (ADB, 2008; Corcoran et al., 2010). At present very few people are connected to sewers, especially in Asia and Sub-Saharan Africa (Table 1-2). Where they are, the effluent is often inadequately treated (Table 1-1) because many sewers and WWT facilities are in a state of disrepair (Corcoran et al., 2010). Raschid-Sally and Jayakody (2008) found that while 74 percent of the cities with sewers treated some of their wastewater treatment levels varied with 30 percent treating all the wastewater collected and half treating less than 50 percent.

Sewer systems and WWT are only part of the urban water management picture. In many cities open defecation and on-site sanitation systems, such as septic tanks, are common (Figure 2-2). When on-site facilities are emptied the contents may be disposed of in ditches, streams, sewers, storm water drains or on land close to the latrine. Indiscriminate disposal of excreta and open defecation cause environmental contamination and potentially contribute to wastewater use as the excreta washes into water bodies which are used for various purposes (Scott et al., 2004; Raschid-Sally and Jayakody, 2008).

Globally, 2.4 billion people including some 701 million urban citizens do not have access to improved sanitation facilities (UNICEF and WHO, 2015b). The current levels of sanitation and wastewater management have implications for how waste is managed and potentially reused, and highlight the need for new paradigms that create a market for the waste, possibly generating revenues that facilitate further developments in sanitation.

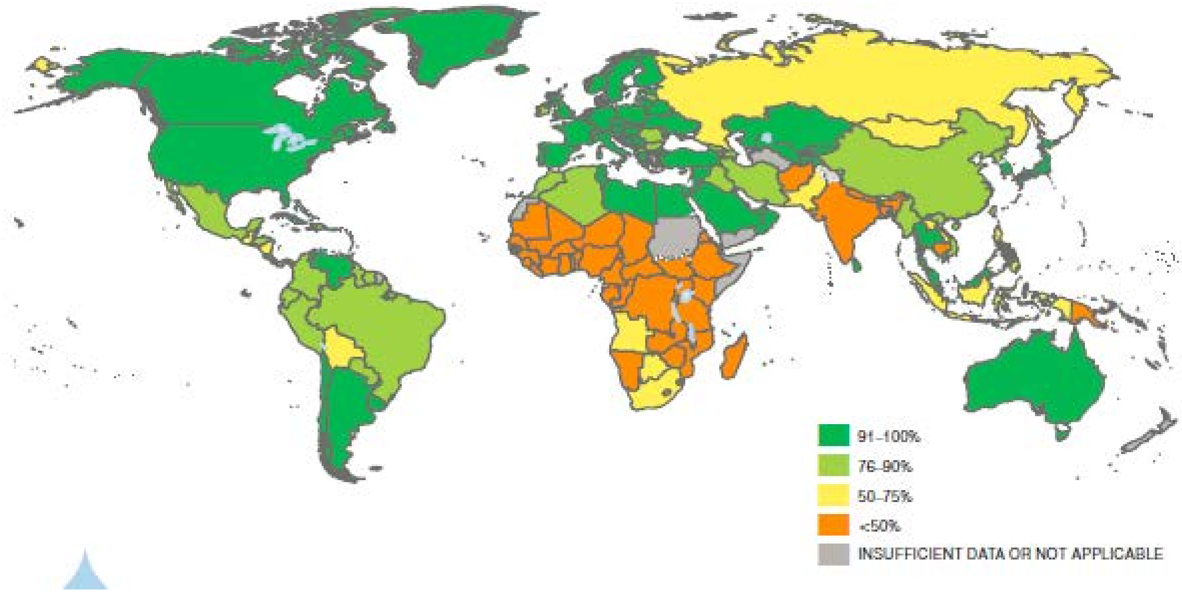


Figure 2-2. Proportion of the population using improved sanitation in 2015
Source: UNCEF and WHO (201b)

2.3.5 Environmental Protection and Wastewater Treatment

When wastewater can be utilized untreated or partially treated, it may offer communities an alternative, effective and safe form of disposal (USEPA and USAID, 2004; Crites and Tchobanoglous, 1998). Examples include wastewater use on fibre and fuel crops or careful irrigation practices, such as subsurface and drip irrigation, used on grains and crops eaten only after cooking (WHO, 2006). It can also reduce the need for abstraction of surface and groundwater (Hamilton et al., 2007), preserving freshwater for other uses and the environment.

Reuse can also provide pollution abatement by diverting effluent discharge away from sensitive ecosystems (Hamilton et al., 2007; USEPA and USAID, 2004; Mekala et al., 2008). In countries where strict environmental standards exist, such as the USA, reuse programmes have been initiated to avoid or reduce the need for costly nutrient removal from wastewater (USEPA and USAID, 2004). This is likely to become increasingly relevant as environmental discharge standards become more stringent and it becomes financially more viable to treat for reuse than disposal (Bouwer, 2000).

2.3.6 Summary

Globally, water demand, created by burgeoning populations and changing living standards, along with pollution, are placing pressure on the fixed global supply of fresh water, and are considered to be the main drivers for planned and unplanned wastewater use (Wichelns et al., 2015; WHO, 2006; Raschid-Sally and Jayakody, 2008; Carr et al., 2004). Pollution abatement, meeting environmental standards and alternative forms of WWT are also reported drivers, especially where infrastructure and finances exist to introduce treatment (Wichelns et al., 2015; USEPA and USAID, 2012; USEPA and USAID, 2004; Hamilton et al., 2007; Yang and Abbaspour, 2007). Where WWT is limited and wastewater enters water bodies and irrigation systems, wastewater reuse may be practiced because there is no alternative (Raschid-Sally et al., 2005; Raschid-Sally and Jayakody, 2008).

2.4 Wastewater Reuse Terminology

There are two major forms of wastewater use, which are succinctly defined by Jiménez et al. (2010) as '*unplanned use of wastewater resulting from poor sanitation, and planned use which tries to address matters such as economic or physical scarcity'*. In countries that can afford treatment, planned use is the norm but in others untreated or partially treated wastewater will be used for as long as wastewater production outpaces treatment. Both forms of use generate economic benefits but have institutional challenges (Jiménez et al., 2010). This section considers the definitions of wastewater use and outlines the different forms it takes.

USEPA (2012) Guidelines for Water Reuse, define wastewater as '*used water discharged from homes, business, industry, and agricultural facilities*', while van der Hoek (2004) considers urban wastewater to be '*a combination of some or all of the following: domestic effluent consisting of blackwater (excreta, urine and associated sludge) and greywater (kitchen and bathroom wastewater); water from commercial establishments and institutions, including hospitals; industrial effluent; stormwater and other urban runoff'*.

The distinction in reuse systems is almost always made between treated and untreated wastewater. Treated wastewater has been through one or more physical, biological or chemical processing steps to remove pollutants to meet certain water quality criteria, sometimes for designated uses but often for disposal. Asano and Levine (1998) use the term **wastewater reuse** to mean the beneficial use of reclaimed (treated) wastewater. They distinguish this from reuse involving one user or use, such as within a factory, which they term **wastewater recycling**. van der Hoek (2004) suggests that since the water is being reused, rather than the wastewater, it would be more appropriate to term it **wastewater use**, which can take place on- or off-site. Wastewater use is described by USEPA and USAID (2012) as 'the *intentional or unintentional use of untreated, partially treated, or mixed wastewater that is not practiced under a regulatory framework or protocol designed to ensure the safety of the resulting water for the intended use'*. By contrast, **water reuse** refers to the use of treated wastewater under a clear regulatory framework and is synonymous with **water recycling**

(USEPA and USAID, 2012). **Reclaimed water** and **recycled water**, mean the same thing but are used by different States in America. It would seem preferable to use the term **wastewater use** to describe the use of untreated wastewater and **water reuse** (USEPA and USAID, 2012) or **water recycling** to describe the use of treated wastewater.

The way in which wastewater is diverted to the point of use has also been part of the terminology debate. In relation to irrigated agriculture van der Hoek (2004) defines **direct use of untreated wastewater**, **direct use of treated wastewater** and **indirect use of wastewater**. This concept has been taken up by a number of researchers such as Garcia and Pargament (2015) and Mateo-Sagasta et al. (2015). For direct use of untreated wastewater the effluent is conveyed to the point of use through a purpose built system such as a sewer. The arrangement may be formal or informal but always has some level of planning, either by the authorities or users. The direct use of treated wastewater or reclaimed water is similar, in that control exists over conveyance, but the water is of a higher quality (at least secondary treatment). Such systems tend to be formally planned. Indirect use of wastewater is the planned use of a water body that receives wastewater. The users may not be aware of the presence of wastewater (i.e. the planned use is of the water body rather than of wastewater). USEPA and USAID (2012) also identify **de facto reuse** where wastewater is used downstream but its use is not officially recognized (e.g. where a drinking water supply intake is located downstream of a WWTP discharge point). These terms are summarized in Table 2-1.

Table 2-1. Terminology for Wastewater Reuse

Term	**Definition**
Wastewater reuse	• Beneficial use of treated wastewater (Asano and Levine, 1998)
Water reuse	• Use of treated wastewater under a clear regulatory framework (USEPA and USAID, 2012)
Wastewater recycling	• One use or user e.g. within a factory (Asano and Levine, 1998) • Use of treated wastewater (USEPA and USAID, 2012)
Reclaimed water	• Use of treated wastewater (USEPA and USAID, 2012)
Wastewater use	• Emphasizes the fact that it is the water not the wastewater that is being used (van der Hoek, 2004)
Direct use	• Use of wastewater that is conveyed to the point of use by a purpose built structure (e.g. sewer or pipe) (van der Hoek, 2004)
Indirect use	• Use of water derived from a water body that contains wastewater (van der Hoek, 2004)
De facto use	• Use of water extracted downstream of a wastewater outlet (USEPA and USAID, 2012)

2.5 Wastewater Applications

This section reviews the main reuse applications, which include: agricultural (crops and aquaculture); urban (non-potable); potable supply; environmental and recreational; industrial; and groundwater recharge (Bouwer, 2000).

2.5.1 Use in Agriculture

Crop irrigation is one of the oldest and most common forms of effluent use and can be viewed as a method of slow-rate land treatment (Crites and Tchobanoglous, 1998). It is a global phenomenon but is more common in water stressed regions. It can be planned or unplanned, direct or indirect, making use of treated or untreated wastewater (van der Hoek, 2004; Jiménez et al., 2010; USEPA and USAID, 2012). The form that it takes and the rationale for the practice have been observed to vary according to the location, economic development of the country and level of sanitation infrastructure (Jiménez et al., 2010; Scheierling et al., 2011; Hamilton et al., 2007). In developing nations, the prime drivers are livelihood dependence and food security, whereas environmental agendas are of greater importance in developed countries (Hamilton et al., 2007).

Planned reuse usually takes place in countries that can afford treatment and irrigation water delivery systems but where lack of water resources stimulate water reuse, for example the Middle East, the USA, Australia, Spain and Italy (Hamilton et al., 2007). In the USA, agricultural use of reclaimed water has a long history and accounts for 29 percent of the water reused in the country. It has become a priority for funding from the United States Department of Agriculture (USEPA and USAID, 2012). Stringent water quality guidelines and treatment processes have been developed, with the California Water Recycling Criteria (Title 22 of the state Code of Regulations) being recognized globally (USEPA and USAID, 2012).

Unplanned use of untreated wastewater in agriculture tends to take place where infrastructure to contain and treat wastewater is inadequate and it enters water bodies that are used for irrigation (Rashchid-Sally and Jayakody, 2008). Also where: urban food demand and market incentives favour food production close to cities; water sources are polluted; farmers lack alternative (cheaper, similarly reliable or safer) water sources; and unemployment and the need for food and incomes drive informal agriculture (Rashchid-Sally and Jayakody, 2008; Scheierling et al., 2011; Scheierling et al., 2010; Drechsel and Evans, 2010). Consequently, wastewater use in agriculture is often observed in peri-urban areas and downstream of large cities (Drechsel et al., 2006). Much of this use is unintentional and is the result of water pollution (Jiménez et al., 2010; Raschid-Sally and Jayakody, 2008; Drechsel and Evans, 2010) but in some places farmers also observe the value of the wastewater and nutrients it contains, for example:

- Faisalabad, Pakistan - farmers pay to receive untreated wastewater rather than water from a waste stabilization pond (WSP) which is lower in nutrients and more saline (Clemett and Ensink, 2006);
- Haroonabad, Pakistan - farmers buy the wastewater from the municipality (van der Hoek et al., 2002);
- Cochabamba, Bolivia - farmers intentionally rupture the sewer pipelines to utilize it for irrigation and the irrigators' organization has an arrangement with the municipal water and sewerage company to use their effluent (Huibers et al., 2004); and
- Quetta, Pakistan - land prices are up to five times higher in wastewater irrigated areas than freshwater irrigated areas (Ensink et al., 2004a).

The crops irrigated with wastewater can include food, fodder, fibre and fuel crops (USEPA and USAID, 2012; WHO, 2006). This diversity allows authorities and farmers to use different water qualities and minimize health and environmental impacts. In planned systems the treatment level will be set according to the use. In unplanned systems the choice of crops will largely depend on market forces but will be influenced by water quality if it affects crop quality and growth.

No comprehensive database exists of the extent of wastewater use in agriculture although FAO Aquastat now publish reported data. Estimates for reuse range from 2-20 million ha (Jiménez et al., 2010; Jiménez and Asano, 2008; Scott, 2004; Future Harvest, 2001) and research suggests that planned reuse is only a small fraction of this (Scott et al., 2010; Scheierling et al., 2011). Although data on the extent of the practice, the quantity of food produced with wastewater and the volume of wastewater utilized is not known with certainty, it is widely accepted that the numbers are growing and will continue to do so (Carr and Potter, 2013; Scheierling et al., 2011; Jiménez et al., 2010; Hamilton et al, 2007). This is largely attributed to growing water scarcity, the larger volumes of wastewater being generated, inadequate infrastructure, pollution, and the greater demand on increasingly stretched freshwater resources (Pescod, 1992; Scheierling et al., 2011; Raschid-Sally and Jayakody, 2008; Scott et al., 2004; Raschid-Sally et al., 2005; van der Hoek, 2004; Qadir et al., 2007a). Combined with this is the demand for fresh agricultural produce in cities, which due to the lack of cool transport and storage infrastructure, is increasingly being met from production systems close to cities, which often make use of municipal wastewater flows (Raschid-Sally and Jayakody, 2008; Drechsel, 2007; Raschid-Sally et al., 2005).

The factors that contribute to reuse are depicted in Figure 2-3. Unplanned or informal reuse is often the result of inadequate infrastructure leading to pollution of water bodies used for irrigation. Both planned and unplanned use are also stimulated by the desire for fresh agricultural produce in or near towns and cities.

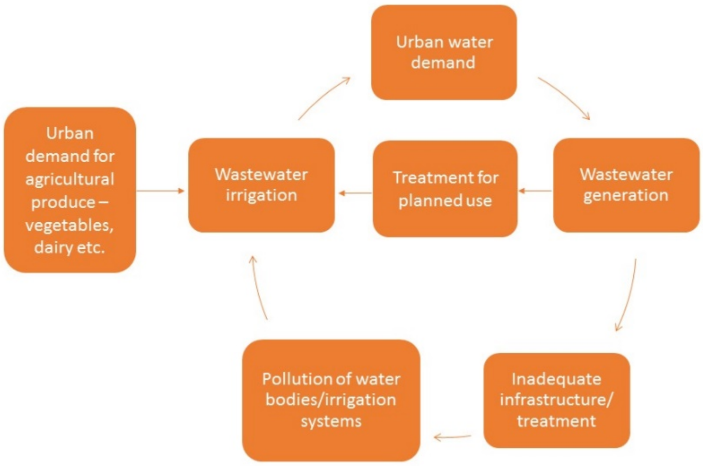


Figure 2-3. Factors influencing wastewater irrigation occurrence and growth
Source: Author (2016)

2.5.2 Use in Aquaculture

Aquaculture covers the production of aquatic plants and animals, for food, animal feed, fibre or fuel (Junge-Berberovic, 2000). The focus in aquaculture is often placed on fin or shell fish, or on aquatic plants for human and animal consumption (Pescod, 1992), but there are a variety of products that can be produced such as: phytoplankton and macrophytes to be used as feed, fibres for buildings, furniture and paper; plant biomass for fertilizer or energy production; and ornamental plants and fish, and pearls (Junge-Berberovic, 2000; Edwards, 1985).

Like agriculture, wastewater aquaculture may involve direct or indirect use (Bunting, 2004). WHO (2006c) and Edwards (2010) suggest that planned wastewater aquaculture is in decline due to urbanization reducing the space for aquaculture, changing diets, producers focusing on higher value goods which require better quality water (e.g. prawns), and dynamic labour markets in urban areas meaning workers move to better paid jobs (Bunting, 2004). By contrast, unplanned, indirect use may be growing as a result of pollution, and in some places urbanization is actually providing greater opportunities for small-scale aquaculture (WHO, 2006b).

Wastewater aquaculture is known to have existed in Asia and China for centuries and has been recorded in historical accounts across other parts of the world (Bunting, 2004; Edwards, 1985). The production of aquatic products within planned WWT systems is likely to be more recent with known projects in Germany in the 1900s (WHO, 2006b). This practice had declined but is seeing a revival in some places, with a view to financing WWT. Examples include Ghana, where the AfDB has been funding work to grow fish in a WSP (Tenkorang et al., 2012) and Karnal, India, where pisciculture was introduced to the facultative and maturation ponds of a WSP (Kumar et al., 2014). The extent of wastewater aquaculture is not well documented but Bunting (2004) postulates that it is widespread and of great significance to poor households.

Proponents of planned wastewater-fed aquaculture see it as a productive and effective WWT system in which nutrients are used rather than being degraded, as they are in other biological WWT systems, and water is reused rather than being disposed of (Junge-Berberovic, 2000; Edwards, 2010; Edwards, 1985). Consequently, work has been done to determine whether it is possible to fund WWT through the sale of aquaculture products (Murray et al., 2011b; Buijs et al., unpublished; Kumar et al., 2014). Cultivating non-edible aquatic products such as microalgae or plant and animal products as feed inputs for secondary aquaculture enterprises or terrestrial farming may be a promising strategy, especially where water quality is an issue, treatment is limited, there are social restrictions on direct wastewater reuse and limited market demand for products from aquaculture (Bunting, 2004). For example, duckweed has been cultivated in WSPs in Bangladesh and is fed to fish; the local community accept this practice (Skillicorn and Patwary, 2013). The production of microalgae has been practiced for some time as a means to remove nutrients from wastewater but scientists are now researching its use as feedstock for biodiesel (Cho et al., 2011).

2.5.3 Use for Municipal Purposes

Urban areas can make use of large quantities of reclaimed water, which can reduce the volume needing treatment in municipal WWTPs or the quality to which it must be treated (UNEP, 2005). The uses can be divided into potable and non-potable uses, as described below.

Non-potable uses outlined by Crites and Tchobanoglous, 1998; UNEP, 2005; USEPA and USAID, 2004; MacDonald et al., 2005; and Qadir et al., 2007b include:

- Landscape irrigation - public parks, urban spaces, playing fields, verges, golf courses and landscaped areas surrounding public, commercial and residential buildings;

- Ornamental landscape uses and decorative water features, such as fountains;
- Cleaning of streets and public places such as market areas;
- Dust control and concrete production for construction projects;
- Fire protection through reclaimed water fire hydrants;
- Toilet and urinal flushing in commercial and industrial buildings;
- Industrial, commercial and domestic uses where dual-plumbing systems exist.

Depending on the exact nature of the reuse, an additional distribution for reclaimed water may be required, as is the case in Bulawayo, Zimbabwe, where reclaimed water is used to irrigate parks, golf courses and various sports facilities (Sibanda, 2002). The dedicated distribution system must be operated like a utility and maintained and managed like the potable water system (Crites and Tchobanoglous, 1998). Care must be taken to ensure there is no cross contamination (UNEP, 2005). Introducing a new distribution system can be expensive, especially if it has to be retrofitted, but in some cases the benefits of conserving potable water justify the costs, for example if '*the reclaimed water system eliminates or forestalls the need to: obtain additional water supplies from considerable distances; treat a raw water supply source of poor quality (e.g. seawater); or treat wastewater to stricter surface water discharge requirements'* (USEPA and USAID, 2004).

Potable reuse is defined by USEPA and USAID (2012) as '*Planned augmentation of a drinking water supply with reclaimed water'*. It can take the form of either direct potable reuse (DPR), which is the introduction of reclaimed water directly into a drinking water treatment plant; or indirect potable reuse (IPR), which is the augmentation of a drinking water source with reclaimed water, which is later extracted, after some sort of environmental buffer, and treated to drinking water quality standards (USEPA and USAID, 2012). They also differentiate between planned IPR and unplanned or *de facto* IPR. The latter is a significant portion of the USA's water portfolio (USEPA and USAID, 2012), as is likely to be the case globally. Bouwer (2000) considers that DPR, or a 'toilet-to-tap' connection, should be a last resort and the effluent should always go through a surface or groundwater 'barrier' to reduce the risk of contamination and increase acceptability. A major factor in the ability to reuse water for potable purposes is the level of sophistication of water treatment technologies (van Houtte and Verbauwhede, 2008).

There is global interest in IPR (e.g. India, USA, UK, Belgium and South Africa), although public perception and lack of political support are limiting uptake (USEPA and USAID, 2012; Miller, 2006). DPR, it is rarely practiced and there is considerable public opposition even though treatment technologies exist to enable safe use. The reasons that unplanned IPR seems acceptable when planned IPR and DPR are not still need research (Ormerod and Scott, 2012) but Miller (2006) suggests that it might be linked to the phenomenon of naturalness or the psychological feeling that '*once contaminated, always contaminated'*. As a consequence, recent attempts to introduce potable reuse have often involved public consultation, awareness raising or outreach (Marks, 2006).

2.5.4 Industrial Use

Industrial use of treated wastewater may take place through on-site recycling or treatment in municipal STPs, and include application in cooling towers, as process water or for cleaning (Asano and Levine, 1998 cited in UNEP, 2005; Miller, 2006). Water for cooling can be a major part of an industry's water use, accounting for 20-50 percent (UNEP, 2005; Crites and Tchobanoglous, 1998). In the USA when industries began recycling, it was generally treated on-site but as water resources have become stressed many municipalities have started to reclaim wastewater for industries, power companies and agriculture (USEPA and USAID, 2012). Industrial users now span a huge range of sectors including food processing, electronics industries, and paper and textile factories (USAID, 2004; USEPA and USAID, 2012). Motivations to use reclaimed water include availability, cost and green certification. Water quality requirements differ according to application types; obtaining the necessary quality may require secondary or tertiary treatment, or specific methods to meet individual needs and depends not only on the use but also the wastewater source (UNEP, 2005).

2.5.5 Environmental Flows and Aquifer Recharge

Wetlands and other aquatic environments serve a number of purposes such as providing habitat for animals and birds, supporting livelihoods, helping to maintain the hydrological balance, including flood protection and aquifer recharge, and attenuating pollutants (USEAP and USAID, 2012; Qadir et al., 2007b). In many places degradation of wetlands, lakes, rivers and coastal environments has a detrimental impact on wildlife and people. Problems are arising as a result of over abstraction (MacDonald et al., 2005), insufficient return flows and pollutants. Augmenting natural flows with wastewater (of adequate quality) can protect water bodies, especially at times when natural flows or rainfall are particularly low, or reclaimed water can be used to create new wetlands (USEPA and USAID, 2012). Alternatively, wastewater can be substituted in other sectors so that freshwater can be released to maintain minimum flows (Howe and White, 1999). In Australia, '*the New South Wales state government has introduced new water sharing rules that require increased water allocations for environmental flows to maintain river health, particularly in low flow periods'* (Anderson, 2006).

In urban areas regeneration of waterways can have both environmental and aesthetic benefits. Examples include Tokyo where the river has been augmented with UV irradiated water resulting in an improvement in water volume and quality and the return of various living species to the river. In Osaka the castle moat has been filled with tertiary treated and chlorinated water, which has significantly increased the amenity value of the castle (UNEP, 2005).

Aquifer recharge has been practiced using freshwater in arid and semi-arid areas throughout the world for centuries. It replenishes groundwater at a rate exceeding natural conditions, through the use of recharge basins, spreading surfaces and injection wells (Nijhawan et al., 2013). Injection wells require high quality water, while soil aquifer treatment (SAT) can utilize secondary treated effluent (Ammary, 2007). As the treated wastewater passes through the unsaturated zone it acts as a natural filter removing suspended solids, biodegradable materials and microorganisms. Significant reductions in nitrogen, phosphorus and heavy metals can be achieved (Pescod, 1992; UNEP, 2005).

Where intentional groundwater recharge has taken place it has often been as a means to dispose of treated wastewater in countries where treatment is prevalent (USEPA and USAID, 2012). Increasingly, there is interest in artificial recharge as a means of water storage, to recharge adjacent streams and to hold back saline intrusion in coastal aquifers (USEPA and USAID, 2012; Bixio, 2006). In India recharge using storm water has been explored and there is now interest and government support for artificial groundwater recharge using treated wastewater (CGWB, 2000). However, a survey of 200 people including water professionals and the general public found that many were concerned about the quality of treated wastewater in India and the potential for contamination of aquifers. Other concerns included inadequate skills, trustworthiness of the companies involved, chemical constituents such as polycyclic aromatic hydrocarbons (PAH) and the ability of authorities to monitor water quality. Despite this, 64 percent were in favour of utilizing reclaimed water for aquifer recharge (Nijhawan et al., 2013). The form of reuse significantly influences acceptability with a survey in Israel revealing that 62 percent of respondents were supportive of aquifer recharge for subsequent use in agriculture but only 11 percent supported it for potable use (Friedler et al., 2006).

Aquifers may also be unintentionally augmented through wastewater irrigation or inadequate containment and management of wastewater (Bahri, 2009). In the Mezquital Valley, wastewater is conveyed from Mexico City through unlined channels for flood or furrow irrigation. This leads to an unintentional infiltration of 25 m^3s^{-1}, equivalent to 13 times the natural recharge (Jiménez, 2005; Jiménez and Chavez, 2004; Bahri, 2009). Over decades, this has raised the water table and springs have appeared that have become the only source of water supply for more than 500,000 people (Bahri, 2009). Many of the pollutants are removed in the process but the nitrate content is high (Jiménez, 2005; Jiménez and Chavez, 2004).

2.6 Risks and Benefits Associated with Wastewater Reuse

It is generally accepted that certain forms of wastewater use, such as irrigation, are justified on economic grounds and can help to realize societal and environmental goals but they can also be hazardous (Pescod, 1992). Hamilton et al., (2007) note that, *'The potential for transmission of devastating pathogenic diseases is real, particularly in developing countries, where poorly treated or untreated wastewater is often used for irrigation. Degradation of agricultural soils and contamination of aquifers and surface waters are also significant threats'*. However, the risks associated with wastewater use vary depending on the characteristics of the waste, degree of treatment prior to use, nature of the reuse system, the subsequent handling, processing and preparation of the products (e.g. vegetables), and the susceptibility of the consumer (Bunting, 2004). This chapter reviews the research on risks and benefits arising from pathogens and chemicals in wastewater used in various reuse systems.

Much of the wastewater reuse literature considers the impacts on human health, with negative impacts being more extensively researched and documented than positive ones (Carr et al., 2004; WHO, 2006). Water quality issues that can create real or perceived health risks can be broadly divided into those arising from the presence of pathogenic enteric microorganisms (bacteria, viruses, protozoa and helminths) and those from chemicals in the water. Wastewater is a complex mixture of components, the presence and concentration of which are a function of the origin of the wastewater and the level of treatment (Qadir et al., 2015). The constituents of wastewater may be beneficial or hazardous depending on their concentration and form, and how the wastewater is treated and used.

Pathogens found in wastewater tend to pose the greatest hazard where treatment levels are low. The bacteria, viruses, protozoa and helminths associated with wastewater use in agriculture and aquaculture are listed and discussed by WHO (2006b), including symptoms, transmission pathways and survival rates, in water, on soils and crops. Chemical constituents that are of particular relevance for reuse include: nutrients, hydrogen ions (pH); hydroxides, carbonates and bicarbonates; chlorides; sulphates; boron; chlorine; and silica (Crites and Tchobanoglous, 1998). Chemicals of concern (COC) are of increasing relevance as the use of household, medical and industrial chemicals rises (Toze, 2006b; Chang et al., 2002; Bouwer, 2000; Salgot et al., 2006; Pescod, 1992). In countries with high levels of treatment to address pathogenic contamination attention is now turning to these chemicals. They include heavy metals, pharmaceuticals and endocrine disrupting compounds (EDC) (van der Hoek et al., 2002; Carr et al., 2004; Toze, 2006a; USEPA and USAID, 2012). They tend to be present at very low concentrations in treated water (usually ng/L) but may be present in much higher concentrations in untreated wastewater. Many of these complex chemical compounds are only recently being identified and understood. They require the ingestion of large doses over long time periods to produce any clinical effect but they may produce long-term chronic effects or bioaccumulation; several organisms show high sensitivity to certain chemicals; and they interfere with hormone production and the immune systems of aquatic species (Bouwer, 2000; and Salgot et al., 2006).

It should be noted that chemicals also originate from sources other than urban and industrial wastewater. For example, agricultural drift and leaching from solid waste dumped near or in water bodies or dumping sites, and combustion of fuel or waste (Bunting, 2004). When analysing water or products for chemical contamination these factors must be considered before assuming that wastewater is the source of contamination.

2.6.1 Pathogenic Risks

2.6.1.1 Agriculture

There are generally considered to be four groups of people that may be affected by wastewater irrigation: farmers and farm workers; farming families; produce consumers; and nearby communities. Epidemiological studies carried out over the past four decades have linked the unplanned use of untreated or partially treated wastewater on edible crops to the transmission of endemic and epidemic diseases to farm workers and crop consumers (Scheierling et al., 2010; Carr et al., 2004; Shuval et al., 1986). Much of the current guidance on risk management has been derived from two major reviews of epidemiological studies undertaken in the past 30 years, by Shuval et al. (1986) and Blumenthal and Peasey (2002), which have been reported on and added to in other literature and which have contributed to the WHO Guidelines in 1986 and 2006 (Carr et al., 2004; WHO, 2006). These studies found the following:

- **Helminth infection** (mainly Ascaris) has been linked to direct contact with untreated wastewater, with more pronounced effects in children than adults (Blumenthal and Peasey, 2002). There is increased risk of hook worm (*Ancylostoma duodenale* or *Necator americanus*) for farm workers who do not wear shoes (van der Hoek et al., 2002; Toze, 2006a; Toze, 2006b) and consumers were found to be at significant risk of infection when eating crops irrigated with untreated wastewater, as were communities living near flood and furrow irrigated areas (Blumenthal and Peasey, 2002).

- **Bacterial/viral infection**, including cholera, typhoid and shigellosis outbreaks, and non-specific watery diarrhoea have been reported from consumption of fruit and vegetables irrigated with wastewater. For farming families, there is an increased risk of diarrhoeal disease and *Salmonella* in young children depending on the water quality used. Sprinkler irrigation with poor quality water (10^{6-8} TC/100 ml) has been associated with increased rates of viral infection (Blumenthal and Peasey, 2002; in Carr et al., 2004).
- **Protozoa** have been found on wastewater irrigated vegetables but there is no evidence of disease transmission to consumers. For farm workers and their families contact with wastewater led to amoebiasis but an insignificant risk of *Giardia intestinalis* infection (Blumenthal and Peasey, 2002; in Carr et al., 2004).

Since these seminal pieces, several more studies have looked at the presence of pathogens in wastewater to determine whether there is the potential for infection, as well as undertaking health-based research (epidemiological studies and broader livelihoods assessments), although WHO (2006b) comments that the '*epidemiological evidence in relation to the reuse of treated excreta and greywater is generally lacking'*. A summary of such studies is presented in Annex 1.

More recently, quantitative microbial risk assessment (QMRA) (Box 2-1) has been used to estimate risk of infection or disease and facilitate comparison of different exposure routes (WHO, 2006; Bos et al., 2010; Strauss, 2000).

The studies have demonstrated that there are a variety of contamination pathways that are linked to water quality, farming practice and hygiene in markets and in the home. Interventions at points along the chain from wastewater production to produce consumption can reduce the risk to human health (WHO, 2006).

Box 2-1. Quantitative microbial risk analysis

QMRA determines a numerical value of the risk (i.e. probability) of disease and/or infection as a result of a person or a community being exposed to a specified number of a specified pathogen as a result of some activity (e.g. consuming wastewater-irrigated foods). QMRA can be used to estimate disease and infection risks for any pathogen as long as there are dose-response data available. The disease and/or infection risks can then be estimated by a dose-response equation (Scheierling et al., 2010).

QMRA is a four step process involving:

(i) hazard identification - involves determining the pathogens of concern
(ii) exposure assessment - comprises defining the exposure pathway so the concentration of the pathogens reaching the consumer can be determined
(iii) dose–response modelling - defines the probability of infection as a function of pathogen dose
(iv) risk characterization - brings together the exposure and dose–response models to arrive at an estimate of an adverse outcome, such as infection (Hamilton et al., 2007).

2.6.1.2 Aquaculture

The primary health hazards associated with the use of wastewater in aquaculture are pathogens, some vectors of parasites and viruses, and certain chemicals (Edwards, 2010; WHO, 2006b). These usually originate from the wastewater but can also enter the system as a result of open defecation and poor sanitation (Bunting, 2004). The exposure routes for excreta related pathogens are contact with the wastewater, the fish or aquatic plants, and consumption of the aquaculture products (WHO, 2006b). The populations at risk are farmers, their families, local communities, vendors and consumers (WHO, 2006b).

Enteric **bacteria** such as faecal coliforms (FCs), faecal streptococci, and *salmonellae* have been found in fish grown in water contaminated with excreted pathogens (Feachem et al. 1983; cited in Edwards, 1992). Studies on the microbial quality of fish and aquatic plants have found that they tend to passively accumulate microbial contaminants on their surfaces (e.g. skin and gills), and concentrate viruses, bacteria and protozoa in their guts, but the pathogens rarely penetrate into the edible fish muscle, as was observed for *E. coli* in a study in Ghana (Tenkorang et al., 2012). However, Ampofo and Clerk (2003) found a number of pathogens in most parts of the fish. Stress, caused by overcrowding and poor conditions, can lead to contamination of the fish flesh (WHO, 2006) and bottom-feeding fish have been shown to accumulate the highest numbers of pathogens (Edwards, 1992). There is also evidence of rapid die-off of enteric organisms in well managed ponds (WHO, 1999), which can in part be attributed to the pH levels (Edwards, 2001).

Links between consumption of contaminated fish and public health outbreaks have been associated with post-harvest contamination during transportation, in markets or during fish preparation (Edwards, 1992; WHO, 2006b; WHO, 1999). The risk associated with consumption of wastewater-fed fish reduces if they are gutted, washed and cooked well (Edwards, 2001; Bunting, 2004; Edwards, 2010).

Parasites are the main cause of infection when wastewater fed fish are consumed inadequately cooked or raw. They are prevalent in only a few countries where eating raw fish is a cultural habit (WHO, 1999) and because trematodes have restricted geographical ranges. Where they exist they are associated with high morbidity and complications leading to death (Edwards, 2010; WHO, 2006b; WHO, 1999).

Based on epidemiological evidence the transmission of enteric viruses from wastewater reuse systems is not as important as that of bacteria and helminth diseases (Engleberg Report, 1985), but consumption of raw molluscan bivalves is a cause of viral disease (WHO, 1999).

2.6.1.3 Ground Water

Concerns have been raised about risks to human health through the contamination of groundwater but most soils retain pathogens in the top few metres of soil, except in certain situations like limestone formations (Scheierling et al., 2010). The removal of pathogens is a function of the soil 'straining out bacteria' and 'adsorbing viruses'. Studies have shown that pathogens in the soil do not reproduce and die after a few weeks to a few months and many studies indicate almost complete faecal coliform (FC) removal after percolation of one to a few metres through the soil (Pescod, 1992). However, pathogens have been detected in the groundwater immediately beneath wastewater-irrigated fields (Ensink et al., 2002) and some EDCs and pharmaceuticals have been found to enter groundwater (Salgot et al., 2006).

2.6.2 Chemical Risks and Benefits

2.6.2.1 Agriculture

Agriculture can utilize lower quality water than domestic and industrial uses but consideration must be given to the possible long-term effects on soil properties, crop health and yields from salinity, sodicity, nutrients and trace elements (Table 2-2) and hence to management practices (Ayres and Westcot, 1985; Toze, 2006a; Scheierling et al., 2010; USEPA and USAID, 2004; USEPA and USAID, 2012). Substances that are harmless or even beneficial at relatively low concentrations may become toxic to plants at high concentration, or may impact on the quality of the soil, groundwater and receiving waters (Pescod, 1992; Scheierling et al., 2010). The impact depends on factors such as wastewater type, application rates, crops, dilution, soils, topography (Scheierling et al., 2011). Ayres and Westcot (1985) provide a list of recommended maximum concentrations (RMCs) of selected metals and metalloids in irrigation water based on toxicity to plants and soil impacts (Qadir et al., 2007a).

Table 2-2. Important components of wastewater for agricultural production

Substance Group	**Possible Effects**
Total dissolved solids (TDS)	Affects crop yield and quality of produce (Pescod, 1992).
Sodium (Na)	when present in the soil in exchangeable form causes adverse physico-chemical changes, leading to the formation of a crust on the soil surface which is hard to till and inhibits seedling emergence (Lal, 2009 and Ghafoor et al., 2010; in Hanjra et al., 2012).
Chlorine (Cl), Boron (B), Na	Some plants are susceptible to specific ion toxicity affecting growth, yield, morphology of the plant and even death. Damage depends on the crop, growth stage, ion-concentration, climate and soil conditions (Qadir and Scott, 2010; Pescod, 1992).
Calcium, Magnesium	Can improve soil structure, counterbalance the effects of Na, and improve the hydraulic properties of low-permeability soils.
Organic matter	Can improve soil structure and bind certain nutrients trapping them or slowing their release. It can also block micro irrigation systems and deplete oxygen leading to hypoxic conditions (Qadir and Scott, 2010).
Metals and metalloids - Arsenic (As), cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), mercury (Hg) and zinc (Zn), Nickel (Ni), molybdenum (Mo)	Can reduce the need for application of micronutrient fertilizer but excessive levels may cause phytotoxicity, affect human and animal consumers, and pollute surface and groundwater. Prolonged application may result in accumulation in soils (Toze, 2006a). As, Cd, Cu, Cr, Pb, Hg and Zn have been shown to have health impacts when taken up by crops (Pescod, 1992). Ni and Zn have visible adverse effects in plants at lower concentrations than the levels harmful to animals and humans, whereas Cd, Cu and Mo can be harmful to animals at concentrations too low to impact plants (USEPA and USAID, 2004). Excessive exposure to Cd, which accumulates in leafy vegetables, has been associated with gastroenteritis, renal tubular dysfunction, hyper-tension, cardiovascular disease, pulmonary emphysema, cancer, and osteoporosis (Wagner, 1993: in Qadir et al., 2007).

The long term application of wastewater containing COC can lead to the accumulation of potentially toxic substances in crops which will ultimately enter the food chain, so damaging human and animal health. In the opinion of Qadir et al. (2007b) these can cause greater and longer lasting health effects than pathogens. Consequently, '*where municipal sewage … is used for irrigation, particularly in untreated form, a whole new spectrum of pollutants can be added to the soil and groundwater and subsequently to the human and animal food chains'* (Bouwer, 2000; Qadir et al., 2003).

Several studies have detected heavy metals in soils or wastewater used for irrigation but few have analyzed levels in the crops and fewer still in meat and milk products. Furthermore studies on soils and wastewater have rarely directly linked contaminants with crop health problems. For domestic sewage being used for irrigation in Hubli-Dharward, India, Bradford et al. (2009) recorded the EC, residual sodium carbonate (RSC), sodium adsorption ratio (SAR), total suspended solids (TSS) and pH and found that all the parameters, except RSC and TSS, were below critical limits for irrigation. Examples of studies of heavy metals in wastewater agriculture can be found in Annex 2. There is also evidence that the input of heavy metals from commercial chemical fertilizer impurities can be far greater than that contributed by reclaimed water (Engineering Science, 1987; cited in USEPA and USAID, 2004; Mohammed, 2012). Other sources may include vehicle emissions and solid waste (Mohammed, 2012; Bunting, 2004).

There is limited but growing evidence of uptake by crops and contamination of groundwater by emerging chemicals and EDCs (Qadir and Scott, 2010). The picture is mixed with concentrations of contaminants in soils and plants varying considerably and insufficient research (Drechsel and Keraita, 2014; Toze, 2006) but the recalcitrance of these substances is prompting research on detection and treatment (Weber et al., 2006; de Koning et al., 2008; Drechsel et al., 2010).

There are also many benefits to agriculture from the substances contained in wastewater. Urban wastewater usually contains significant concentrations of nutrients, which are essential for plant growth, improve soil fertility, enhance plant development and increase agricultural productivity (Bahri, 2009). Nitrogen helps crop establishment; P helps throughout the growth period; K aids crop maturity and quality; and N and K mitigate the effects of excess salt if present (Qadir and Scott, 2010). Studies have shown that reclaimed water can have adequate concentrations of K, phosphate, sulphate and Mg to meet all or part of the crop's requirements (Carr et al., 2011a; 2011b; Martijn and Redwood, 2005) and that there is minimal or no need for the addition of chemical N, P and K (Qadir and Scott, 2010).

Farmers are often aware of the nutrients present in wastewater but are not able to optimize them because the wastewater quality varies and the concentrations may not be in ratios that are advantageous to crop growth or may be present at times when the crop does not require them (Martijn and Redwood, 2005). Consequently farmers may continue to apply fertilizers in excess of requirements (Mojid et al., 2010; Ensink et al., 2004b; van der Hoek et al., 2002). A study by Carr et al. (2011a) revealed that out of 23 farmers who were aware that wastewater contained nutrients only 12 reduced their chemical fertilizer application. The reasons reported for this were '*the perception that nutrients are a limiting factor for productivity, and larger yields result from greater additions of fertiliser, and concern that while nutrients are present in the water, their quantity is either insufficient to meet the demands of intense cropping or the crop is unable to take up nutrients from reclaimed water'*.

Without careful management the nutrients in wastewater may be detrimental and farmers may be required to alter their cropping patterns, change their irrigation schedule (introducing fresh water if possible) or apply supplemental fertilizer (Hanjra et al., 2012). Reported problems include, lodging[3], delayed crop maturity, failure to ripen, and excessive plant growth or a prolonged vegetative state leading to susceptibility to pests and diseases and the need for larger quantities of pesticides, herbicides and labour, thus increasing costs (; Pescod, 1992; Qadir et al., 2007a; Bradford et al., 2009; Carr et al., 2011a). The provision of information on the nutrient content of wastewater through formal and informal channels remains a key challenge for determining the optimal fertilizer requirements (Hanjra et al., 2012; Carr et al., 2011b).

2.6.2.2 Aquaculture

As with crops there are a number of possible effects that the constituents of wastewater may have on aquatic organisms either directly or via changes to the environment in which they live. Some of the more obvious impacts are the depletion of oxygen due to high organic loads and the growth of toxic algae (Table 2-3).

A study by Khalil and Hussain (1997) into the effectiveness of growing Nile tilapia (Oreochromis niloticus (L.)) and common carp (Cyprinus carpio) reported high mortality rates for common carp in primary and secondary treated effluent (100 percent and 80 percent respectively), which they associated with high ammonia levels. Mortality for Nile tilapia was much lower at 39, 19 and 17 percent for primary and secondary effluent, and groundwater respectively. A trial of fish

[3] Plant stems weaken and can no longer support the weight of the upper portion of the plant (i.e. the grain head), causing it fall in the field.

production in a WSP in Ghana found that algal blooms existed throughout the six month growth period and that this caused oxygen levels to dip below the optimal 1 mg l^{-1} leading to fish deaths (Tenkorang et al., 2012).

Table 2-3. Categories of substances found in wastewater and their effects

Substance Group	**Examples**	**Possible Effects**
Organic compounds	• natural products of metabolism (carbon-compounds) • manmade organic compounds (tensides, pesticides)	• oxygen depletion • chronic toxicity • acute toxicity • bioaccumulation
Inorganic compounds	• nutrients (e.g. N, P, K) • trace elements and heavy metals (e.g. Cu, Zn, Pb, Ca ...)	• fertilisation effects • toxicity • bioaccumulation • death
Particles (> 0.45 µm)	• wood, metal, plastic, sand, clay	• physical interference
Microorganisms	• pathogens	• disease • death
Dissolved gases	• oxygen, carbon dioxide, ammonia, methane	• fertilisation effects • toxicity • death

Source: Adapted from Junge-Berberovic (2000)

The use of untreated or partially treated effluent may lead to the accumulation of contaminants in cultured fish and aquatic vegetables and present a food safety risk unless water quality is managed (Marcussen et al., 2007; Edwards, 1992). Analyses of fish raised in WSPs indicate accumulation of heavy metals (and other contaminants) but usually the levels are within acceptable limits (Edwards, 1992; Marcussen et al., 2007; Cuevas-Uribe and Mims, 2014). A study in Vietnam found As, Cd and Pb in the muscle, liver and skin of fish but concentrations were low as compared to threshold values established by the European Commission (Marcussen et al., 2007). A study by Seffern et al. (1981; cited in Edwards, 1992) highlighted the biological magnification that takes place with levels of Hg and Cu in fish flesh being several times higher than concentrations in the pond water. In addition the review showed that whilst phytoplankton readily accumulates heavy metals and halogenated hydrocarbons, they do not appear to be accumulated by the fish that feed on the phytoplankton. Hence, the concentrations of heavy metals and metalloids in the edible parts of fish are perhaps less of a hazard than other contaminants and the consumption of edible plants, which more readily take up metals, may be more of a concern.

A wide variety of chlorinated compounds are found in aquatic environments arising from sources including pesticides and deposition from the combustion of fuel. They can be of concern but very little has been published on concentrations in aquatic products. That which does exist shows levels to be below permissible concentrations (WHO, 1999). However, the WHO (1999) considers that they should still be treated as a hazard due to the limited amount of available data (Edwards, 2001). Furthermore they are not removed in many WWT systems, such as WSPs, which are used for aquaculture (Cuevas-Uribe and Mims, 2014).

2.6.2.3 Ground and Surface Water

Long-term irrigation with wastewater adds large amounts of carbon, major and micro-nutrients to the soil, and can cause eutrophication of water bodies, and growth of weeds and algae, reducing their utility and ecological value. Nutrients can also pollute groundwater, leading to health consequences if used for drinking (Qadir and Scott, 2010; WHO, 2006). A comparison of the spatial distribution of nutrients and toxic elements after three decades of wastewater found a build-up of N, P and K in the soil and traces of nitrate, Pb and Mg in well water near the disposal point (Yadav et al., 2002). Some EDCs and pharmaceuticals have been found to enter groundwater (Salgot et al., 2006). Halogenated carbons remain in the parts per billion level which is considered acceptable for irrigation but not drinking water, which would require further treatment (Pescod, 1992).

2.6.3 Environmental and Societal Benefits of Wastewater Use

There are multiple benefits arising from the use of wastewater such as:

- sustainable and dependable alternative supply of water that can extend existing supplies;
- typically less energy used than importing water;
- can cost less than alternatives supplies;
- under local control;
- avoids construction impact of new supply development;
- lessens demand on existing water bodies;
- contributes to WWT and reduces WWT and disposal costs;
- reduces the quantity of wastewater discharged to sensitive or impaired surface waters;
- employment and income generation; and
- improved nutrition and food security (Miller, 2006; Buechler and Devi, 2003; Buechler and Scott, 2006; Heinz et al., 2011).

2.6.3.1 Water Conservation

Wastewater reuse provides a sustainable alternative supply and can safeguard existing (scarce) good-quality water resources for purposes such as drinking (Miller, 2006; WHO, 2006; Ayres and

Westcot, 1985; van der Hoek et al., 2002; Qadir et al., 2007b). In Saudi Arabia, a study has shown that water conservation and reuse across the oil and gas sector could reduce water withdrawals by 29 percent (Kajenthira et al., 2012). The use of wastewater, especially in agriculture, horticulture and aquaculture, also helps to recycle nutrients and reduce contamination of water bodies, and lessens the costs of treating wastewater to meet environmental standards. The treatment and storage of wastewater, particularly as groundwater, can help to attenuate differences between times of water supply and demand: 'water reuse basically compresses the hydrologic cycle from an uncontrolled global scale to a controlled local scale' (Bouwer, 2000).

2.6.3.2 Environmental and Health Protection

Wastewater entering natural water bodies contributes significantly to their degradation (Liu and Persson, 2013; Toze, 2006a), therefore reusing wastewater or disposing of it onto land, reduces the quantity of wastewater and pollutants entering surface water bodies (van der Hoek et al., 2002; Raschid-Sally et al., 2005) and can avert downstream health and environmental impacts (Carr, 2005). As Ensink et al. (2002) point out, by using wastewater for irrigation, the direct health risks through actual contact with wastewater are localized within an irrigated area, the exposed group is relatively small, and the risks can potentially be managed more easily and with less cost. If wastewater were to be disposed of to open water bodies, larger populations of downstream water users would be exposed to uncertain health risks.

Treatment processes themselves can also contribute to pollution. The use of chlorine to kill pathogens can result in effluent containing chlorine degradation products, which have been linked to cancer and other health effects. There may be more effective ways to avoid infectious disease outbreaks and prevent further pollution, such as soil aquifer treatment (Bouwer, 2000). When managed correctly, certain uses can be viewed as low-cost and hygienic ways of disposing of municipal wastewaters (van der Hoek et al., 2002; Raschid-Sally et al., 2005), a method for lessening nutrient discharge and improving the quality and ecological conditions of water bodies (Garcia and Pargament, 2015), and of reducing the loss of freshwater to the sea (Liu and Persson, 2013).

2.6.3.3 Phosphorus Conservation

When wastewater containing P is used in agriculture it can contribute to the preservation of phosphate reserves, which are predicted to run out in 30 to 160 years (Cordell et al., 2009; Dawson and Hilton, 2011; Rosemarin and Ekane, 2015; Wellmer and Becker-Platen, 2013). Phosphate is usually mined in open cast mines and due to inefficiencies in the food production and consumption chain, only one-fifth of this reaches the food eaten (Cordell et al., 2009). '*There is a clear requirement to ensure that phosphorus is recycled … so that the rate of exhaustion of the reserves of phosphate rock is significantly reduced'* (Dawson and Hilton, 2011). Cordell et al. (2011) see P scarcity as an emerging global challenge for food security that will mean that P will have to be recovered from all current waste streams for use as a fertilizer.

2.6.3.4 Agricultural Productivity and Incomes

One of the main benefits associated with wastewater irrigation is that the wastewater acts as a reliable water supply to farmers, particularly in low-income, dry areas, which, according to Hanjra et al. (2012); van der Hoek et al. (2002); Raschid-Sally et al. (2005); Jiménez et al. (2010); Bradford et al. (2003); Huibers and Van Lier (2005); and Martijn and Redwood (2005) enables farmers to:

- grow high value crops out of season;
- cultivate multiple crops;
- grow more intensively;
- be more responsive to crop water needs; and
- achieve higher incomes.

In a one year study in Haroonabad, during which there was no rainfall, the greatest benefit for farmers using wastewater was the reliable water supply, which allowed them to grow high-value short-duration vegetable and fodder crops, out of season and command higher prices (van der Hoek et al., 2002; Ensink et al., 2002). By contrast canal water irrigators had to grow crops that were less sensitive to water stress (cotton and wheat), but which have longer growing cycles. Even though there was no rainfall 100 percent of wastewater farmers felt that they had sufficient water to meet their needs compared to 30 percent of the canal water farmers (van der Hoek et al., 2002). Similar findings were reported by Raschid-Sally et al. (2005) who observed that the year round availability of wastewater allows for multiple cultivation cycles and different cropping patterns, which can improve earnings and lift farmers out of poverty.

Benefits are maximised by the advantages associated with urban agriculture, which van Veenhuizen (2007) reports as being: direct access to urban consumers and markets; proximity to institutions that provide market information, credit and technical advice; and the availability of reliable and cheap inputs such as nutrients (in Scheiering et al., 2011). In Kumasi the farmers producing lettuce and spring onions for urban consumers can earn incomes of USD 400–800, twice what they would earn from rural farming (Keraita, 2003). An economic analysis by Qadir (unpublished, reported in Qadir et al., 2007b) based on the cost of production of crops in Syria, found that each 1 USD invested in production gave a return of USD 5.31 for wheat (*Triticum aestivum L.*) irrigated with wastewater and USD 2.34 for wheat irrigated by groundwater; and USD 7.48 for vegetables irrigated with wastewater compared to USD 3.29 for groundwater irrigated vegetables.

Aquaculture using wastewater also shows high levels of productivity and incomes. Research on wastewater-fed duckweed, has shown several positive attributes such as high annual yields of 10-40 tonnes dry matter/ha and high crude protein content of 25-45 percent on a dry matter basis (Edwards, 2010). A model sewage-fed aquaculture system in Karnal, India, produced 12,000-16,000 kg of fish and generated an annual profit of INR 0.8-1 million (USD 12,000-15,000) through their sale in the local market. In addition the effluent was sold to local farmers (Kumar et al., 2014).

2.6.3.5 Cost Savings

Cost savings in agriculture have been reported by a number of authors, particularly in relation to nutrient and organic matter which, if managed properly, can help farmers to achieve better yields and reduce their expenditure on chemical fertilizer (Pescod, 1992; Haruvy, 1998; Jiménez et at., 2010; Qadir et al., 2007a; 2007b; Hanjra et al., 2012; Murray and Ray, 2009; Bradford et al., 2009; van der Hoek et al., 2002). Links between the nutrient content of wastewater and crop yields have been shown in various field studies:

- Jordan - wastewater met 75 percent of the fertilizer requirements of a typical farm (MWI, 2004; cited in Carr et al., 2011a).
- Saudi Arabia - supplemental irrigation with wastewater reduced the inorganic fertilizer requirement by 50 percent when the wastewater contained a nitrogen concentration of 40 mg l^{-1} (Hussain and Al-Saati, 1999).
- Field trial - irrigation of olive trees with untreated wastewater resulted in a 50 percent yield increase compared to rainfed trees, and improved the flesh to pit ratio (Lopez et al., 2006).
- Faisalabad, Pakistan - farmers reduced their chemical inputs and achieved higher yields (Simmons et al., 2010).
- Syria - farmers growing wheat with wastewater saved USD 95 ha^{-1} due to reduced fertilizer requirements compared to those growing the same crop with groundwater (Qadir, unpublished, reported in Qadir et al., 2007b).

2.6.3.6 Employment

The availability of wastewater supports agriculture, aquaculture, fishing and horticulture, all of which provide opportunities for income generation and employment. It is estimated that the wetlands in Kolkata directly employ around 8,000 individuals but as many as 32,000 may be temporary employees (Bunting, 2004). Thousands more benefit indirectly as boat builders, net makers and fish sellers for example (Bunting, 2004). Along the Musi River in India, wastewater irrigation provides livelihoods to a diverse set of people from different castes and social classes, and due to the year-round nature of wastewater production, many of these activities are permanent when once they were seasonal. However, it continues to be a hidden economy (Buechler et al., 2002; Buechler and Scott, 2006).

2.6.3.7 Food Security and Dietary Diversity

Wastewater agriculture and aquaculture can lead to improved household food security, dietary diversity and household incomes, which in turn lead to better overall household outcomes and improved child education (Carr, 2005; Ensink et al., 2002; Matsuno et al., 2004; in Qadir et al., 2007b; Buechler and Scott, 2006; Bunting, 2004). Malnutrition affects approximately 800 million people in the developing world (WHO, 2000), results in the deaths of 10.4 million children under the age of 5 each year and can have long-term effects on the health and social development of communities. Wastewater irrigation can be an important strategy to improve nutrition rates and can potentially reduce the impact of other diseases, such as malaria, by providing families with the resources to invest in preventative measures (Carr et al., 2004).

The ability to cultivate throughout the year, to grow a greater diversity of crops, and to support livestock and fish production also benefits consumers by contributing to the supply of perishable produce to urban areas, thus improving nutrition (Scott et al., 2004; Drechsel et al., 2006; Amoah et al., 2007; Drechsel et al., 2002). Wastewater use may also support urban and peri-urban livestock production by facilitating the growth of fodder crops which are necessary when land for grazing is limited (Jiménez et al., 2010; Carr et al., 2011a). Aquaculture, both fish and plant, can also be an important source of vitamins, minerals and protein, especially in diets dominated by rice consumption (Bunting, 2004; WHO, 2006b). Deficiencies that aquaculture can help to address include Vitamin A, which can cause blindness in children; iron which can cause anaemia; protein and minerals (Bunting, 2004; WHO, 2006b). The result of crop, fish and animal production in or near cities is a more balanced diet, better nutrition and lower food prices (Jiménez et al., 2010).

2.6.4 Societal Risks - Commodification of Wastewater

In addition to the livelihoods and societal benefits there can be negative implications for certain stakeholders, specifically where wastewater use is already undertaken with partially or untreated wastewater and where new schemes are introduced to improve the quality of that water. Increasingly wastewater is the subject of private and public economic interests, which has social welfare and environmental implications (Scott and Raschid-Sally, 2012). It is also more closely regulated than at any other time in the past (Scott and Raschid-Sally, 2012) and as '*Trends in resource-endowed settings are moving toward the use of treated water at increasingly higher water quality standards for higher-value uses, such as industrial and municipal uses. The prospect of water scarcity begins to discourage lower-value uses, such as agricultural irrigation and aquifer recharge and free or heavily-subsidized use of reclaimed water'* (GWI, 2010; cited in USEPA and USAID, 2012). The result of this commodification and regulation of wastewater can be that informal users who have come to rely on the resource may be forced out by higher value uses such as industry and municipal uses.

In a study from Guanajuato, Mexico, Scott (2003) reported on plans to treat wastewater and sell it to a golf course, thus depriving the farmers of a resource valued at 31 USD/ha. Silva-Ochoa and Scott (2004) calculated that based on a proposed payment of 0.07 USD /m^3 of treated wastewater, farmers could meet the cost through changes in cropping patterns but concluded that financially the WWTP would not be a benefit to the farmers; unlike industry users which they calculated could afford up to 0.50 USD/m^3. There are plenty of examples where farmers can and do pay for wastewater, including Jordan and Pakistan (McCornick et al., 2004; Ensink et al., 2004a) but improved treatment and intensions to achieve greater cost recovery could be deleterious to their livelihoods, essentially forcing them out of the wastewater market. However, studies comparing the cost of irrigating with wastewater, canal and groundwater, suggest that farmers pumping groundwater are paying several times more than wastewater farmers and are still profitable (Clemett, unpublished), hence some wastewater farmers may be able to cope with higher prices.

Another way in which farmers may be impacted by increased water reuse is through diversion of wastewater within the city, which results in less wastewater flowing downstream where it is already used by farmers, fishermen or other stakeholders (Molle and Berkoff, 2006). There are very few places where water flowing downstream is completely unused, either by people or nature.

2.7 Risk Reduction

Safe use of wastewater is often considered to relate to the level of treatment, and standards for reuse were typically based on water quality criteria (WHO, 1989; USEPA and USAID, 2012). For example, the WHO Guidelines (1989) recommended FC levels of ≤1000 per 100 ml and ≤1 nematode egg per litre for unrestricted irrigation. The USEPA and USAID (2012) has stricter standards of: no detectable FCs for unrestricted urban use, agricultural use on food crops, unrestricted impoundments and groundwater recharge; and ≤200 FC per 100 ml for restricted urban use, processed food and non-food crops, restricted impoundments, environmental and industrial use. Consequently many treatment technologies have been developed to meet these standards. However, the high investment and O&M costs of these technologies limit their use in resource constrained settings (Keraita et al., 2015).

2.7.1 International Thinking and Guidance

A major shift in thinking took place at the turn of the century when the knowledge about the benefits of wastewater and excreta reuse and the potential risks were combined to stimulate an risk reduction approach that could maximise the benefits and minimize the risks of reuse even in areas where wastewater and excreta management was constrained by resources and governance factors. The **Hyderabad Declaration on Wastewater Use in Agriculture**, was a milestone in this change of attitude, when *'professionals from 27 institutions across 18 countries formally recognized that (i) wastewater (raw, diluted, or treated) is a resource of increasing global importance, particularly in urban and peri-urban agriculture; (ii) with proper management, wastewater use contributes significantly to sustaining livelihoods, food security, and the quality of the environment; and (iii) without proper management, wastewater use poses serious risks to human health and the environment'* (Hamilton et al., 2007).

This thinking and much research and debate, culminated in the **WHO (2006a) Guidelines for the Safe Use of Wastewater, Excreta and Greywater.** The WHO (2006a) Guidelines were preceded by the 1973 and 1989 versions but the 2006 iteration was a substantial update and a move away from prescriptive water quality criteria and treatment systems. The latest WHO Guidelines are '*meant to be adapted to the unique social, economic and environmental factors in each situation'* (Carr, 2005) and offer a multi-barrier approach to risk reduction, as well as guidance on identifying and quantifying risk in each given situation. One reason for this approach was that there is considerable informal, direct and indirect wastewater use taking place which is difficult to monitor and regulate. If countries are to protect health and the environment, they need to form policies and strategies that meet with national and international support and that incrementally reduce risk and increase benefits (Carr, 2005).

This section briefly reviews some of the main reuse technologies to remove pathogens and chemical pollutants, as well as options along the wastewater production and use chain that form the multi-barrier approach.

2.7.2 Treatment Options

A wide range of treatment options exist that enable different water quality levels to be achieved depending upon the use of the reclaimed water (USEPA and USAID, 2012). The choice of technology depends on factors including: costs; availability of land, technology and expertise; and climate. Options range from conventional activated sludge to extensive, low cost systems such as lagoons, WSPs and constructed treatment wetlands (CTWs) to various anaerobic systems such as upward flow anaerobic sludge blankets (UASBs) (Qadir et al., 2015). Tertiary or advanced treatment for uses that require high quality water include UV treatment, chlorination, reverse osmosis, ultrafiltration and ozonation, to name a few (USEPA and USAID, 2012). Discussion of their relative merits can be found in several publications, notably Crites and Tchobanoglous (1998), von Sperling (2007, 2002) and Libhaber and Jaramillo (2013), along with a plethora of articles that consider individual options, comparisons of options or technologies for particular contexts or reuse practices, for example, de Koning et al. (2008) who developed a treatment matrix based on raw wastewater quality and the intended use; Mara (2001) who focusses on appropriate collection, treatment and reuse; Battilani et al. (2010), who tested a prototype '*small-scale compact pressurized membrane bioreactor and a modular field treatment system including commercial gravel filters and heavy-metal specific adsorption materials*'; Ayaz (2008) who considers constructed wetlands for post-treatment and reuse of treated effluents; Brissaud (2007) who evaluated low technology systems for WWT (not specifically for reuse); and Morari and Giardine (2009) who analyse the efficiency of vertical flow CTWs to treat municipal wastewater for agricultural reuse. The literature covers numerous field trials, reviews of full-scale treatment systems, and comparisons of technology choices.

2.7.3 Non-Treatment Options for Irrigation

Wastewater treatment, combined with strict implementation of water quality standards has been shown to safeguard public health, however in many low-income countries and resource constrained settings treatment is severely lacking (Keraita et al., 2015) and there is limited capacity to enforce standards. The multi-barrier approach proposed by WHO (2006b) has proven to be an effective way of protecting users (e.g. farm workers), local communities and consumers because it addresses contamination of wastewater after treatment, as well as on farm and post-harvest contamination of produce (Keraita et al., 2015), and it offers security if one barrier fails (Drechsel et al., 2015a). Although mostly applied in developing countries the approach is already institutionalized in developed countries through the hazard analysis critical control point (HACCP) approach (Keraita et al., 2015; Ilic et al., 2010) as well as the *Codex Alimentarius* which calls upon countries to work towards food safety standards (Ilic et al., 2010).

The multi-barrier approach identifies critical control points and options to reduce the risk. Individually the interventions may not be sufficient but taken along the production chain they should afford adequate protection (Ilic et al., 2010). Methods of risk reduction, or barriers, and the stakeholders that would benefit from these interventions are shown in Figure 2-4.

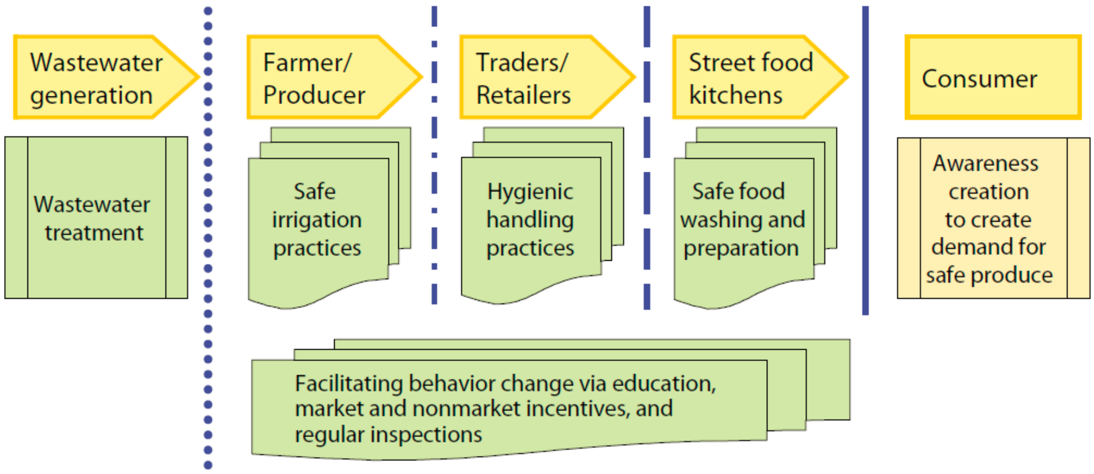


Figure 2-4. Multi-barrier approach to consumer health risk reduction in wastewater agriculture
Source: Amoah et al. (2011)

Several options were tested with farmers in Ghana by Amoah et al. (2011) including reducing disturbance of sediments in farm ponds to prevent re-entrainment of helminth eggs, filtration, and cessation of irrigation before harvesting to allow pathogen die-off. Handling in the market was also tested including storage, removal of outer leaves and washing. Allowing solids to settle in ponds overnight showed a high reduction in helminth eggs and filtration resulted in good removal of bacteria and helminth eggs (Table 2-4).

Table 2-4. Effectiveness of treatment and non-treatment options for pathogen removal

Intervention	Pathogen reduction	Chemical pollutant

	(log units)*	reduction (%)
Wastewater treatment	6-7	
On-farm options		
• Crop restrictions (food crops cooked)	6-7	
• On-farm treatment (tank system, sedimentation, filtration)	0.5-3	45 % of BOD, 60 % of suspended solids
• Wastewater application (furrow, drip, reduced splashing)	1-4	
• Pathogen die-off – irrigation cessation	0.5-2 per day	
Post-harvest options		
• Storage in baskets overnight	0.5-1	
• Washing	1-3	
• In kitchen preparation (washing, peeling, cooking)	2-6	

*A reduction of 1 log unit represents a reduction to 90% of the original coliform counts. A 2 log unit reduction represent a reduction to 99%, 2 logs to 99.9% and so on.
Source: Adapted from Keraita et al. (2015); WHO (2006); Amoah et al. (2011)

2.7.4 Sanitation Safety Planning

Linked to the barrier approach is the recently developed concept of Sanitation Safety Planning (SSP), a risk based management tool for sanitation systems, which is similar to Water Safety Planning. Sanitation Safety Planning assists users to:

- systematically identify and manage health risk along the sanitation chain;
- guide investment based on actual risks, to promote health benefits and minimize adverse health impacts; and
- provide assurance to authorities and the public on the safety of sanitation-related products and services (WHO, 2016).

The process is collaborative and incremental, bringing together actors from different sectors to identify health risks and agree on improvements and regular monitoring, to ensure that control measures target the greatest health risks and improvements increase over time (WHO, 2016).

2.7.5 Obtaining Value from Reuse

There are clear benefits and risks associated with wastewater use in its many forms which must be balanced. The frequent calls to ‘properly’ treat wastewater before use are often impossible to implement and may remove useful constituents (Jiménez et al., 2010). The solution is to find appropriate management strategies that provide the required water quality for the desired use while minimizing risk and which contribute to the overall sanitation or IWRM strategy (Jiménez, et al., 2010; WHO, 2006; Bunting, 2004).

One such concept in this field is 'design for service' (DFS), in which wastewater use is planned to ensure that the treatment results in an effluent quality that is suitable for the proposed use (Pescod, 1992; Murray and Buckley, 2010; Murray and Ray, 2010; Huibers and Van Lier, 2005). In agriculture, this could potentially increase agricultural yields, conserve surface water, offset chemical fertilizer demand, and reduce the costs of WWT by eliminating nutrient removal processes (Murray and Ray, 2010). As Huibers and Van Lier (2005) explain, '*… the need for nutrient removal in wastewater treatment systems becomes less when the effluents are used by farmers downstream in the chain*'. An evaluation of two scenarios, estimated that there could be a USD 20 million annual increase in profits from supplemental irrigation and that 35 million cubic metres (MCM) of river water could be conserved annually by replacing existing irrigation water with wastewater in the peri-urban district of Pixian, China (Murray and Ray, 2010).

However, '*water and nutrient recycling has … so far not been considered as an objective sufficiently important to modify the general approach to sanitation. When conventional technology is adopted for treating wastewater, treatment plants are designed with no concern for reuse …'* (Bahri, 2009). To address this Bahri (2009) proposes the following approach:

- Water reuse should play a key role in sustainable development – wastewater as a resource.
- A watershed approach to urban IWRM: managing water, wastewater, pollution control and water reuse in an integrated way.
- Appropriate and cost-effective treatment levels to correspond to each reuse option.
- Integrate agriculture into the treatment cycle.
- Decentralized approaches and the full range of sanitation options.
- Protect wastewater from pollutants to facilitate use.
- Combine treatment and non-treatment options to reduce health risks.

2.8 Public Perception and Engagement in Reuse

It has been shown many times that public acceptance can be the single most important factor in the success or failure of a water reuse project, often proving more significant than economic and environmental feasibility (Po et al., 2003; Friedler and Lahav, 2006). Public acceptance is not straightforward and even when key factors like high levels of water scarcity, education and treatment capacities exist (Drechsel et al., 2015b) or where there is widespread acceptance of the concept of wastewater use, this does not always translate into successful projects (Po et al., 2003).

The disgust or ‘yuck’ factor is often cited as a reason for people’s unwillingness to accept reuse, especially projects that require close personal proximity or involvement (Po et al., 2003; Miller, 2006). It is a psychological barrier that produces a disgust emotion due to fear of dirtiness or contagion (Po et al., 2003; Miller, 2006) and is often something that stakeholders cannot explain. In general people are more willing to accept uses that involve less contact, such as landscape irrigation, than recreational, domestic or potable use (Friedler and Lahav, 2006; Miller, 2006; Drechsel et al., 2015b; Robinson et al., 2005).

2.8.1 Reuse Projects

People are concerned about the risks of using wastewater, even when they are reassured. This may be because experts describe risk in terms of probabilities while the public has a broader perception of risk. So, while a one in a million chance of infection may be acceptable to a scientist, a member of the public may be concerned that the one person could be them or their child (Po et al., 2003). People also use social and moral values, or ‘outrage factors’ to judge risk and may perceive reuse to have unknown future consequences (Po et al., 2003).

The source of the wastewater is also important. Studies have shown that people prefer to reuse their own waste, rather than that of the community or city, and preferentially accept grey water over black water. However, other studies have disputed this, with respondents choosing large scale projects because of the level of treatment and management of the system. Some respondents feel that systems managed by individuals or communities are more likely to fail (Po et al., 2003).

Trust in the authorities or organizations involved in developing and implementing reuse projects is fundamental to stakeholders’ opinions of reuse (Marks, 2006; Dolnicar and Schäfer, 2009; Hartley, 2006; Baggett et al., 2006; Ormerod and Scott, 2012). The public tends to trust academic researchers and scientists over public agencies and officials (Hartley, 2006; Po et al., 2003; Baggett et al., 2006).

Po et al. (2003) cite attitudes to the environment as influencing project success. People who have already implemented environmental projects were more accepting of reuse schemes. Conversely, the availability of alternative sources is a major disincentive to reuse (Drechsel et al., 2015b), even if the quality is poorer or it is more difficult to treat. Miller (2006) suggests that a flawed price system for water, which keeps it unrealistically low, diminishes acceptance of reuse. Knowing the financial viability of a reuse project, not just to the community but from an individual perspective, is important for a consumer to form an opinion (Drechsel et al., 2015b).

2.8.2 Introducing Safe Reuse Practices

Public perceptions also have a bearing on the transition from informal to formal, or unsafe to safe reuse practices, and can affect the risks and benefits (Drechsel et al., 2015a; 2015b). Where reuse of untreated or partially treated wastewater is common and where regulation of the practice is weak, the adoption of safety interventions will depend on: personal risk awareness, interlinked with educational, social and cultural factors; and financial benefits and costs to individuals. In low-income countries people face numerous risks, including insufficient food and water, and inadequate sanitation, this sets the context for their perception of the risk of wastewater use. This, in turn, can influence their willingness to introduce risk reduction strategies, even though there may be contradictions between actual and perceived risks, as wastewater farmers seldom associate infections and diseases with their irrigation practice (Rutkowski et al., 2007; Bos et al., 2010).

In Ghana, much of the vegetables produced with wastewater are sold to wealthier urban consumers, whose risk perception may be different to farmers (Dreschel et al., 2015a). In many places consumers are unaware of the origin of agricultural produce but as they gain knowledge of the provenance of their food their perceptions may change. *'This not only restricts the market potential but may also affect social interactions, possibly resulting in victimisation or ostracism'* (Bunting, 2004). This is the case in Addis Ababa, where farmers encounter obstacles in marketing their produce because direct buyers recognize that wastewater-irrigated produce may present food-quality and safety risks (Scott and Raschid-Sally, 2012). Consequently authorities may distance themselves from waste reuse practices. Examples exist of this resulting in the decline of wastewater aquaculture systems (Bunting, 2004). Similarly, governments of countries purchasing products may impose restrictions that damage agricultural systems, as happened in Jordan (McCornick et al., 2004).

Drechsel et al. (2015a) identify six components that contribute to behaviour change in relation to the adoption of risk reduction strategies. These are:

- awareness creation, which plays a supporting role and is best achieved through demonstration and local networks;
- incentives, especially direct economic returns;
- social responsibility, facilitated by the private sector through 'out-grower schemes' or accreditation;
- social marketing, using positive core values to trigger change;

- laws and regulations, based on locally feasible standards; and
- media pressure.

2.8.3 Summary

The general message for both planned and unplanned reuse projects is that public engagement and trust building are essential components for success (Po et al., 2003; Dreschel et al., 2015b). Hartling (2001; cited by Friedler and Lahav, 2006) describes three main measures that if implemented correctly may ensure public acceptance of wastewater reuse schemes: to be transparent and reveal all the facts about the project; to talk to the public in a language they understand, and in a clear and interesting way; and to have the public participate in the decision making process. Campaigns should clearly explain risks and potential economic benefits (Friedler and Lahav, 2006). Dolnicar and Schäfer (2009) suggest that successful projects require contributions from three sides: professional knowledge for the technical foundation; community acceptance and desire; and 'issue management' (managing information, maintaining motivation, demonstrating commitment, promoting communication, ensuring a fair decision making process and outcome, and building and maintaining trust). However both Po et al. (2003) and Marks (2006) are clear that the effectiveness of public consultation and respectful deliberation are far more successful than social marketing and strategic communication, which can be alienating.

2.9 Guidelines and Legal Frameworks for Wastewater Reuse

Several countries and international organizations have developed guidelines and legal frameworks for wastewater reuse. Some of the internationally best known and adopted guidelines are described briefly in this section to highlight the similarities and differences in the approaches. The section also considers some national guidelines and laws to highlight good practice, and how legal frameworks and standards develop.

2.9.1 WHO Guidelines

The WHO Guidelines are arguably the most well-known and utilized international guidelines on wastewater use in agriculture and aquaculture. The first guidelines were proposed in 1973 (WHO Technical Report Series, No. 517) and took a low-risk approach (Carr, 2005). They were revised in 1989 to take account of the best and most recent epidemiological evidence, which suggested that a more realistic approach could be taken to control the transmission of communicable diseases. The evidence showed that limits on the presence of viable ova of parasitic helminths in irrigation water were necessary to safeguard public health but also that the quality criterion for FCs in irrigation water could be relaxed without creating an unacceptable risk to the exposed population (Strauss and Blumenthal, 1989). It was also perceived that overly strict standards were impossible to achieve in many situations and were often ignored, so guidelines needed to include risk management approaches that would complement available treatment processes or could be used in the absence of WWT (Carr, 2005). Revised quality criteria were based on epidemiological evidence of actual risks to public health, rather than on potential hazards indicated by the survival of pathogens on crops and in soil (Mara and Cairncross, 1989).

The WHO guidelines are designed to aid policy makers in decisions about which WWT processes, crops and irrigation methods are appropriate for safe agricultural production; not as standards for regular water quality monitoring. Standards for wastewater reuse in many countries have been influenced by the WHO (1989) health guidelines including parts of Europe, Asia, and Latin America (Blumenthal et al., 2001). Many countries have adopted two fundamental points of the guidelines: that FC counts should be < 1000/100 ml in water used to irrigate crops that might be eaten raw, for sports fields and public parks; and the concentration of nematode eggs for the same uses, as well as for cereal, industrial and fodder crops, and pastures, must be < 1 egg/L (WHO, 1989).

In 2006, the WHO published the third edition of its 'Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture' to take account of recent scientific evidence regarding pathogens and chemicals, changes in population characteristics and sanitation practices, and better methods for evaluating risk, social/equity issues and socio-cultural practices (WHO, 2006a). The Guidelines are essentially a suite of good management practices to ensure that wastewater is used safely and with minimal risks to health. They are therefore more than a set of guideline values. The approach taken is that one or more barriers can be put in place to reduce the risk to farm workers and their families, and consumers of crops (Mara and Sleigh, 2009), as explained in section '2.7. Risk Reduction'. In practice, the WHO 2006 Guidelines have not been implemented in any low-income countries and the adoption of on- and off-farm safety measures where untreated wastewater dominates, still requires proof of concept (Drechsel et al., 2015a).

The SSPs, discussed earlier in this chapter, are the latest approach from WHO to try to improve implementation of the Guidelines and to introduce risk reduction strategies for sanitation and reuse.

2.9.2 FAO Guidelines

The FAO developed a comprehensive document on Wastewater Treatment and Use in Agriculture (Pescod, 1992), which deals with both irrigated agriculture and aquaculture. The document includes health risks, environmental hazards and crop production potential associated with the use of treated wastewater. It draws on the WHO Guidelines for health protection measures and introduces natural biological treatment systems as viable alternatives for WWT in developing countries, particularly in hot climates. It deals extensively with water quality requirements for optimum crop production and potential impacts on soils and crops (Pescod, 1992), and is widely utilized by policy makers and practitioners for this aspect in particular.

2.9.3 USEPA Guidelines

The USEPA Guidelines (1992; 2004; and 2012) were developed to help with conservation of limited supplies of high-quality freshwater. The context at the time of the 2004 guidelines was of supply limits, which were creating greater acceptance of reclaimed water; and strict discharge limits, which required considerable investment and resulted in a number of industries and communities striving to recover at least part of the investment cost (USEPA and USAID, 2004). The Guidelines are designed to supplement state regulations and guidelines in the USA by providing technical information and outlining key implementation considerations. However, they also contain information that will aid in the expansion of safe and sustainable water reuse globally and include 100 case studies from around the world. The 2012 Guidelines emphasize the concept of 'fit for purpose' because technologies are now advanced enough to treat wastewater to the quality desired for specific, predetermined, uses (USEPA and USAID, 2012).

'*Globally, the EPA Guidelines for Water Reuse has also had far-reaching influence. In fact, some countries either reference the document or adopt the guiding principles outlined in the 2004 guidelines'* (USAID and USEPA, 2012). The 2012 Guidelines have taken into account the WHO 2006 Guidelines and have expanded the international reuse chapter to include similar principles such as mitigating risks where treatment does not exist (USEPA and USAID, 2012).

Interestingly, Fattal et al. (2004), estimate that the cost of treating raw sewage used for direct untreated irrigation to meet the WHO 1998 microbial guideline of 103 FC per 100 ml is approximately USD 125 per case of infection (hepatitis, rotavirus, cholera, or typhoid) prevented compared to the incremental cost of further treating wastewater to the USEPA microbial guideline (of no detectable FC per 100 ml), of USD 450,000 per case of infection prevented. These calculations do not accounted for removal of helminth eggs which are more persistent (Raschi-Sally et al., 2005).

2.9.4 EU Guidelines

The EU Water Framework Directive is a piece of European Union (EU) legislation, to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which prevents further deterioration and protects and enhances the status of aquatic ecosystems (European Parliament, 2000). Each member state has to transpose the directive into their own national legislation, utilizing the 'Common Implementation Strategy', and must designate a Competent Authority to oversee this (CIWEM, 2012). The Directive does not cover the reuse or recycling of water *per se* but its focus on water pollution and the protection of receiving waters has implications for wastewater management, treatment and use.

The AQUAREC project on "Integrated Concepts for Reuse of Upgraded Wastewater," funded in part by the EU, concluded that there was an urgent need to establish water reuse guidelines because the current lack of guidance leads to misunderstanding and misjudgement. Despite the lack of EU guidelines several countries, Belgium, Cyprus, Spain, Italy and France, have developed their own criteria for reuse (Wintgens et al., 2002). Where legislation does not exist, alternative solutions are provided. For example, in the UK, there are no nationally agreed standards for irrigation water quality but standards are imposed through assured produce schemes often initiated by retailers and buyers which are subject to local audit. Generic advice is available to those not in assured produce schemes from the Food Standards Agency (Groves and Hulin, 2014).

Since then, the European Commission (EC) has developed the 'Strategic Implementation Plan of the European Innovation Partnership on Water'. This considers water recycling and reuse to be a priority area of work and at the core of an IWRM approach to support the provision of safe, available and affordable water, while decreasing energy needs, reclamation costs and environmental impacts (EC, 2012). In addition, the EC is evaluating the most suitable EU-level instruments to encourage water reuse, with a view to make a policy proposal (EU, 2015).

2.9.5 Australian Guidelines

Australia has one of the most well developed sets of guidelines on water recycling globally. The 'Australian Guidelines for Water Recycling: Managing Health and Environmental Risks,' released in 2006, has two phases. Phase 1 covers the use of recycled greywater and treated sewage for:

residential gardens; car washing; irrigation of urban recreational and open spaces; agriculture and horticulture; and industrial uses. Phase 2 covers: the augmentation of drinking water supplies; the use of stormwater and roofwater; and managed aquifer recharge (NRMMC-EPHC-AHMC, 2006).

The Australian Guidelines take a risk management approach similar to the HACCP approach. Like the WHO 2006 Guidelines they adopt a multiple barrier approach and use health-based targets and DALYs. The Guidelines have no formal legal status but, similarly to the USEPA and USAID 2012 Guidelines, are intended to create consistency across the States and Territories, which regulate recycling and have their own legislation (NRMMC-EPHC-AHMC, 2006). They include institutional capability and capacity, recommending that utilities and agencies have: sufficient resources; appropriate levels of expertise and personnel; and a commitment to high levels of management and monitoring. In addition, designers and operators of schemes, and regulatory agencies need to have appropriate expertise (NRMMC-EPHC-AHMC, 2006).

2.9.6 Jordan

Jordan has had standards for water reuse since 1995, prior to which the WHO 1989 Guidelines had been used. The Jordanian Standards for Water Reuse (JS893/1995) allow: irrigation of vegetables eaten cooked, fruit trees, forests, industrial crops, grains, public parks and fodder; discharge to streams and catchment areas; artificial groundwater recharge; and use in fish hatcheries. Certain acts are prohibited, namely: irrigation of crops eaten raw; irrigation two week before harvest; use of fallen fruit; deterioration of soil properties; use on crops sensitive to constituents of reclaimed water; sprinkler irrigation; transport of reclaimed water in unlined channels across recharge areas; dilution of reclaimed water with freshwater to meet the criteria; and use of reclaimed water to recharge aquifers used for drinking water supplies (McCornick et al., 2004).

Jordan also has a National Wastewater Management Policy (1998) which '*states that, water reuse for irrigation should be given a high priority, and that reclaimed water is to be sold at prices that, at a minimum, cover the operation and maintenance costs of delivery'* (McCornick et al., 2004). Furthermore, reuse must protect the public, conserve resources, comply with international treaties and ensure sound environmental practices. The Policy also allows for the Jordanian Standards on Water Reuse to be periodically examined (McCornick et al., 2004). In 1998 Jordan began the process of revising its management of scarce water resources and a review of the standards was initiated in 2000 to: make best use of resources; address limitations and discrepancies in the current standards; simplify compliance and enforcement; take account of new knowledge; and address international concerns about the safety of certain agricultural products. The standards were negotiated with a number of government departments and sector experts and accepted in 2006. The Jordanian Standard dealing with "Water-Reclaimed Domestic Wastewater" separate reclaimed water discharged to streams, *wadis* or water bodies, and reclaimed water for reuse, which had been considered a complication in the previous version. The new standards have two tiers for agriculture. Tier 1 contains legally enforceable water reclamation standards aimed at protecting public and farm-worker health, to be accomplished through regulation and optimal performance of WWTPs. Tier 2 is a set of non-binding guidelines to protect the soil and maintain the highest possible level of crop productivity (McCornick et al., 2004; Ulimat et al., 2004).

2.9.7 Mexico

Mexico provides an interesting example of how wastewater use regulations can develop as a result of existing use and negotiation between users and the state. Here, regulations for agricultural wastewater use were developed to reconcile the need to protect public health with the demand for water and fertilizers from farmers (Jiménez, 2005). Farmers have been using wastewater for irrigation in parts of Mexico since the late 1800s and in the 1990s the President of Mexico, at the request of the farmers, granted them an entitlement to use the wastewater. In 1994 the farmers objected to the development of a conventional WWTP which might reduce the quantity of wastewater they received and also remove the all-important nutrients. At that time, organic matter, phosphorus and nitrogen were considered pollutants by Mexican standards and therefore the first step was to modify the discharge standards. '*A set of 44 standards regulating the treated effluent quality according to the wastewater origin, …, was changed to a unified framework of only three standards regulating treated effluent quality based on the use and type of the receiving body (water or soil). Five different uses were considered: drinking water, ecological protection, wetland conservation, irrigated agriculture and wastewater disposal. In the case of agricultural use, the 1989 WHO microbial indicators, i.e. fecal coliforms and helminth eggs, were adopted for farmer and consumer protection*' (Jiménez, 2005). The 1992 EPA standards were adopted for heavy metals and for helminth eggs the treated effluent standards were based on economically viable treatment methods (Jiménez, 2005). The resulting standards, were designed to be achievable and more realistically policed with the technology and resources available in Mexico (Kramer and Post, nd).

2.9.8 Summary

There are several comprehensive sets of guidelines for wastewater use, which have slightly different motivations, approaches and applications. The WHO 2006 Guidelines, are designed to address wastewater use in agriculture and aquaculture, particularly where treatment has yet to be developed and where alternative methods can reduce health risks. The USEPA Guidelines are focused mainly on WWT and use, although the most recent iteration draws on the WHO 2006 Guidelines. The FAO Guidelines emphasise crop production and soil health, along with implications for human health. National guidelines, standards and legislation vary considerably across the globe. In many countries legislation around reuse does not exist, although standards for effluent discharge and water quality are used.

2.10 Institutional and Organizational Analysis

This section moves away from the literature around wastewater use and water recycling into the realms of policy and institutions. The purpose of this section is to consider methods for policy and institutional analysis and ways in which they have been used that are relevant to this study.

Terminology is an important starting point for this section. The vocabulary used in different fields is often open to debate and interpretation but perhaps none more so than “institutional analysis”. As a concept, institutions are highly abstract and frequently invisible elements of the policy environment (Polski and Ostrom, 1999), the result being that those on the periphery of the field often use the term loosely. North (1990) defines institutions as the humanly-devised “rules of the game” in society that shape and constrain human interaction and individual choices. Crawford and Ostrom (1995) define an institution as a widely understood rule, norm, or strategy that creates incentives for behaviour in repetitive situations. Institutions guide us to modify our behaviour in a situation that requires cooperation and coordination between one or more individuals or groups (Hurwicz, 1994). These institutions may be formally described as laws, policies or procedures, or they may emerge informally as norms, standard operating practices, or habits (Polski and Ostrom, 1999).

North (1990) stresses the distinction between institutions, which provide the rules, and “organisations” which are bound together to achieve common objectives within those institutional constraints. Institutions and organizations are often discussed synonymously, and while there are important overlaps between the two they are quite different. Polski and Ostrom (1999) clarify the difference by considering an organization as a set of institutional arrangements and participants who have a common set of goals and purposes, for example, legislatures, government agencies, multi-lateral organizations, non-governmental organizations (NGOs), business enterprises, religious groups, social networks, tribes and families. Although institutions and organizations are distinct, the analysis of one is almost always impossible without the other. For example, one can analyse a piece of legislation as it is written on paper, but without considering the organizations that implement it, their behaviour and their interaction with those stakeholders to whom the law applies, the analysis would be one-dimensional and of limited benefit in understanding the effectiveness or limitations of the legislation, or opportunities for improvement or replication.

The analysis of institutions is essential in understanding why a policy or course of action is taken and why it is supported or not, because institutions create incentives to act in a particular way in a given situation. Therefore, "if we wish to evaluate, design, or reform policy, we must have a systematic way to analyse existing arrangements and to generate and compare alternatives" (Polski and Ostrom, 1999).

2.10.1 Approaches to Institutional Analysis

Poverty and Social Impact Analysis (PSIA) is one system of analysis commonly used by the World Bank, the United Kingdom's Department for International Development (DFID) and the International Monetary Fund (IMF) to assess the impact of policies, lending and grants on social improvement. It "*is an approach for assessing the distributional effects of policy reform by analysing impacts on the wellbeing of different social and livelihoods groups*" (Holland et al., 2005). It combines a number of techniques and is based on three overlapping areas of analysis of the rules and relations that underpin and influence reform outcomes, these are **institutional, political and social analysis**. Holland et al. (2005) also describes a forth analysis that can take place at the meso-level; **stakeholder analysis**. These are defined as:

- **Institutional analysis** looks at the "rules of the game" that people develop to govern group behaviour and interaction in all spheres of life. It is based on an understanding that these rules, whether formally constructed or informally embedded in cultural practice, mediate and distort, the formation, implementation and impact of policies.
- **Political analysis** looks at the structure of power relations and often entrenched interests of different stakeholders that affect decision making and outcomes. It is built on recognition that political interests underpin many areas of policy debate and decision making and influence policy as much or more than technical information.
- **Social analysis** looks at the social relationships and cultural norms that govern interaction at different organizational levels, including households, communities and social groups. It has implications for the degree of inclusion and empowerment of specific social groups.

- **Stakeholder analysis** is built on the recognition that decision making outcomes are a function of the interests of policy stakeholders. A stakeholder being an individual, community, group or organisation with an interest in the outcome of an intervention, either because they will be affected by it or because they are able to influence the intervention (DFID, 2003, 2.1). The aim of stakeholder analysis is to identify their characteristics, interests, and influence over policies, reforms, or interventions and to uncover the formal and informal organizations and institutions that shape the context in which these policies, reforms, or interventions take place.

PSIA can be undertaken at a number of levels:

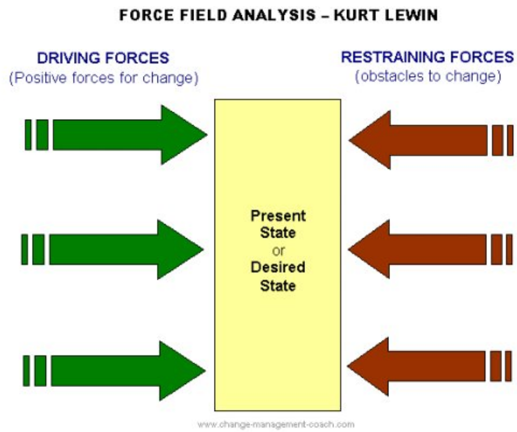
- **Country analysis** - investigating the inherited and evolving mix of political, economic and social variables that influence policy agendas and change. It helps to unpick such assumptions as "lack of political will" and to answer questions as to how to address these problems.
- **Macro-level analysis** – can encompass stakeholder analysis and institutional analysis. The former is done in order to take account of the fact that decisions are a reflection of the interests of key policy stakeholders, by understanding them and their motivations it is possible to influence the decisions they make. The latter is done to understand the processes around policy reform or decision making, what Holland et al. (2005) call the "institutional architecture" that will frame the design of policy reform. These two components can be analysed using a number of tools.
    - **Stakeholder analysis matrices** can be used to list and plot the stakeholders and their relationship to the policy process with respect to several variables such as degree of interest, power, resources or the impact that a given policy may have on them. There are several variations of the tool. The "*Stakeholder Analysis Matrix*" identifies stakeholders, lists their relevance to the area of reform, their characteristics, their interest in policy and the degree of influence that they have over the process. The "*Importance/Influence Matrix*" lists stakeholders and the nature of their interest in policy reform and then maps their importance to and influence over the reform onto four quadrants. The "*Policy Interest Matrix*" considers the policy objectives of key players within government and the degree of influence they wield.
    - "**Political Mapping**" is another tool used for stakeholder analysis at the macro-level but which focuses more directly on the political landscape, identifying the strength and nature of political-ideological opinion on an issue. The result is a matrix that shows which groups are most/least supportive of a particular policy/the regime and those groups which are least/most aligned to one another in terms of their ideologies.

- **Institutional analysis** is often more descriptive and subjective than stakeholder analysis and requires methods to organize the information obtained. Methods include “*network analysis*”, to examine the relationships between stakeholders rather than their individual characteristics. The tool helps to trace flows, for example of information, and thereby provides an understanding of who is influencing who and in what way.

- **Meso-level analysis –** is designed to explore the context of policy implementation, and the mechanisms and processes, in order to understand how, why and under what conditions a policy intervention might work or fail. “Force-field analysis” is one particular tool that can be used to map stakeholders’ opinions of policies and the strength of their opinion (Box 2-2).

Box 2-2. Kurt Lewin’s Force-field analysis

The premise of force-field analysis is that an issue is held in balance by opposing forces - those seeking to promote change (driving forces) and those attempting to maintain the status quo (restraining forces). For change to take place either the **driving forces** must be strengthened or the **restraining forces** must be weakened. Force-field analysis is used to distinguish which factors within a situation or organisation drive a person towards or away from a desired state, and which oppose the driving forces. To understand what makes people resist or accept change we need to understand the values and experiences of that person or group. If the factors **for** change outweigh the factors **against** change we will make the change. If not, there is low motivation to change.



In practice it can be used in focus group discussions to identify the supporting or constraining factors around policy decisions. The driving and restraining forces should be sorted around common themes and should then be scored according to their ‘magnitude’, ranging from one (weak) to five (strong).

Source: Start and Hovland (2004)

Another approach is that of the **Institutional Analysis and Development “IAD” framework**, developed by Polski and Ostrom (1999), a systematic method for organizing policy analysis which helps analysts comprehend complex social situations and break them down into manageable sets of practical activities, thereby avoiding simplification. The objectives are:

- To identify factors in each of three areas that influence the behaviour of individuals and groups in the policy situation: physical and material conditions, community attributes (culture), and rules-in-use.
- To identify and evaluate patterns of interactions that are associated with behaviour in the action arena, and outcomes from these interactions.

The process gradually unpicks and identifies the most salient policy issues through a series of steps:

- *Step One: Define the Policy Analysis Objective and the Analytic Approach* – identify the policy or issues, ask questions about observed outcomes, look for relevant patterns and try to answer the questions 'How are policy outcomes occurring?'
- *Step Two: Analyse Physical and Material Conditions* – ask questions about the activity that the policy is designed for, such as how is the service or good produced and provided? Can people be excluded and does consumption reduce the availability to others?
- *Step 3: Analyse Community Attributes* - demographic features of the community, generally accepted norms about policy activities, the degree of common understanding about activities in the policy area, and the extent to which potential participants' values, beliefs, and preferences about policy-oriented strategies and outcomes are homogeneous. Pokski and Ostrom (1999) note that whilst such analysis is notoriously difficult, there is plenty of literature on why policies have failed, if these factors can be determined after a policy has been implemented why can they not be identified before the policy is put in place.
- *Step 4: Analyse Rules-in-Use* - the operating rules that are commonly used by participants, the sources of these rules, and who does and does not observe them. They include position rules (roles that participants assume in a situation); boundary rules can be thought of as exit and entry rules (e.g. licensing rules); authority rules that govern what certain participants may do, such as how environmental officers must treat polluters; aggregation rules determine how decisions are made (e.g. irrigation decisions based on water quality and timings); scope rules specify the jurisdiction of outcomes that can be affected; information rules affect the amount and type of information available to participants in an action arena, which in turn can affect their decisions; payoff rules determine how costs and benefits are meted-out in the action arena.
- *Step 5: Integrate the Analysis* – the IAD policy analysis is linked by explaining behaviour in terms the **actions** and **actors**.
- *Step 6: Analyse Patterns of Interaction* - the structural characteristics of an action situation and the conduct of participants in the resulting structure. Policy situations are rarely

constrained and participants may choose a number of actions, either independently or collectively, and strategies may change over time as they see and review the results of past strategies. A policy analyst must try to make inferences about these strategies, however weak, because well-informed weak inferences can still provide important policy information.

- *Step 7: Analyse Outcomes* - insight about outcomes flows logically from well-founded observations about patterns of interaction. Analysing policy outcomes requires some form of evaluation criteria. The IAD framework considers: economic efficiency, fiscal equivalence, distributional equity, accountability, conformance to general morality, and adaptability.

IFAD also defines a step-by-step approach for institutional[4] analysis that includes assessment of "action arenas", which can be undertaken either to understand what is causing results or to identify the changes in institutions and processes required for desired future results (IFAD, 2009). Two areas of results are considered: "delivery results," relating to the outcome of the policy; and "governance results," which are about the relationships and the process. The evaluative criteria recommended for each are given in Table 2-5. The premise of the IFAD approach is that once these results have been understood, the organizations and institutional processes that have produced these results can be analysed in terms of the specific sets of actions or functions that have generated these results.

Table 2-5. Evaluative criteria for institutional analysis

Evaluative criteria for "delivery results" – goods and services	Evaluative criteria for "governance results"
• Availability • Quality and quantity • Choice, price and affordability • Distribution and timeliness	• Equity • Transparency and accountability • Participation, consultation and inclusiveness • Efficiency • Stability, sustainability and responsiveness of the institutional systems.

Source: IFAD, 2009.

The benefits of this approach are that it provides a more holistic analysis of the institutions that produce results because the focus is on the result and not an individual organization or stakeholder; and it concentrates on factors that are responsible for specific impacts by considering an action arena, similar to the IAD approach. In the IFAD approach mapping these action arenas involves linking each of the actions that make up a particular action arena to:

- The different actors involved in performing these actions.

[4] It should be noted that in IFAD's terminology institutions are synonymous with organizations.

- Their respective roles and responsibilities (or mandates).
- Their capacity to perform the responsibilities they have been assigned (resources and skills).
- The relationships between different actors – how they are linked and interact; and separation of their functions.
- The rules and incentives that influence different actors leading to the results observed – rules include formal rules and regulations as well as “rules of the game”; incentives may be material, financial or less tangible.

2.10.2 Analysis Techniques

Several techniques are used within institutional analysis approaches to sort the information. **Matrices** (Table 2-6) can be used to identify relationships, relative opinions or influence, and a whole range of other linkages and comparisons.

Table 2-6. Matrices for stakeholder analysis

Matrix	Application
Importance/influence matrix	To map the relative importance and influence of key stakeholders. Assists projects in deciding who should be involved.
Conflict/ complementarity matrix	To map areas of co-operation and conflict between stakeholders. Areas of consensus are useful starting points for co- operative work.
Actor linkage matrix	To map linkages and flows of information between stakeholders. It can be used to gain an understanding of the key institutional linkages with which the project should work, or strengthen, to achieve its aims. It is useful in development of meaningful indicators of change.

Source: Matsaert (2002); Biggs and Matsaert (1999)

SWOT analysis is a strategic planning tool used in many sectors. The framework supports consideration of the internal situation (e.g. of a business or policy arena) by considering current strengths and weaknesses. Analysis of the external environment that could affect the strategy (i.e. business, policy or project) in the future is achieved through consideration of opportunities and threats (Figure 2-5). The analysis allows consideration of the current and future state and leads to identification of strategies to deal with both. In the process of the SWOT analysis the importance of identified elements can be ranked.

Figure 2-5. Schematic representing SWOT analysis

Source: Start and Hovland (2004)

Triangle analysis is a technique for problem identification and solving that breaks the situation down into consideration of content, structure and culture (Figure 2-6).

- **Content** refers to written laws, policies and budgets relevant to a specific issue.
- **Structure** refers to mechanisms for implementing a law or policy. This would include government and non-government structures.
- **Culture** refers to the values and behaviour that shape how people deal with and understand an issue (Start and Hovland, 2004).

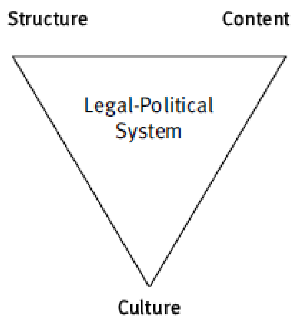


Figure 2-6. Pictoral representation of triangle analysis
Source: Adapted from New Weave (2002:170) and Schuler (1986); in Start and Hovland (2004)

2.11 Discussion

The literature on wastewater use covers an enormous field. It spans treated and untreated wastewater, technical aspects such as treatment technologies, environmental and health risks and impacts, management and policy issues. It can also be divided into the type of wastewater under consideration (i.e. industrial or domestic; black or grey water) and the use to which it is put (e.g. agriculture, aquaculture, industry or municipal). This review has tried to cover as many of these aspects as possible but it has become clear that certain areas have more or more accessible literature. For example, literature on wastewater use in agriculture, as well as literature on health aspects of reuse was relatively common. It was more difficult to find relevant literature on wastewater use in industry and other sectors. This may be because much of the current literature on these aspects is highly technical and focuses on treatment technologies. Relevant information was mainly found in general wastewater related documents such as USEPA and USAID (2012).

Literature on policy and institutional aspects of wastewater use is also less well covered in the literature review than had been anticipated. This is because, by comparison with other aspects, such as health, there was very little literature available. Documents that included institutional aspects generally did so as part of wider studies, rather than as the primary focus (see Ensink et al., 2002; Keraita and Drechsel, 2004; and Qadir et al., 2007b). Furthermore, the use of the term 'institutional' referred, in most cases, to organizations and did not cover the boarder concept of institutions (see Amponsah et al., 2015; Drechsel and Keraita, 2014; Kramer and Post, nd). Consequently, it is felt that there is considerable scope for studies on institutional aspects of wastewater use that cover stakeholders, policies, legislation and informal arrangements

3 Research Design and Data Collection Methodology

3.1 Chapter Outline

This chapter explains the conceptual framework for the study, the guiding research question and the methodology. It provides a schematic of the research components and details the protocol followed for the case study, the main research method utilized, within which are nested several other methods – document analysis, stakeholder analysis and institutional analysis.

3.2 Conceptual Framework for the Study

The research is undertaken in the context of growing demand for water and sanitation but limited resources. Given this dichotomy, there is a need for an approach to WSS that moves from the traditional formula of disposal (with or without treatment) to one that recognizes wastewater as a resource. Potentially, creating value from this resource could contribute to funding sanitation and further improvements in wastewater management. At present there are only a limited number of such examples, mainly in areas of water stress or scarcity, or where stringent environmental regulations exist, but there are promising models that could be replicated or scaled up.

Many factors influence whether or not a RRR system is viable and replicable; one of which is the institutional environment within which it resides. This research is concerned with that space, recognizing that many studies have been conducted on technical fit, economics, health risks and other factors; and acknowledging that these elements must also be 'correct' or 'appropriate' and that good institutional arrangements are not sufficient in isolation. The study is therefore set as a component within the larger picture of examining the factors that influence the uptake and expansion of water reuse. It was undertaken within the 'Resource Recovery and Reuse (RRR) Project' funded principally by the Swiss Agency for Development and Cooperation (SDC), and implemented by IWMI, WHO, Swiss Tropical and Public Health Institute (Swiss TPH), International Centre for Water Management Services (CEWAS) and the Department of Water and Sanitation in Developing Countries (Sandec) at Eawag.

3.2.1 Research Outline

The research was designed to answer the question: ***What institutional arrangements support or hinder wastewater reuse in developing countries*****?**

The aim of the research was ***'to identify a set of key institutional factors that are necessary for wastewater reuse and that can be used by stakeholders to: determine whether the institutional context is conducive to wastewater reuse and identify barriers that need to be removed to facilitate reuse*'.**

A case study approach was taken in which the phenomenon under investigation was wastewater reuse within the context of a city's water supply and sanitation systems. Two case studies were selected but due to initially unforeseen circumstances, one was field-based (*in situ*) and one was desk-based (*ex situ*), relying primarily on literature. Identification of primary case studies made use of an initial scoping study of reuse globally, which was later developed into a landscape analysis (presented in Chapter 4). The case studies comprised of a stakeholder and institutional analysis, which facilitated the identification of institutional factors supporting reuse. The use of an *in situ* and an *ex situ* case study also allowed for a review of the utility of the method for investors wishing to assess the institutional feasibility of reuse. The elements of the study are depicted in Figure 3-1 and an initial description given in Table 3-1.

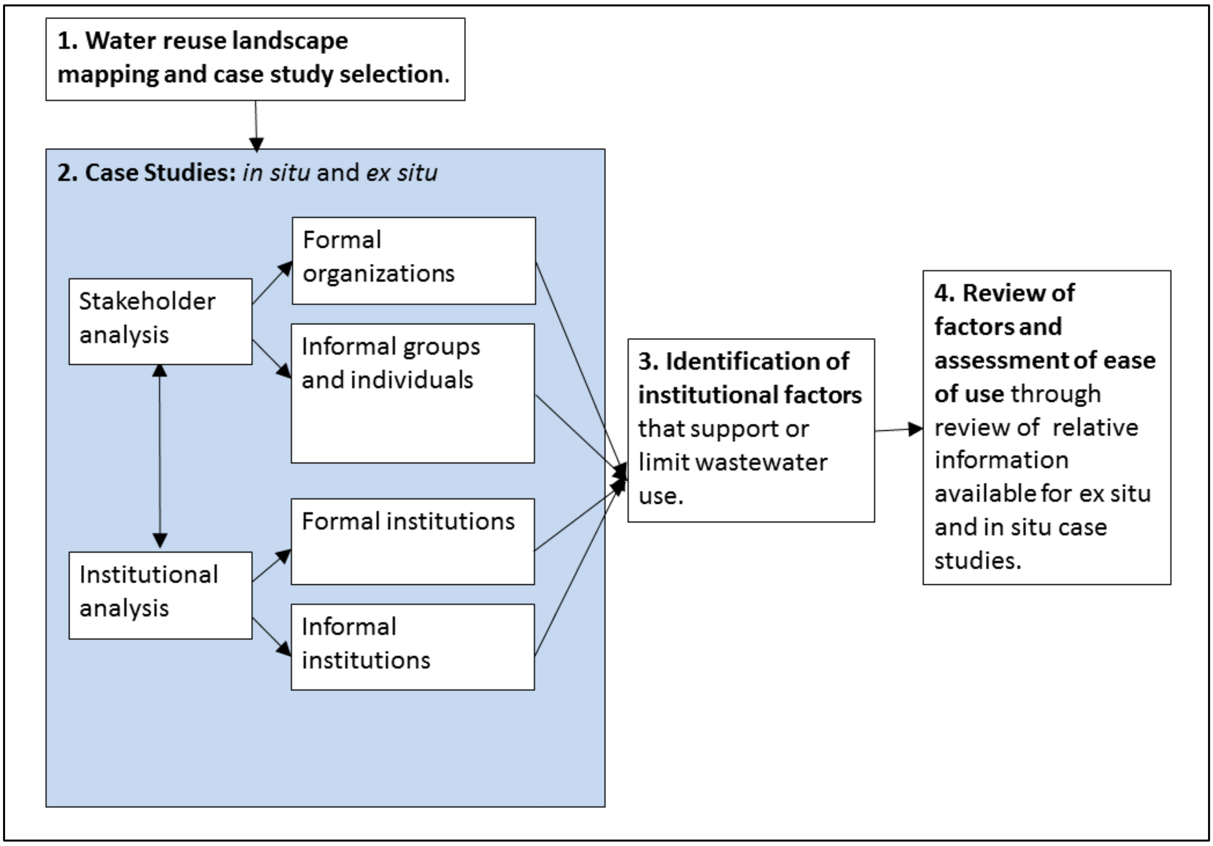


Figure 3-1. Schematic of research components

Table 3-1. Logical development of research components

Objective	Details	Methods
Wastewater Reuse Landscape Mapping	• To provide a context for the case study and highlight existing good practice by identifying and describing wastewater reuse systems around the world. • To aid in selection of case studies.	• Literature review • Personal experience
Stakeholder analysis	To elucidate: • **Who the players are** in the wastewater reuse arena. • What their **role or interest** is. • **How they implement that role** in practice and how effective they are. • **How important they are** in terms of their ability to influence RRR practices. • **How they interact** with other stakeholders to support/disrupt RRR.	• Literature review. • Key person interviews. • Interest and influence matrix. • Relationship mapping.
Institutional analysis	To identify the rules that govern the field of wastewater RRR. This includes: • The formal institutions (policies, laws and budget allocation) that exist. • The informal institutions (beliefs and norms) that exist around RRR. • How these affect the establishment and functioning of RRR practices. • The operating procedures and institutional ethos of the RRR practices.	• Literature review • Document review (laws/policies). • Interviews. • Focus group discussions. • Triangle analysis.
Identification of institutional factors for reuse	• To propose a set of institutional factors or arrangements (e.g. policies, stakeholder agreements, funding mechanisms or beliefs) that contribute to the success of reuse projects and can therefore be used in feasibility studies.	• Based on stakeholder and institutional analysis.
Critique of factors and assessment of ease of use	• To evaluate the usefulness of these factors and the utility of using them to undertake a rapid, desk based assessment, to determine whether there is support for or barriers to reuse systems in other contexts (cities) and thereby provide further guidance on how to utilize the institutional factors in assessing reuse feasibility.	

3.3 Research Methods

The methodology draws on several qualitative research methods, as seen in Table 3-1, including:

- Landscape mapping
- Case studies
- Policy analysis
- Stakeholder analysis
- Institutional analysis
- Document analysis
- Triangle analysis

3.3.1 Landscape Mapping

The term 'landscape mapping' can be used to mean different things (see Bradley and Hammond (1993) and Jones (2008), for two quite different interpretations of mapping). In this study the term conforms more to the use of the word in social studies, for example, the WHO's use of landscape analysis to understand barriers to health-related technology adoption, and USAID's landscape analysis of community based organizations (WHO, 2010; USAID and Eastern Congo Initiative, 2011). In this study the intention is to provide a background to the types of reuse models currently operating around the world and as a means of identifying case studies.

3.3.2 Case Study

Case studies are defined by O'Leary (2014), as *'A method of studying elements of our social fabric through comprehensive description and analysis of a single situation or case, e.g. a detailed study of an individual, setting, group, episode, or event.'* The distinctive need for a case study arises out of the desire to understand complex social phenomena (the 'case') in its real world context, especially when the boundaries between phenomena and context may not be clearly evident (Yin, 2014). Case studies are appropriate when: no control is required over behaviour; the focus is on contemporary issues; and a survey would not yield the desired depth of information (Yin, 2014).

The choice of case study was appropriate for this research because the phenomena of wastewater use is bound to the institutional arrangements that surround it. Understanding this requires empirical inquiry in the location in which the reuse takes place. Hence in this study the case is the reuse of wastewater and the case study is spatially bounded by the city (or the jurisdictions of the organizations that operate within it), temporally bounded by the period of reuse (the assumption being that most reuse started within living memory), and physically bounded by the water supply and use process. The unique strength of a case study approach is its ability to deal with a full variety of evidence, such as documents, observations and interviews (Yin, 2014), which is essential in such a complex system.

Furthermore, the case study approach has been chosen because it allows the selection of a situation that is favourable for the research (Rose, 1991). If a city or water user group had been chosen at random, or as a statistically representative group, it would have been unlikely that reuse would be taking place and therefore it would have been impossible to investigate the institutional arrangements that facilitate such systems (Rose, 1991). Theoretical generalization will be possible and will be strengthened by the evidence from two cases.

3.3.3 Stakeholder Analysis

A stakeholder can be an individual, or a formal or informal group, that has an interest in or is influenced by a policy, process or intervention. A stakeholder analysis considers their characteristics, interests, and the nature and degree of their influence over policies, reforms or interventions. The intention is to uncover the formal and informal organizations that shape the context in which policies, reforms or interventions take place (DFID, 2003).

3.3.4 Institutional Analysis

Institutional analysis looks at the "rules of the game" that people develop to govern group behaviour and interaction in all spheres of life, and that shape and constrain human interaction and individual choices (North, 1990). Institutional analysis is based on an understanding that these rules, whether formally constructed or informally embedded in cultural practice, mediate and distort the formation, implementation and impact of policies (Holland et al., 2005), interventions and projects. These institutions may be formally described as laws, policies or procedures, or they may emerge informally as norms, standard operating practices or habits (Polski and Ostrom, 1999). An institutional analysis naturally follows on from a stakeholder analysis and cannot be achieved without the former.

3.3.5 Document Analysis

Document analysis uses existing materials to collect information that is already available in print or other media. It includes traditional literature reviews of scholarly articles as well as reviews of newspaper articles, grey literature, laws and policies. The purpose of document analysis is to obtain existing information which can then be checked and clarified, or which can shape the next phase of the research (e.g. interview questions) and reduces the time required of interviewees or workshop participants.

3.3.6 Policy Review

Policy review is fundamentally a form of document analysis. A desk-based review of policy documents and legislation formed a large component of the institutional analysis to glean pertinent information such as the legality of specific reuse systems, and the incentives and benefits that exist.

3.3.7 Key Person Semi-structured Interviews

Semi-structured interviews use a checklist of questions related to the topic of interest. Key informants are selected because they have a good knowledge of the situation and can give an overall view of how things work and the opinions and positions of others (Gosling and Edward, 1995). The interview is flexible and the interviewer builds on the answers of the interviewee. The responses will include the opinions of the interviewees but if several interviews are conducted pieces of information can be cross checked. They can be analysed by identifying significant similarities and differences.

3.3.8 Focus Group Discussions

Focus group discussions provide the opportunity for stakeholders to share opinions, to discuss subjects and provide feedback on research. They are important because they provide a number of verbal and non-verbal cues including interactions between different stakeholder groups. In this study the purpose was to present initial findings and obtain feedback.

3.4 Data Analysis Methods

3.4.1 Interest and Influence Matrix

A number of matrices have been developed to analyse stakeholders. They variously consider aspects such as linkages, complementarities, power and interest; several of these are described by Matsaert (2002) and Holland et al. (2005). For this study an influence and interest matrix was chosen as it was deemed the most relevant to the study. Matsaert (2002) considers influence matrices to be a method to map out the relative importance and influencing power of stakeholders in order to assist projects to decide who should be involved. In this study the intention is to see who is already supporting wastewater reuse, who should be contacted to champion reuse and who needs to be 'brought on side'. It can also help to identify stakeholders who are influenced by wastewater reuse but who have little control over the process.

The matrix takes the form shown in Figure 3-2 where stakeholder 1 has little interest or influence; stakeholder 4 has considerable influence but little interest and should therefore be worked with to show them the importance of reuse and their potential role; stakeholder 2 is somewhere in the middle; and stakeholder 3 is very interested and is either highly affected by reuse or keen to work in the sector but has limited power. Critically the matrix does not give all the information but provides an initial visual impression around which discussion can be established. It is useful in a workshop setting as a means of opening conversations about the policy setting and roles. The level of influence and interest cannot be quantified, but the perceived levels of both can be illustrated in a two-dimensional diagram.

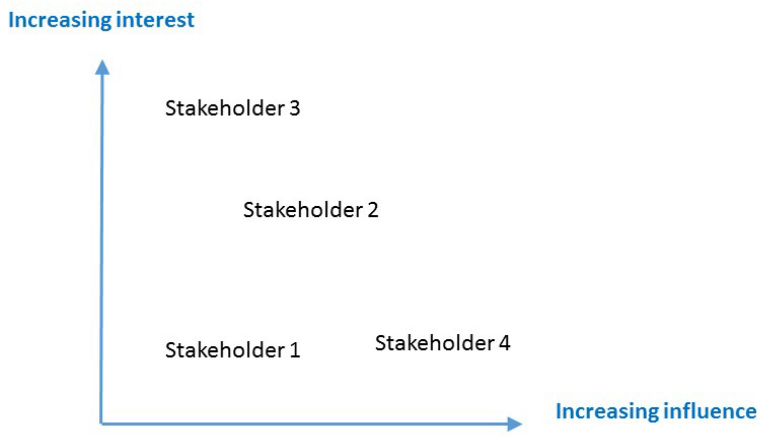


Figure 3-2. Example interest and influence matrix
Source: Author (2015)

3.4.2 Triangle Analysis

Triangle analysis is a technique for problem identification and solving that breaks the situation down into consideration of content, structure and culture (

Figure 2-6):

- **Content** refers to written laws, policies and budgets relevant to a specific issue. For example, if there is no policy on wastewater reuse, it may affect the ease with which a business, project or intervention can be established. Even if there is a pro-reuse policy it may not benefit those wishing to introduce reuse unless there is a budget for implementation.
- **Structure** refers to mechanisms for implementation. This would include, for example, ministries responsible for WSS, environmental authorities, donor programmes, NGOs and local business groups or chambers of commerce. Structure can refer to institutions and programmes run by government, NGOs or businesses at local, national or international level.

- **Culture** refers to the values and behaviour that shape how people deal with and understand an issue. Values and behaviour are influenced, amongst other things, by religion, custom, class, gender, ethnicity and age. Lack of information about laws and policies is part of the cultural dimension (Start and Hovland, 2004).

In this study triangle analysis will be used as the culmination of a descriptive analysis of stakeholders and institutions in order to tease out the most relevant points. These points will be structured around various 'action arenas', a phrase borrowed from the IAD and IFAD frameworks for institutional analysis (Polski and Ostrom, 1999; IFAD, 2009). The term 'action arena' is being used here to refer to certain components of the water, sanitation and reuse chains in the case study. It seems necessary to break the systems down into these parts because wastewater reuse spans many sectors, and the stakeholders, policies and actions do not necessarily fit neatly into the existing sectoral delineations for policy or management within the case study location. The action arenas also operate at different levels. For example, one action arena could be defined as water management, while another could be much more narrowly focused on a specific reuse system. An example of what the triangle analysis outcome might look like is provided in Table 3-2.

Table 3-2. Example of triangle analysis table

Action Arena	Content	Structure	Culture
Water management	National water policy supports reuse - 'reuse of treated wastewater will be practiced to the extent possible' (Article 19). No specific budget or financing instruments.	Establishes the water management board but the board has no reuse section. There are a handful of NGOs working on reuse.	The water board is not interested in water reuse. They perceive public opinion to be against reuse. Attitudes in the city are changing.
Sanitation	Currently no approved sanitation policy.	No organization dedicated to sanitation.	No political interest. Major civil society movement on sanitation.
Agriculture	No policy on reuse.	No organizations established to promote or manage reuse.	Informal use but not supported by general public or government.
Treatment ponds and fish production	Water policy supports appropriate technologies including pond systems. Fisheries policy requires water of a certain quality.	No structure in place to monitor water or fish quality. Limited markets.	Public have high fish demand and are happy to eat fish from polishing ponds, but not from other ponds.

Source: Author (2015)

3.5 Study Components

3.5.1 Wastewater Reuse Landscape Mapping

Existing wastewater reuse systems were identified through personal experience, internet searches, literature review and information from contacts. Information was gathered from donor reports, local NGOs' websites, networks (e.g. SuSanA) and conference proceedings (e.g. World Water Forum, World Water Week and the Water Engineering and Development Centre (WEDC) Conference), and regional networks and conferences (e.g. India Water Portal and Sacosan).

A table was developed of all the reuse systems identified, describing key attributes. Where possible institutional arrangements were noted. The mapping exercise was used to showcase the variety of wastewater RRR systems around the world, to provide a narrative of their establishment and development, and to produce a simple typology of systems. It also facilitated the selection of case study cities.

3.5.2 Case Studies – Stakeholder and Institutional Analysis

Two research sites were selected for the study. These were Bangalore, India and Hanoi, Vietnam. The varied reuse systems identified in Bangalore led to its selection as the primary case study. Hanoi was selected because of the long-term use of wastewater in agriculture and aquaculture. It was intended that field research would take place in both cities however work in Vietnam was complicated by the political setup and the need for personal contacts within government; as well as the relatively limited use of wastewater. Consequently the methodology was adapted to involve one field study (Bangalore) and one desk study (Hanoi).

The case study format was that of a multi-case embedded study, because there are multiple units of analysis (Yin, 2014). These are the individual wastewater reuse systems – within the overall water supply and sanitation landscape of the city, each of which is institutionally discrete. A case study protocol was developed with project partners, Biome and S3IDF in Bangalore, and Hanoi University of Agriculture in Vietnam. A summary of the protocol is provided in Box 3-1. Many of the steps are iterative.

In Bangalore more than 25 interviews were conducted over several weeks with stakeholders from government departments, academic institutions, NGOs, activists, implementation agencies, and community members as detailed in Annex 3. In some cases interviewees were met more than once.

All interviews were conducted with at least two researchers with one holding the conversation and the other taking notes.

Box 3-1. Case Study Protocol

Background and Development of the Case Study

- Opening workshop to introduce the project and identify reuse systems.
- Field visits and scoping study.

Data Collection Procedures

- Document collection – laws, policies, grey literature, newspaper articles. Search the internet and ask local stakeholders (e.g. government departments). Translation of documents were necessary.
- Interviews – (1) Selection of interviewees – prioritize primary stakeholders; interview several in key groups at different levels (2) Develop interview checklists for each group with specific questions for each stakeholder where appropriate. (3) In interviews ensure all are aware of the nature of the project; use friendly, non-confrontational language and open questioning, Note non-verbal cues, be aware of their mood (e.g. do not continue if the respondent is clearly pressed for time; try to arrange another meeting).

Data storage and processing

- Electronic documents stored in Mendeley.
- Interviews typed and shared in Dropbox.
- Data analysis – document analysis, stakeholder analysis, institutional analysis, triangle analysis (see descriptions below).

Review

- Share findings with stakeholders in FGDs and with key informants.

Source: Author (2015)

The case study was designed to answer the following questions:

- What wastewater use systems exist in the case study cities?
- What policy and legislative components are in place relating to wastewater use in the case study cities?
- What stakeholder structures are in place relating to wastewater use in the case study cities?
- What institutional arrangements contribute to the success or failure of wastewater reuse systems in the case study cities?

The case study approach facilitated the development of a set of factors that could be looked for in any given setting to determine whether or not wastewater use was likely to be feasible, and what institutional arrangements might need to change to improve the likelihood of success. Having two case studies added strength to the findings and provided a comparison of the effectiveness of analysing institutional arrangements for reuse *in situ* and *ex situ*. The rationale being that investors may have limited resources or access to local stakeholders and therefore a desk based method for assessing institutional feasibility could be highly beneficial.

3.5.2.1 Stakeholder Analysis

A **stakeholder analysis** was conducted in both cities to identify and understand all the players in wastewater production, management and reuse including:

- **Who the players are** in the wastewater, sanitation and reuse arena. It covered waste producers, managers, users (e.g. agriculture, forestry, fisheries etc.) and those with ancillary roles such as financing, technical support and facilitation.
- **What their roles, responsibilities or interests are**, and whether they are directly involved with or are impacted by wastewater use.
- **How they implement that role in practice**, how effective they are at doing so and whether they have the capacity to perform all their required tasks.
- **What their attitudes are to reuse**, including official and unofficial attitudes within organizations.
- **How important** each stakeholder is in terms of their ability to influence wastewater reuse practices, and whether they are champions of reuse or create opposition to reuse systems.
- **How they interact** with other stakeholders to support or disrupt water reuse practices.
- **Whether there are gaps in the stakeholder landscape**, such as the absence of an effective NGO community.

Firstly a list was made of all the relevant stakeholders that had been identified in the city as well as a list of the types of stakeholders that were expected such as wastewater producers, government WSS agencies, NGOs and wastewater users or potential users. Where a group did not appear to contain any stakeholders (e.g. if no NGOs could be found that worked on wastewater RRR in the city) then a further search was conducted. Contact details for each stakeholder group were collected and a list of proposed interviewees was made, aiming to cover all groups as follows:

- Policy makers (national and local e.g. Ministry of WSS and local department of WSS)
- Policy/legislation implementers and enforcers (e.g. municipal council, environment department)
- Chamber of Commerce (or other business group)
- National and local NGOs
- Local communities (i.e. wastewater producers and users)
- International organizations
- RRR business owners or managers

A short justification for interviews was written for each stakeholder as shown in Annex 3. A simple interview checklist is provided in Box 3-2. These were produced for each group and tailored for each individual stakeholder once they were identified.

Box 3-2. Example of semi-structured interview checklist.

Policy makers (national and local e.g. Ministry of water supply and sanitation and local department of water supply and sanitation)

- Can you tell me about your organization's role in RRR?
- What are the key pieces of legislation related to RRR in the country/city?
- What are the processes and instruments for implementation, monitoring and enforcement?
- Which organizations are responsible for implementing, monitoring and enforcing them?
- In your opinion, are the policy, rules and regulations effectively implemented and enforced? If not, what do you think limits this?
- Do you have any suggestions for how the limitations could be overcome?
- Is your organization supportive of RRR? If it is, what are they doing to actively support it and if not why are they not supportive? If your organization is not supportive of RRR do you think this is likely to change in the near future?
- Does your organization actively pursue its remit in terms of RRR or are there things that limit it? Ask for examples of what the organization is doing.
- Do you think that the people within the organization are generally supportive of RRR or not?
- Do you see any problems with RRR and if so how could these be overcome?
- Are there incentives for the government and government officials to support RRR businesses? E.g. public opinion, environmental benefits, reduced costs for the city.
- How do you think the organization as a whole and the staff within it could be given more incentive to support RRR?
- What about investment – is the government currently funding RRR or do they have plans to do so?
- If they are, how does it work or how do they expect it to work?
- What budgetary allocation is made for waste management in the country/city?
- What budgetary allocation is made for RRR in the country/city and in what form (e.g. grants, loans or subsidies) and is it a complicated process?
- How much has actually been paid out?

Source: Author (2015)

In reality many of the questions were difficult for interviewees to answer because the project focus was on wastewater reuse but not all of them saw the importance of their role in this. For example, the fishermen who were utilizing a lake that was replenished with treated wastewater had very little interest in the process of lake management. Consequently interviews became more open and fluid and often started with asking the interviewees about their role and gradually teasing out elements of reuse. Several of the questions could not be answered at all by interviewees, for instance budgetary allocations, and therefore different approaches were tried such as further literature searches.

3.5.2.2 Institutional Analysis

An **institutional analysis** was conducted: to investigate the institutions, formal (i.e. policies, laws and budget allocation) and informal (i.e. common beliefs and practices) that exist around wastewater use; to examine how they affect the establishment and functioning of reuse systems; and to determine which ones are most important in either supporting or hindering reuse. As with the stakeholder analysis, a number of guiding questions were used. These are given below. The words in brackets relate to the component of the 'triangle analysis' that was performed using the information collected.

Guiding questions:

- **What policies, legislation and strategies** exist that relate to wastewater conveyance, treatment and use, the financing thereof, and to the establishment of businesses? (Content)
- **What funding** (level and form) is given to reuse related activities (e.g. wastewater treatment or conveyance infrastructure)? (Structure)
- **What are the process and instruments for implementation, monitoring and enforcement?** (Content and Structure).
- What are the **rules and incentives** (formal and informal) that influence the different actors in performing their roles? (Structure and Culture)
- What, if any, **agreements** exist between official organizations, reuse system operators and other stakeholders? (Structure)
- What **support,** if any, is provided to stakeholders undertaking reuse? (Structure)
- How do reuse **stakeholders perceive** the institutional environment for the establishment, continuation or expansion of reuse systems? (Culture)

The institutional analysis relied heavily on interrogation of laws and policies, as well as on the interviews. In terms of the document analysis, key elements were extracted from the laws, such as those that explicitly mentioned reuse. A short summary was produced for each relevant law with quotes as well as comments on who was responsible for implementing and enforcing those elements or the law as a whole, who it applied to, and what the incentives or penalties were. Where a relevant law made no mention of reuse this was also noted.

The findings of the document analysis were compared to the interviews and elements of certain policies were also discussed in follow up meetings. For example, if a law existed that required wastewater producers to recycle their wastewater was this happening and if not, why?

Newspapers and online discussions also provided useful insight into the perceptions of certain groups and organizations across the city, and were used to identify legislation that was not being adequately implemented.

The elements of the stakeholder and institutional analysis and the outputs of these components of the project are provided in Table 3-3.

Table 3-3. Summary of case study components

Area of Analysis	**Methods of Data Collection**	**Outputs**
Stakeholder analysis	• Document analysis • Stakeholder interviews • Feedback and discussion - workshops	• List of stakeholders • Description of the role of each group • Interest and influence matrix • Network map identifying relationships, their strength and nature (e.g. antagonistic or supportive) • List and description of stakeholders that are absent from the arena
Institutional analysis	• Document analysis • Stakeholder interviews • Feedback and discussion • Focus group discussions	• List of relevant policies • Brief description of key policies, highlighting critical components for water reuse • Description of reuse case studies and the perceptions of stakeholders • Triangle analysis matrix

3.5.3 Identification and Testing of Key Institutional Arrangements

The stakeholder and institutional analysis were used to identify key institutional arrangements that facilitate or limit water reuse. The process for determining these was be based on:

- Recurring factors cited by interviewees.
- Elements brought to light through the triangle analysis.
- Feedback and discussion with key informants.

The next step was to attempt to repeat the process in another city. Initially this was to take the form of a second field study in which the same process would be applied and comparison made between the two cities. However, this was unfeasible and therefore the methodology was adapted to utilize literature only, including pieces of legislation and grey literature. The intention was to determine:

- whether similar factors could be found that support or limit reuse in another setting;
- whether this methodology could be used effectively with limited or no field work.

Ultimately the information gathered in this process was used to develop a list of recommendations for stakeholders interested in supporting or establishing wastewater reuse systems. These take the form of suggestions for institutional arrangements that are conducive to reuse and ways to overcome barriers.

3.6 Ethical Considerations

This study required a considerable degree of trust on the part of the interviewees who were at times giving personal opinions which may have contradicted official opinions. In other cases individuals may have been engaging in reuse activities that were considered illegal by the authorities. Ethical considerations were therefore important. Yin (2014) highlights four elements which were addressed as follows:

- *Gain informed consent and avoid deception* – all interviewees were given a brief introduction about the project and a project description (flyer). Their role and how the information would be used was discussed. Participants were told that they were welcome to stop the interview at any point, to decline to answer any questions and to ask their own questions at any time.
- *Protect privacy and confidentiality* – interviewers assured participants that their names would not be used in the report unless their permission was sought and the content of the report provided to them for approval.
- *Select participants equitably* – a rigorous process was followed to identify all stakeholders and select individuals from a wide array of groups. More than one interview was conducted with certain key groups to obtain a range of opinions (e.g. several residents' welfare associations; more than one water board employee) but a balance was maintained across the range of stakeholders. Some groups declined to be interviewed.

A workshop was held in both cities in which the essence of the findings was presented to the participants. In addition key individuals were visited more than once to discuss the findings and to provide their opinion.

3.7 Validity and Reliability

The design tests described by Yin (2014) for case study validity and reliability were incorporated into the research design. Construct reliability was ensured through the use of multiple sources of evidence, establishing a chain of evidence and the review of findings by key informants. External validity was considered through the process of multiple case studies. Reliability was ensured through the development of a detailed study protocol which was agreed and followed by all team members, after lengthy discussions and training in both countries.

4 Global Wastewater Use and Water Reuse Landscape

4.1 Chapter Outline

Water is reused worldwide for agriculture, aquaculture, industry, drinking water, non-potable household uses, landscape irrigation, recreation, and groundwater recharge (USEPA and USAID, 2012). This section identifies several examples of wastewater use and water reuse that have been reported from around the world. The examples are grouped according to the type of use and the level of treatment. In addition, for use in agriculture and aquaculture, the notion of 'direct' and 'indirect' use is considered (Van der Hoek, 2004). It also draws on the structure for categorizing reuse systems used by Lautze et al. (2014), and USEPA and USAID (2012).

The chapter provides a number of examples of each reuse system, including the countries in which they are practised. In all cases the most recent data available are used, however some of the systems have very few current examples, or information on them has not been updated. Where this is the case it is clearly acknowledged. The final section of the chapter takes several cases from the most widely practised systems and gives more detail on each.

The purpose of this chapter is to showcase the diversity and extent of reuse globally, to highlight regional variations and, where possible, to link this to the prevailing conditions. It should be noted that the categories used are to aid in the identification of cases and to highlight the diversity of systems, as well as to provide some indication as to which types of reuse are more prevalent and/or widespread. They are not intended as a definitive typology. The landscape also facilitated the selection of the case study cities.

4.2 Types and Locations of Reuse

The broad categories of RRR covered in this chapter are provided in Table 4-1, which gives a brief description of each category and lists locations where these practices occur. More detailed descriptions and examples for each are given in subsequent sections of the chapter.

Table 4-1. Types of wastewater use and water reuse across the globe

Type	Description	Country examples
Use in Agriculture and Forestry		
Direct use of untreated wastewater	Wastewater flows directly onto fields from drains or sewers. It is used to grow crops (for human consumption, fodder or fuel) or trees.	Pakistan, India, Bangladesh, Mexico, Ghana
Indirect use of wastewater	Wastewater flows into water bodies which are subsequently used for irrigation of crops (for human consumption, fodder or fuel) or trees.	Mexico, India, Pakistan, Cambodia, Vietnam, China, Sri Lanka, Ghana, Bolivia
Use of treated wastewater	Treatment in a wastewater treatment plant (WWTP) leading to provision of water considered to be safe for agricultural use.	Syria, Tunisia, Egypt, Israel, Jordan, Cyprus, Morocco, Argentina, Peru, Mexico, India, Australia, Italy, Greece, Spain
Use in Aquaculture		
Direct use of untreated wastewater	Wastewater flows directly into ponds from drains or sewers. It is used for aquaculture (e.g. to grow edible water plants for human or animal consumption or to provide nutrients for fish production). The aquaculture process may act as a treatment mechanism or aquaculture may take place within a treatment system e.g. waste stabilization ponds (WSPs).	India, China, Bangladesh, Germany, Hungary, Israel, Poland, Soviet Union, Kenya, Malawi, South Africa, Zimbabwe, Ghana
Indirect use of wastewater	Wastewater flows into water bodies or faecal waste is disposed into water bodies that are subsequently used to grow aquatic plants or provide nutrients for aquaculture.	Mexico, India, Pakistan, Cambodia, Vietnam, Bangladesh, Indonesia, Vietnam, China
Use of treated wastewater	Treatment in WWTP leading to provision of water considered to be safe for aquaculture use.	Bangladesh, Peru, Ghana
Use of faecal sludge	The direct application of faecal sludge from latrines and septic tanks into ponds that are used to cultivate fish or aquatic plants.	Taiwan, Indonesia, Vietnam, Cambodia, Bangladesh
Aquifer Recharge and Environmental Flows		
Aquifer recharge	Groundwater levels are supplemented by the planned or unplanned infiltration of treated wastewater; by planned injection of treated wastewater; or by the planned or unplanned infiltration of untreated wastewater.	Israel, South Africa, Germany, Belgium, Australia, Namibia, India, Italy, Mexico, China, Barbados and Cyprus
Environmental Flows	Wastewater is treated and some or all is released to waterbodies to dilute pollution and maintain environmental flows.	India, Jordan
Domestic and Municipal Uses		
Domestic use – after private/onsite treatment	Use of treated domestic wastewater within residential or commercial complexes or campuses (e.g. colleges, hospitals) after treatment on site.	India, Australia, Japan, Mexico, China
Domestic use –	Wastewater is treated to an appropriate level, in	Australia, China

Type	Description	Country examples
after treatment off site	central or off-site treatment plants, and supplied to various third parties (usually below the cost of treated freshwater or where access to water is limited).	
Indirect and direct potable use	Domestic wastewater is treated to tertiary level and either disposed of into a water body that is used downstream as a source of drinking water or it is further treated to potable quality.	Singapore, Israel, United Kingdom, USA, South Africa, Namibia, Belgium, India
Municipal use, including urban greening	Treatment in WWTP leading to provision of water considered to be safe for urban greening (urban parks, along verges), street cleaning, dust suppression etc.	China, Mexico, Philippines, India, Spain, Australia
Industrial Uses		
Use of treated municipal wastewater	Domestic wastewater is treated to tertiary level and supplied to industries (usually below the cost of treated freshwater or where access to water is limited).	India, China, Mexico, South Africa
Recycling of industrial effluent	Use of treated industrial wastewater within industry premises or within industrial zones*.	

*Not covered in this chapter because the focus in on the use of domestic wastewater.
Sources: Edwards (1985); Bunting (2004); WHO (2006a); USEPA and USAID (2012); Lautze et al. (2014); Martijn and Redwood (2005); Ensink et al. (2002); Cirelli et al. (2012); Agrafioti and Diamadopoulos (2012); Pedrero et al. (2010)

4.3 Use of Wastewater in Agriculture

4.3.1 Direct Use of Untreated Wastewater

Direct use of untreated wastewater in agriculture is found extensively across Asia, Sub-Saharan Africa and Latin America (Figure 4-1). The usual practice is that farmers tap into sewers or urban drainage channels that receive wastewater. This is usually a planned system but may not always be formal or officially approved, although authorities tend to ignore the practice unless complaints are made or health issues are believed to arise.

4.3.2 Indirect Use of Untreated Wastewater

Indirect use of untreated wastewater occurs when effluent has entered a water body that is used for irrigation, usually by diversion or lifting. It is almost always unofficial and unplanned, and often, but not always, results from a lack of alternative or reliable water sources. Hyderabad is a clear example of this, where farmers withdraw water from the Musi River, which is polluted up to approximately 40 km downstream of Hyderabad (Ensink et al., 2010). Indirect use often occurs in low-income countries, but also in rapidly growing economies that have limited capacity to collect and treat the expanding volume of wastewater produced. Examples of this are China and Brazil (Jiménez et al., 2010). Indirect wastewater use usually occurs as a consequence of pollution. In some cases it is not recognized as wastewater use by farmers, authorities or other stakeholders because they are continuing to make use of traditional water resources that have become polluted. There are also situations where it may be difficult to distinguish between direct and indirect use because the dilution factor is so low, especially in the dry season, that farmers are essentially using pure wastewater. The difference in this case lies in the form of distribution channel (i.e. stream or irrigation channel rather than sewer or drainage channel) but not the water quality.

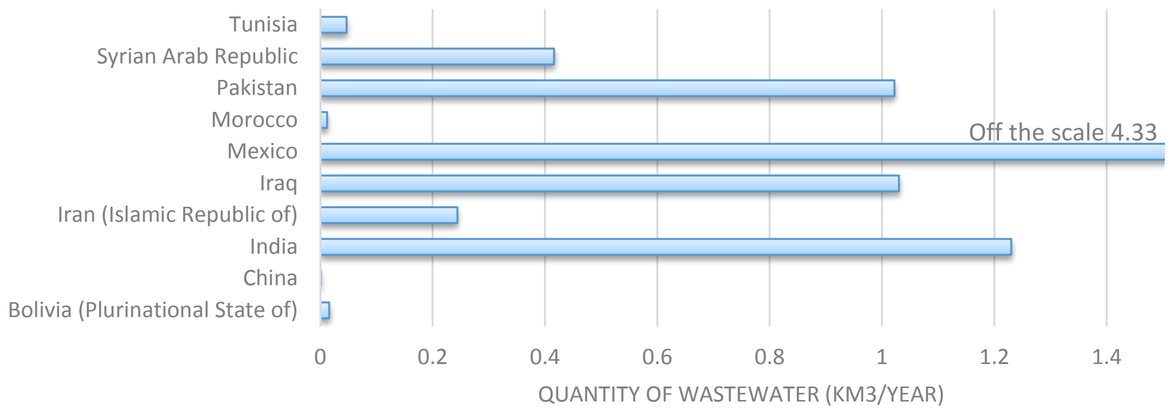


Figure 4-1. Direct use of untreated municipal wastewater for irrigation purposes
Note: Data are the most recent figures for each country (1995-2010). 70 percent are 2005 or later.

Source: FAO (2015)

4.3.3 Direct Use of Treated Wastewater

Most examples of treated wastewater use in agriculture are from drier regions, such as the Middle East, North Africa and Latin America (Jiménez et al., 2010). Examples are, Saudi Arabia, Egypt, Kuwait, Jordan, Morocco, China and Australia (Figure 4-2). The main drivers appear to be water stress or scarcity and the financial ability to implement treatment and reuse schemes. Strong institutional arrangements are also an important factor.

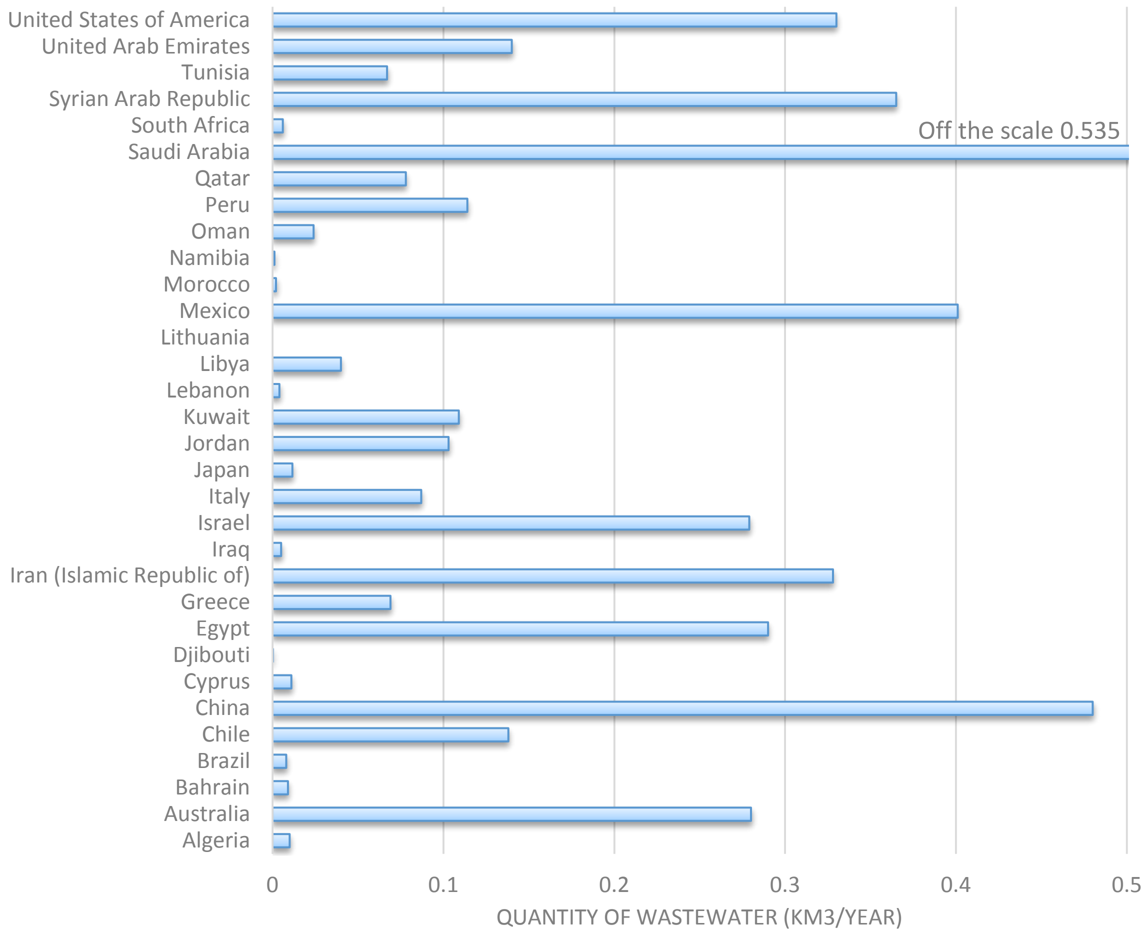


Figure 4-2. Direct use of treated municipal wastewater for irrigation purposes

Note: Data are the most recent figures for each country (1997-2013). 48 percent are 2010 or later and 84 % are 2005 or later.

Source: FAO (2015)

4.3.4 Summary of Reuse in Agriculture Landscape

Examples of agricultural reuse of wastewater are given in Table 4-2. Direct and indirect use have been merged in the table for two reasons (i) in some cases both direct and indirect use take place in the same location or are described in the same case studies; (ii) it is not always possible from the descriptions given in secondary literature to distinguish between the two. Where possible the type of use (direct or indirect) is given in brackets.

Table 4-2. Locations and examples of agricultural use of wastewater

Country	Reuse Practice	Reference
Use of untreated wastewater		
Mexico (direct and indirect)	60,000 L/s of wastewater produced in Mexico City, is reused without treatment for the irrigation of 90,000 ha in the Tula Valley, 100 km north of Mexico City. Reuse has been performed, although not always officially, for more than 110 years, and as infiltration (estimated at >25,000 L/s) has created new groundwater sources. These are used to supply 500,000 people living in the Valley with municipal water, using only chlorination for treatment. The quality has proved acceptable. The use of wastewater for agriculture has been regulated since the 1980s. The Mexico's National Water Commission estimates that nationally about 350,000 ha are irrigated with municipal wastewater, at a rate of about 160 m^3/s.	Jiménez-Cisneros (2012); Jiménez and Chavez (2004); Rojas-Valencia et al. (2011)
India: Hyderabad, Ahmedabad, Kapur, Hubli-Dharwad (indirect)	In Hyderabad, along the Musi River, about 2,100 ha of paddy, vegetables, herbs and jasmine are cultivated with wastewater. However, the majority of wastewater use is for para grass, an animal fodder, which is grown on 10,000 ha of land along the river. In Ahmedabad and Kapur, wheat is extensively irrigated with wastewater. In Hubli-Dharwad, indirect use occurs due to the availability of permanent streams of sewage-contaminated wastewater emanating from the city. It has enabled farmers to cultivate vegetables, field crops and fodder grass. Dry season vegetable production is particularly important when wholesale prices rise 2-6 fold. Further from the city early season irrigation with wastewater increases the yields from fruit trees. Water is pumped from the channels and delivered by furrow irrigation. Most farmers have adopted some form of filtration.	Mekala et al. (2008); Winrock International India (2007)
Pakistan, Faisalabad (direct)	Farmers in Faisalabad have been channeling wastewater from the city drains for around 50 years. The practice started because the canal water supply was dwindling, but soon farmers became reliant on the year round supply of wastewater, which enabled them to grow high value vegetable and fodder crops out of season. The city water authority, with donor funding, constructed a WSP but the farmers continue to use untreated wastewater because they feel that the treated water is more saline and less nutrient rich. They pay the Water and Sanitation Agency for untreated wastewater.	Ensink et al. (2004); Ensink and Clemett (2006); Weckenbrock et al. (2011); Bradford et al. (2009)
Vietnam (indirect)	In Hanoi an estimated 658,000 farmers use wastewater to irrigate 43,778 ha of land. The area is reducing however due, in part, to industrial pollution.	Raschid-Sally and Jayakody (2008);

Country	Reuse Practice	Reference
Nepal (direct and indirect)	In Bhaktapur, farmers plug sewers carrying domestic waste and divert it to their fields. In Kirtipur, farmers divert or pump water from polluted streams.	Rutkowski et al. (2007)
Iran (indirect)	The Firuz-Abad canal, in Tehran, receives municipal and industrial wastewater and is used for irrigating fruit and vegetables. Nearly 70 % of the 9,700 ha of land suitable for irrigation in Tehran is irrigated with wastewater. In Shiraz it has been reported that during dry seasons the main discharge of the river is wastewater, which is used for agriculture. In Tabriz, wastewater enters the Ajichai River and is used for irrigation and sludge is commonly used as fertilizer on agricultural lands.	Tabatabaei and Najafi (2009)
Ghana: Kumasi, Accra and Tamale	Less than 5 % of households in Kumasi and Accra are connected to sewers but 21 % dispose of wastewater to floodwater drains that essentially act as open sewers. In Kumasi, around 11,900 ha is under dry season vegetable farming, a significant proportion of which uses wastewater. A survey in 2002 found that 84 % of the 800 farmers interviewed in Accra used wastewater in the dry season, as did around 700 farmers (100 % of the sample) in Tamale. Farmers usually lift water with watering cans, sometimes after storing water in ponds. Crops grown with wastewater in or near cities are generally of high value; such as salad crops, tomatoes and other 'exotic' vegetables.	Keraita et al. (2002); Keraita and Drechsel (2004)
Direct use of treated wastewater		
Argentina	In Medoza, the city's wastewater has traditionally been used for indirect irrigation. In the dry season 40 percent of the water available for irrigation is wastewater. In the Campo Espejo waste stabilization ponds (WSPs) were upgraded and used for irrigation. Today they provide 147,000 m^3/d of effluent via the Moyano Canal for direct irrigation of 2,700 ha of a special restricted irrigation area. Farmers receive the water free of charge but must follow strict regulations. The drainage water enters the Jocoli Canal, mixes with river water and is used downstream on a further 7,000 ha.	Zuleta (2011) cited in Bartone (2012)
India, Karnal	Karnal District, in Haryana State, has a community managed 8 MLD WSP that was established under the Jamuna Action Plan in 1999. Later it was used to cultivate fish and to irrigate crops. Farmers grow mostly grains and oil crops and save around INR 1,700 per acre per year (USD 26) due to the reduction in fertilizer requirements of 50 kg Urea and 50 kg diammonium phosphate (DAP).	Kumar et al. (2014)
India, New Delhi	The Okhla STP in New Delhi, which was developed from 1937 to 1990, has a treatment capacity of 636 MLD, and is managed	Amerasinghe et al. (2012)

Country	Reuse Practice	Reference
	by the Delhi Jal Board (Delhi Water Board). At present, in addition to use at the power plant and for urban greening, 45 MLD is sold to the Minor Irrigation Department for a nominal fee. It is estimated that over 300 farmers in the Jaitpur area use the treated water on vegetables such as cucumber, brinjal, tomato, cabbage, radish and green leafy vegetables.	
Australia	In Victoria, reclaimed water is used to irrigate vineyards, tomatoes, potatoes, and other crops in addition to traditional landscape irrigation.	USEPA and USAID (2012)
Cyprus	Cyprus treats around 59 MCM/year of which 90 % is recycled, mainly in agriculture for citrus trees, olives and fodder crops. A small amount is used for urban greening and aquifer recharge.	Papaiacovou (2012)
Israel	There are various reuse projects ranging from small, local schemes supplying 50,000 m^3/year, to large, regional ones that supply more than 100 MCM/year. To date, more than 65 % of the collected municipal sewage is reused for agriculture, and by the end of the decade it is envisaged that more than 90 % will be reused. Constructed vertical wetlands are being tested and applied for irrigation of fruit trees and gardens in decentralized treatment systems.	Friedler et al. (2006); USEPA and USAID (2012)
Jordan	The Water Authority of Jordan (WAJ) provides farmers with reclaimed water, which in 2009 was used on 760 ha. Larger sites include As-Samra, Madaba, Ramtha, Akeder, and Mafraq. By law reclaimed water can only be used on crops that are not eaten raw. Direct reuse occurs near WWTPs and unused water is used downstream (indirect use). Khirbet As Samra is the largest WWTP in Jordan and has recently been upgraded from WSPs to advanced tertiary treatment. It has an estimated discharge of 60 MCM/year of which approximately 1 MCM is used directly on lands very near the WWTP. The rest flows down the Zarqa River to the King Talal Reservoir and then onto the Jordan Valley. Across Jordan reclaimed water is used predominantly for date palms, olives, citrus fruits and fodder crops such as alfalfa, barley and maize.	Carr et al. (2011a); Kassab and Tsuchihashi (2012)
China, Beijing	Reclaimed water is replacing groundwater in south-eastern Beijing where in 2010, 300 MCM of reclaimed water was used for agricultural purpose on 400 km^2 of cultivated lands. Compared with the high pumping costs, the current price of approximately USD 0.008/m^3 for reclaimed water is economically acceptable.	Chang and Ma (2012)
Peru	Constructed vertical wetlands are being tested and applied for irrigation of fruit trees and gardens in decentralized treatment systems.	USEPA and USAID (2012)
Mexico	In Mexico City, nearly 46 MGD of reclaimed water is used to	USEPA and

Country	Reuse Practice	Reference
	irrigate green areas, recharge recreational lakes and for agriculture. In San Luis Potosi, seven WWTPs have been built since the 1990s to treat 70 % of wastewater; 100 % of the treated wastewater is reused in agriculture and industry. The largest of the WWTPs is Tenorio, which has a capacity of 90,720 m^3/d. It consists of primary treatment and a polishing wetland for irrigation of fodder crops. The system includes 39 km of distribution network and pumping equipment.	USAID (2012); Rojas et al. (2012)
Tunisia	Treats most of its urban wastewater, uses 30 % of the treated effluent to irrigate 7,000 ha of fruit trees and fodder following strict sanitary standards, and plans to expand wastewater irrigation to 20,000–30,000 ha by 2020 as part of the government's overall water resources management and pollution-control strategy.	Louati and Bucknall 2009: cited in Scheierling et al. (2011)
Spain	In 2010, Spain reused 346 km^3 of treated wastewater in agriculture. Reuse is concentrated in the Mediterranean coast and the islands. Of all the wastewater treated in Spain, Valencia and Murcia reuse 57 %. The Canaries and Balearics use 23 % of the total amount reused at national level. Madrid uses 5 km^3/year and Victoria 11.5 km^3/year. Royal Decree-Law 11/95 of National Sewerage and Water Treatment Plan (1995) has been the main tool for developing water reuse.	Pedrero et al. (2010)

4.4 Use of Wastewater in Aquaculture

Wastewater aquaculture has been practised for centuries in countries across Asia. It encompasses the production of aquatic organisms, including finfish, molluscs and crustaceans, and aquatic plants (including seaweeds and freshwater macrophytes) and implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding and protection from predators (Edwards and Demaine, 1998; Bunting, 2004). In terms of the wastewater element, like agriculture, this can be divided into direct reuse, which is the planned and deliberate use of wastewater as a nutrient and water resource; indirect reuse, through the use of water bodies that have received wastewater; and use of treated wastewater.

Although still practised, wastewater aquaculture appears to be on the decline in many areas due to rising peri-urban land prices, industrial pollution and demand from urban populations for higher value fish (Edwards, 2010). However in some countries there have been attempts to develop both plant and animal aquaculture as part of wastewater treatment systems, for example in Ghana, Bangladesh and Peru (Murray et al., 2011b; Buijs et al., unpublished; UNEP, 2001).

4.4.1 Direct Use of Untreated Wastewater

The direct use of untreated wastewater for fish cultivation is found across Asia, including China and India, Latin America and Europe, including, Germany, Hungary, Czechoslovakia, Poland and the Soviet Union (Bunting, 2004; Edwards, 1985). It has been estimated that there are more than 132 sewage-fed fisheries in India alone, covering about 12,000 ha (Edwards, 1992) and the most extensive and well documented system in the world is probably the Kolkata wetlands (Ghosh, 2001). Sewage fish culture also occurs in several areas across China. However, the lack of reticulated sewage systems in developing countries reduces the extent of this practice (Edwards, 1992), but in areas where sewers have been introduced wastewater flows have been exploited (Bunting, 2004). An advantage of using sewage for aquaculture and horticulture is that it results in high yields and economizes on fertilizer and feed costs, resulting in higher profits (Tripathi and Sharma, 2001). Intentional, direct use is reported to be on the decline because of expanding urban areas, the cost of land and its use for higher value activities (WHO, 2006).

4.4.2 Indirect Use of Untreated Wastewater or Contaminated Water

The indirect use of untreated wastewater or the use of faecally polluted surface water is, in the opinion of Edwards (1992), probably widespread wherever fish cultivation takes place near human habitation, and where there is inadequate sanitation. As with indirect wastewater agriculture, the producers may not be fully aware of the content or quality of the water; they may be concerned about pollutants, especially if commercial or industrial waste is entering the system; or they may value it for its nutritive value. Indirect use of wastewater for aquaculture has been reported in Sri Lanka[5], Indonesia and Taiwan (Edwards, 1992).

4.4.3 Use of Treated Wastewater

The use of treated wastewater for aquaculture usually takes the form of raising fish or aquatic plants within WSPs or treatment wetlands, or may be the result of higher water quality in open water bodies that receive treated wastewater and where stocking and fish management take place. For example, in the USA, use of duckweed-covered lagoons for tertiary treatment is classified by the USEPA as an innovative or alternative technology, where the duckweed is used to purify secondary effluents from aerated and non-aerated lagoons (Iqbal, 1999). There are also examples of waste stabilization pond operators funding the treatment system by selling fish produced in the final ponds

[5] Although the example given, of Beira Lake in Colombo, is likely to involve very few fishermen and will most likely have declined since the report by Bunting (1992) was written, due to the high level of contamination of the lake.

of WSP systems, as well as fruit grown along the banks. One such example is in Mirzapur, Bangladesh (Skilicorn, 2012). Use of treated or partially treated wastewater has been reported in Ghana, USA, India, Bangladesh, Peru, Germany and Africa (Bunting, 2004; Edwards, 1985; 1992).

4.4.4 Use of Faecal Sludge

Many examples of the use of faecal sludge exist across the world, based on direct entry of faecal matter to the pond, for example via an overhanging latrine, or indirectly when latrines are emptied and the contents tipped into water bodies where aquaculture takes place. In the case of overhanging latrines, this has been a traditional means of introducing faecal matter to water bodies in many places, while in others it is simply a convenient form of household sanitation that also serves the purpose of providing nutrients to the fish. In many countries, such as Bangladesh, the practice is declining because overhanging latrines are not considered sufficiently sanitary and are being replaced by other systems (Edwards, 1985). The second system, often referred to as cartage, involves the transport and disposal, into fish ponds, of faecal matter that has been excavated from latrines, either manually or mechanically. This practice occurs in parts of China, and previously occurred in Malaysia, Hong Kong, Singapore and Japan but seems to have fallen out of favour for reasons including changes in sanitation practices, public opinion and cost (Edwards, 1992).

4.4.5 Summary of Reuse in Aquaculture Landscape

This section gives a summary of several cases of wastewater use in aquaculture. The cases are only divided into treated and untreated wastewater, rather than direct and indirect use because of the difficulties in identifying which system is operating, either because of the practice itself or the description provided in the literature. Furthermore, there may be some ambiguity and potential for disagreement as to whether certain cases constitute treated or untreated wastewater. This is because several of the examples involve the growth of aquatic plants and/or fish within WWTPs, principally WSPs. The level of treatment and the ponds in which the products are grown determine how to categorize the system, however, it may be that some products are grown in one pond and another in a later pond: e.g. duckweed in the early ponds followed by fish in the maturation pond. In this case, the fish could be classified as being grown in treated water while the duckweed is grown in untreated water. Furthermore, in some cases the secondary literature does not give sufficient information for definitive categorization. In all cases every attempted has been made to choose the most fitting category, however the critical point of this chapter is to showcase the variety of systems and not to neatly categorize, and therefore it is the descriptions of the systems that are of most interest, rather than the categories.

Table 4-3. Locations and examples of aquaculture with wastewater and faecal sludge

Country	Reuse Practice	Reference
Use of untreated wastewater use in aquaculture		
Cambodia (direct)	Phnom Penh is surrounded by wetlands that receive 1 MCM of wastewater and urban drainage daily. Numerous plots are used to cultivate aquatic vegetables. Boeung Cheung Ek Lake is the largest of these (3,403 ha) and receives 90 % of the wastewater. It acts as an effective, low cost means of biological treatment, capturing and using valuable nutrients for cultivation of aquatic plants (mainly water spinach). Cultivation increased in the 1980s when farmers saw greater incomes from water spinach than rice, because water spinach can be grown all year. Estimated average yield was approximately 5 tons/ha/year in 2003.	Dalsgaard (2006) and Khov et al. (2006); cited in Kuong et al. (2007); Marcussen et al. (2009)
India, Kolkata (direct)	In Kolkata, changes to hydrological regimes brought about by human activities, including fishing and drainage resulted in the loss of traditional fishing grounds on salt lakes. Over several decades these were replaced by a complex system of aquaculture ponds, filled primarily from the sewage draining from the city. Ponds managed for wastewater aquaculture cover over 3,500 ha, with production of carp and tilapia estimated at USD 18,000 t/yr. Fish are sold through nearby markets in central Kolkata, many of which serve poor communities.	Bunting (1985); Bunting (2004); WHO (2006c); Little et al. (2002)
Ghana (direct)	In southern Ghana, tilapia are grown in ponds at Akuse, Many Krobo District because inorganic fertilizers to enrich ponds are becoming expensive and farmers are looking for alternatives.	Ampofo and Clerk (2003); cited in Bunting (2004)
Nigeria (direct)	Sewage water from a residential area was used to raise common carp and Sarotherodon galilaeus.	Ogbondeminu (1993); cited in Bunting (2004)
Taiwan (indirect)	Faecally polluted surface water is used to fertilize empty fish ponds in the winter months when the ponds are drained. The water is pumped into the ponds to a depth of around 30 cm where it encourages the growth of benthic organisms. The water reduces in turbidity and is drained out before another load of wastewater is pumped in. This is repeated 3-4 times and then the water level is raised and fish introduced. The polluted surface water continues to be used to maintain the level of benthic organisms which the fish consume.	Edwards (1985)
Treated wastewater use in aquaculture		

Country	Reuse Practice	Reference
Bangladesh	The NGO, PRISM, introduced a system to treat wastewater from a hospital in Mirzapur in ponds with duckweed. They also implemented a similar system in Khulna to treat municipal wastewater. The duckweed was fed to fish which were harvested and sold. They also grew fruit along the banks of the WSPs. The income from selling fish and fruit was used to fund the treatment process.	Gijzen and Ikramullah (1999); Haq and Ghosal (2000); cited in WHO (2006c); Skilicorn, 2012
India, Karnal	Karnal District, in Haryana State has a community managed 8 MLD WSP that was established under the Jamuna Action Plan in 1999. Later it was used to cultivate fish and to irrigate crops. The WSP meets water quality standards and fish production is 12000-16000 kg/year bringing an income of INR 6-800000 (USD 9,220-12,294). The wastewater sold to farmers provides an income of around INR 10-15,000 per year (USD 154-230).	Kumar et al. (2014)
Europe	Wastewater aquaculture in Europe is now largely confined to reusing wastewater from industrial processes. Cooling water from power stations is used to produce ornamental fish in Bulgaria, to raise juvenile fish in France for on-growing in sea cages, and in England, to culture marine worms for fishing bait and feed for shrimp broodstock.	Bunting and Little (2004); cited in Bunting (2004)
Germany	The Munich sewage fish ponds started operation in 1929. They were designed to treat the sewage, following mechanical treatment, of 500,000 people, with a peak of 700,000 people, equivalent to a 2,000 population equivalent/ha. Although changes have been made to the system over the years, the fishponds still treat some 25 % of the settled sewage as a tertiary treatment system.	Edward (1985)
North America	Extensive cultivation of aquatic plants as a means to treat wastewater. The biomass is mainly used for animal fodder or composted.	Bunting (2004)
Faecal sludge use in aquaculture		
China	Nightsoil was extensively used in aquaculture, especially in rural areas, but use has declined for reasons such as land development, excessive nutrients in the water, industrial pollution and improved sanitation. Nightsoil is also used to cultivate duckweed to feed grass carp fingerlings.	WHO (2006c); Edwards (1985)
Peru	Demonstration to test the growth of tilapia in wastewater showed that it was safe from a public health perspective and acceptable to the community.	Cavallini (1996); cited in Bunting (2004)
Indonesia	In Bandong, some 200 ha of ponds are fed with surface waters that receive faecal matter. The practice is not	Edwards (1985)

Country	Reuse Practice	Reference
	confined to this location. They also rear fish in cages placed in polluted streams and rivers.	
Vietnam	In Thanh Tri district, Hanoi, fishponds are filled with water pumped from a wastewater channel that was constructed in the 1960s to transport wastewater away from urban areas. Fish yields are reported to average 5.6 t/ha for the 10-month fishing period. In Than Liet commune, Thanh Tri district, the local farmers have converted unproductive land to fish ponds filled with wastewater. Aquatic vegetables and fish production can generate USD 5,760/ha-yr and USD 7,200/ha-yr), respectively which is three times higher than rice production. Examples of overhanging latrines and nightsoil use are also reported for Ho Chi Minh City and Bac Ninh in the north of the country.	Hoan (1996); cited in Bunting (2004); WHO (2006c); Lan Huong Nguyen et al. (2012)
Taiwan	Used in brackish and freshwater ponds to feed fish in Taiwan. In this model faecal sludge is spread on the bottom of empty brackish ponds prior to filling with water and fingerlings or pumped into freshwater fish ponds at regular intervals.	Edward (1985)

4.5 Aquifer Recharge and Environmental Flows

The recharging of aquifers with wastewater is a widespread practice that takes several forms. In many cases it is unplanned and is the result of polluted or partially treated wastewater draining into waterbodies that are connected to underlying, unconfined aquifers. Some of these may be used for drinking water. There are also many cases of planned aquifer recharge, using water of various qualities. The quality of water used often depends on the final planned use. Planned recharge with reclaimed water provides subsurface storage and can be followed by further treatment. Documented cases of aquifer recharge include Israel, South Africa, Germany, Belgium, Australia, Namibia, India, Italy, Mexico, China, Barbados and Cyprus. Indirect potable recharge following advanced treatment has been studied in Tijuana but not yet implemented (USEPA and USAID, 2012).

The release of wastewater into the environment as a means of ensuring flows in rivers and augmenting water levels in lakes is becoming increasingly important around towns and cities where water demand is growing, and extraction from natural water bodies is impacting on the environment. In some months, the wastewater, treated or untreated, is the only flow in some rivers. Where the infrastructure and financing is in place local authorities may undertake primary or secondary treatment before releasing water to the environment. Locations where this is occurring include China, Mexico and India.

Examples of aquifer recharge and augmentation of open water bodies are provided in Table 4-4.

Table 4-4. Locations and examples of wastewater use for aquifer recharge/environmental flows

Country	Reuse Practice	Reference
Aquifer Recharge		
Australia	A decline in drinking water supplies in the main storage reservoir for Sydney and low flows in the Hawkesbury Nepean River system led to the development of St Marys Advanced Water Recycling Plant. The intervention was part of the New South Wales State Government's Metropolitan Water Plan implemented by Sydney Water. The objective of was to produce an alternative high quality water source to replace 18 billion litres of drinking water annually released from Warragamba Dam for environmental flows in the Hawkesbury Nepean River system. Water is received from three STPs and further treated using ultra filtration and reverse osmosis, decarbonation and chlorine disinfection.	Khan and Chapman (2012)
Belgium	In the Western part of Belgium's Flemish coast water demand has risen sharply over the past 50 years. Water is supplied from an unconfined aquifer and additional pumping was not possible due to the potential for saltwater intrusion. It was decided to artificially recharge the unconfined dune aquifer of St-André. However, the lack of alternative water sources resulted in the decision to use reclaimed water from the Torreele facility for the production of infiltration water. The treatment process consists of primary sedimentation, pre-denitrification, aerobic treatment, secondary clarification and RO. Recharge is by way of an 18,200 m^2 pond with an average residence time of 55 days. The plant provides 35-40 % of the region's drinking water.	van Houtte (2012)
Environmental flows and lake recharge		
China, Beijing	Since 2010 it has been a requirement that freshwater is replaced with reclaimed water for 'scenic environment', which includes rivers and lakes. In the same year they received 200 MCM of reclaimed water.	Chang and Ma (2012)
Mexico	The local water and wastewater utilities in Mexico City have implemented projects to reuse wastewater since 1956. In 2012, 2,000 L/s was used for irrigation of green areas, recharge of recreational lakes and agriculture; 1,200 L/s for groundwater recharge; and 600 L/s for ecological purposes.	Jiménez-Cisneros (2012)
India,	Several lakes are being rehabilitated in Bangalore, and STPs	McKinsey and CII

Country	Reuse Practice	Reference
Bangalore	installed to introduce treated water to improve lake quality. One example is Jakkur lake where a comprehensive INR 215 million (USD 1.9 million) rejuvenation project started in 2000. The rehabilitation included de-silting, construction of a 10 MLD STP and wetland polishing system. Results have included improved fisheries and groundwater recharge.	(2014)

4.6 Municipal Use

Municipal use of wastewater takes many forms but almost always involves the use of treated wastewater, although the level of treatment may depend on the use and factors associated with the location (such as infrastructure and available funding). The most common uses include urban greening (i.e. watering urban areas such as parks and verges), irrigation of golf courses, road cleaning, cleaning of other urban infrastructure (e.g. markets) and dust suppression in hot, dry climates. Increasingly wastewater is being treated to quality levels that make it possible for reuse within domestic and commercial properties for such activities as toilet flushing and car washing. The treatment process may occur on-site by recycling the water used within the building, or it may be treated off-site and returned to the original wastewater user, shared between many properties or sold to a third party. It is not easy to categorize all these uses but an attempt has been made to do so in Table 4-5, although, as with previous sections, the emphasis is on the examples rather than the categorization.

Table 4-5. Locations and examples of municipal use of wastewater

Country	Reuse Practice	Reference
Non-potable domestic use after treatment on-site		
Australia	In Sydney treatment and recycling takes place in high-rise offices as well as other residential buildings such as retirement homes, where it is used for toilet flushing and landscaping. One such building (1 Bligh Street) treats nearly 100 % of its wastewater and reuses it in the building. This has avoided sewer capacity issues and reduced the building's freshwater demand by approximately 90 %. The building uses additional wastewater from the city sewer to meet its needs for toilet flushing and for the cooling towers. The system uses a modular membrane bioreactor (MBR) and treats 90 m^3/day of wastewater.	Fisher (2012)
Japan	In several large cities including Tokyo, regulations require a greywater reuse system or a runoff harvest system for new buildings exceeding a specified floor area. This includes public and private offices, and schools. The reclaimed water is mainly	Kimura and Funamizu (2012)

Country	Reuse Practice	Reference
	used for toilet flushing but also for watering plants, fire protection, cooling and car cleaning.	
India, Bangalore	Around 10 years ago, the Karnataka State Pollution Control Board (KSPCB) mandated that STPs be built and operated in individual residential complexes with 50 or more dwellings, or generating 50 m^3/day or more of sewage. An additional condition was that treated water quality should meet stringent “Urban Reuse Standards” and be reused for toilet flushing, car washing and irrigation within the complex.	Kodavasal (2011a)
Mexico	Although they are not formally registered, several dozen private WWTPs in schools, sports clubs and golf courses, treat wastewater and reuse it for lawn irrigation or toilet flushing. Private reuse is not controlled by the government.	Jiménez-Cisneros (2012)
Non-potable domestic use after treatment off-site		
China, Beijing	In Beijing, by 2011, eight out of 16 districts had integrated reclaimed water into their water resource distribution systems. It is utilized for domestic, municipal, industrial and agricultural purposes, and scenic environmental use. The price is considerably lower than freshwater to encourage its use and is free for irrigation. Household use accounted for 5.4 MCM in 2010, of which 28 % was for toilet flushing. The high cost of water delivery restricts its development.	Chang and Ma (2012)
Australia	See Sydney example above where wastewater was tapped from the sewer, treated and used within an apartment block.	Fisher (2012)
Potable use – direct and indirect		
Singapore	Singapore is severely limited in its natural water resources and therefore makes use of advanced wastewater treatment and recycling for industry and indirect potable use. Five ‘NEWater’ factories produce 554,600 m^3/day of high quality water and this is planned to rise to 873,000 m^3/day by 2020. The water is mainly used in the electronics industry and for cooling, but a small proportion is now blended with raw reservoir water, up to a maximum of 2.5 % of the total water quantity. The mixed water is extracted and treated in the normal way prior to being used in the potable supply. The system uses advanced membrane technologies and ultraviolet disinfection.	USEPA and USAID (2012)
India, Bangalore	In Bangalore the in Vrishabhavathi Valley (V Valley) ‘Water Recycle and Reuse’ project is designed to provide highly treated water to the Tippegondanahalli (TG Halli) reservoir, which is a domestic water source for the city. Under the scheme, 200 MLD of urban wastewater will go through tertiary treatment and disinfection with chlorine at V Valley STP. It will then be pumped to the Tavarekere advanced treatment facility, where it will pass through ultrafiltration membranes and a granular activated carbon adsorption filter followed by low dose of terminal	Kelkar et al. (2012)

Country	Reuse Practice	Reference
	chlorination. Financing for V Valley was 30 % from the government under JNNURM and 70 % from the private contractor in a Build-Own-Operate Public-private Partnership for 15 years.	
Namibia	Veolia, together with two international partners, operates the Namibia-based Goreangab wastewater reuse plant, where potable-grade water is produced for the City of Windhoek. The plant has been operating for 12 years and supplies 5.5 million m^3/year, almost a quarter of the city's total water demand.	Borralho (2013); Lahnsteiner and Lempert (2007)
Non-domestic urban uses (urban greening; road cleaning; dust suppression etc.)		
Australia	Barwon Water, a government owned water authority operating in Victoria, supplies recycled water from five of its nine water reclamation plants (WRP). The water is used for a number of commercial and municipal uses, including: irrigating golf courses, sporting grounds, public open spaces, vineyards, hydroponic tomatoes, potatoes, turf and flower farms; and for dust suppression for road and construction works. The users construct the distribution network and pay Barwon Water to service it. Usually one large company funds this and charges a network fee to smaller users. This arrangement is uncommon in Australia as most recycled water schemes are wholly owned and operated either by the water authority or a private owner. The price of water covers the cost of production; no additional profit margin is included.	Jones (2012)
China, Beijing	In Beijing, by 2011, eight out of 16 districts have integrated reclaimed water into their water distribution systems. Municipal water is used for urban landscaping and road cleaning. It totals approximately 420 MCM/year but lack of infrastructure and the need for costly road transport limits use.	Chang and Ma (2012)
Mexico	The local water and wastewater utilities in Mexico City have implemented various projects to reuse wastewater for municipal and industrial purposes since 1956. (See other sections e.g. environmental flows and industrial use for more details).	Jiménez-Cisneros (2012)
Philippines	The Muntinlupa Public Market, in Metro Manila, is one of the largest public markets in the area with 1,448 stalls. The wastewater from markets tends to be very concentrated and land available for treatment is generally small. In 2006 a treatment and recycling facility was constructed and the water used for flushing toilets, watering plants and street cleaning. The system treats 210 m^3/day of wastewater, of which 50 % is discharged to Laguna de Bay Lake and 50 % is reused. The same technology is being used in other locations in the Philippines.	Jochico and Lapus (2012)
Spain	In Costa-Brava, reclaimed water is used for traditional irrigation, street washing, fire hydrants, street cleaning, parks and	Mujeriego and Sala (2012)

Country	Reuse Practice	Reference
	environmental flows. The WRP of Tossa de Mar has a capacity of 840 m^3/day, which represents 13 % of the potable water use during the peak tourist season. Initially water was collected by tanker and distributed around the city but there is now a 5.7 km distribution network.	
India, Bangalore	Lalbagh Park and Cubbon Park are two of the most important parks in Bangalore, with Lalbagh also being the largest. They both suffered water shortages, so tertiary STPs were constructed to treat 1.5 MLD each. Cubbon Park STP utilizes membrane technology and disinfection. Lalbagh Park STP uses extended aeration, filtration and UV disinfection. Both STPs feed water to sprinkler systems.	BWSSB (2015)

4.7 Industrial Use of Municipal Wastewater

Industries are increasingly being seen as potential users of treated wastewater, and are being encouraged to do so with inducements such as tax breaks or lower water supply prices. There are essentially two systems, firstly recycling of processes water on site, which is relatively common, and recycling of municipal wastewater for use by industries located around the WWTP. In some cases wastewater is treated to the quality required by a specific industry. In other cases WWTPs are established in areas that the local authority has zoned for industrial processes or where a group of industries exist that have large water requirements. Examples of these are given in Table 4-6, which, due to the remit of this study, includes only recycled municipal wastewater, not internal recycling.

Table 4-6. Locations and examples of wastewater use in industry

Country	Reuse Practice	Reference
Industrial Use		
China, Inner Mongolia Province	In Hohhot, the capital city of Inner Mongolia province, the Jinqiao Reuse Water Plant (JRWP) treats 31,000 m^3/d of secondary effluent from a municipal WWTP. The process uses a tertiary MBR. The reclaimed water from the JRWP system is used as the influent for the cooling tower water supply for Jinqiao power plant.	da Silva and Lin (2012)
South Africa	eThekwini Metro Water Services (EMWS) and Veolia Water Services (VWS). Together they have increased the capacity of a WWTP and added a tertiary treatment plant. The system now produces 47.5 MLD of high quality water to serve Mondi Paper Mills, which produces fine grade paper that is extremely sensitive to process water quality and its impact on paper brightness. At operational capacity the reclamation plant will meet 7 % of the	Bhagwan (2012)

Country	Reuse Practice	Reference
	city's current potable water demand and reduce the city's treated wastewater output by 10 %. EMWS is responsible for primary treatment while VWS operates the activated sludge plant. Funding was provided by VWS under a 20 year production, operation and transfer concession. The incentive was that the industry partner (Mondi) was prepared to accept an assured supply of recycled water at a tariff that was attractive (50 % below the normal water tariff). The result for the municipality is that they can delay investment in marine outfall (or other wastewater management system) and bulk water supply. This was the first such PPP in South Africa and can be considered a model for future projects.	
Mexico	In the late 1990s, the State Government of San Luis Potosi decided to implement an Integral Plan for Sanitation and Water Reuse to stop the use of raw wastewater in agriculture and foster the substitution of groundwater for reclaimed water for all non-potable uses. The largest WWTP and reuse operation in the system is the Tenorio Project, which provides water for agriculture and industry. The WWTP has a capacity of 90,720 m^3/day, part of which is used to supply water for the cooling towers at the "Villa de Reyes" Power Plant. Funding is repaid through the collection of three tariffs. The industries benefit because treated water costs 33 % less than groundwater.	Rojas et al. (2012)
India	The Okhla STP in New Delhi, provides 158 MLD of treated effluent to the Badarpur Thermal Power Station for cooling purposes. Industrial users are charged INR 4 for 1000 L.	Amerasinghe et al. (2012)

4.8 Detailed Case Descriptions

4.8.1 Faisalabad, Pakistan - Untreated Wastewater Use in Agriculture

4.8.1.1 Reuse Situation

Faisalabad, in Punjab Province, Pakistan, has a population of over 2 million and despite being the third largest city in the country remains highly dependent on agriculture. Agricultural land receives water from a complex canal system while the city relies on the Chenab River and is supplied with some 170,000 m^3 per day of water by the Water and Sanitation Agency (WASA). Around 32 percent of households in the city are connected to the sewage system and there is a WSP that treats some 30 percent of the wastewater generated (Clemett and Ensink, 2006).

Farmers in Chakeera, a village near the WSP were once reliant on distributaries of the Rukh Branch Canal and the Jhang Branch Canal to irrigate their crops but as time went on they found that their water supply was dwindling. Farmers began to purchase wastewater from a neighbouring village and in the mid-1970s, farmers constructed an irrigation canal to make wastewater available in more parts of the village and the existing canal-water infrastructure was modified to facilitate wastewater irrigation of vegetables, fodder crops, wheat and sugarcane (Weckenbrock et al., 2011; Clemett and Ensink, 2006).

In the 1980s WASA purchased land in Chakeera to build a WSP. The plant consists of six anaerobic, two facultative and four maturation ponds and was designed for an inflow of 90,000 m^3 per day. It was intended to provide safe irrigation water that would be sold to farmers to pay for operation and maintenance costs but, since its completion in 1998, farmers have been reluctant to use final effluent and have continued to use untreated wastewater. The farmers' reticence appears to be due to water quality, as the actual hydraulic retention time (HRT) is 46 days compared to a design of 16 days, which results in a saline effluent with lower nutrient content than untreated wastewater (Clemett and Ensink, 2006). The outcome is that only 4.4 percent (28.2 ha) of land is irrigated with water from the WSP while 71.3 percent (456.6 ha) is irrigated with untreated wastewater from the channel that supplies the WSP, and just 1.8 percent (11.6 ha) is irrigated with canal water (Weckenbrock, 2010). In 2003, approximately 200 farmers were using about 60,048 m^3/day of wastewater in Chakera (IWMI, 2003).

4.8.1.2 Policy and Institutional Arrangements

Although not legal, the farmers and WASA have entered into an agreement in which WASA sells untreated wastewater to the farmers. One farmer in the village pays WASA a fee and he then distributes the water among the farmers based on a carefully worked out irrigation schedule, and takes payment based on land area. In most cases farmers paid around USD 15/ha/year for wastewater, or received it free if they were cultivating land owned by WASA. By contrast, farmers in a neighbouring village, who used a combination of canal and groundwater, paid around USD 10-20/ha for one irrigation turn (Weckenbrock et al., 2011). The system appears to work well and most wastewater farmers feel that they receive sufficient water at the time that they need it. They are also able to grow high value crops throughout the year, which is not the case for farmers who use canal water. There are problems with this type of arrangement, for example WASA has raised the price at times, or refused to supply water, but these difficulties have always been overcome.

4.8.2 Tunisia - Treated Wastewater Use in Agriculture

4.8.2.1 Reuse Situation

Water availability in Tunisia is limited, with current availability of only 4.2 billion m^3 or 480 m^3 per capita, compared to a regional average of 1,100 m^3 and a global average of 6,600 m^3 (World Bank, 2010). With high agricultural water requirements and a large irrigation sector, accounting for 80 percent of the country's water consumption, mainly from over exploited aquifers, finding alternative water sources is imperative (World Bank, 2010). Furthermore, in the early 1960s, 1,200 hectares of citrus in the Soukra (northern suburbs of Tunis) were threatened, due to a lack of water and saline intrusion. To address this, the government developed an ambitious reuse policy and, in 1989, Tunisia became the first North African country to adopt regulations for the reuse of wastewater (GIZ, nd).

Currently most municipal wastewater in Tunisia receives secondary biological treatment, of which 80 percent is activated sludge, 15 percent lagoons and 4 percent filter beds (GWI, 2012). As a result of the reuse policy, much of this treated wastewater is utilized for agriculture and landscape irrigation, and there are proposals to augment groundwater reserves. The purpose of the reuse policy is not only to increase water resources but also to protect receiving waters, including coastal waters, and to provide supplemental nutrients to crops (Qadir et al., 2010).

The annual volume of treated wastewater in 2010 was 0.24 km^3 and is predicted to reach 0.29 km^3 by 2020 (Bahri, 2009), however this is still only around 25 percent of the available wastewater, which is lower than anticipated. The area of land irrigated with reclaimed water is 8,100 ha on which is grown grapes, fruit trees, olives, and fodder crops (alfalfa, sorghum), grain and industrial crops. Treated wastewater is also used for landscape irrigation and green areas (1,450 ha). Irrigation of vegetable crops is forbidden, and is monitored by the regional agricultural departments, which also collect a user fee of around USD 0.02 m^{-3} (Qadir et al., 2010).

4.8.2.2 Policy and Institutional Aspects

The reuse of treated wastewater in Tunisia is regulated by the following legal documents:

- The 1975 law on the promulgation of the Water Code, under which the use of treated wastewater for watering salad crops is prohibited.
- The 1989 decree setting the conditions for the use of treated wastewater for agricultural purposes.
- The Tunisian standard of 1989 which specifies the quality of treated wastewater for use in agriculture.

- The 1994 Order establishing the list of crops permitted to be irrigated with treated wastewater.
- The Decree of 1995 setting the terms of use of treated wastewater for agricultural purposes (GIZ, nd).

In general there is broad government support for water reuse, but this has yet to lead to widespread uptake, with groundwater being the farmers' preferred source of water. Part of the reason for this is that treated wastewater quality is designed to meet the requirements of receiving waters, and does not necessarily meet farmers' needs (GIZ, nd). There are also issues relating to social acceptance, crop choice and other agronomic decisions. For example, vegetables are a high-value crop which farmers are keen to produce, therefore the restriction on growing vegetables limits their desire to use reclaimed water (Qadir et al., 2010). To address the slow uptake, policy-makers have improved coordination and implemented 'follow-up commissions' at national and regional level with government officials, as well as representatives of water user associations (Bahri, 2008).

4.8.2.3 Plans

The XIth National Development Plan (2007 - 2011), of the Government of Tunisia sets as priorities: the protection of sensitive ecosystems; the reduction of nutrient discharges in the Gulf of Tunis; and development of the use of treated wastewater for agriculture and, where feasible, groundwater recharge. The Ministry of Environment and Sustainable Development, and the National Sanitation Corporation (Office National de l'Assainissement - ONAS) have developed a National Program for Wastewater Reuse aimed at treating waste and directing it for use on 25,000 hectares of agricultural land in Zaghouan, Nabeul and Kairouan. The strategy also plans for the use of treated wastewater to recharge the Mornag and Grombalia aquifers (potentially 30 MCM a year) at an estimated cost of USD 555 million over a 15-year period (World Bank, 2010).

There is currently a project, implemented by ONAS and funded in part by the World Bank, to treat and utilize wastewater from Tunis. Some 2.3 million people live in the Greater Tunis area, where 86 percent of the volume wastewater (96 MCM) is collected and treated annually. The project aims to initiate the use of treated wastewater in accordance with the National Program for Wastewater Reuse; improve the availability and quality of treated wastewater for use in the Borj Touil Irrigation area; and improve the quality of wastewater discharged to coastal waters (World Bank, 2010). In 2010, when the project started, 3 MCM of wastewater was being used for irrigation in the Borj Touil area. By 2012 this had increased to 5.4 MCM, with a goal of 9 MCM by 2017 (World Bank, 2015a).

4.8.3 Kolkata Wetlands, India - Untreated Wastewater in Aquaculture

4.8.3.1 Reuse Situation

The East Kolkata Wetlands (EKW) sustains the World's largest and perhaps oldest integrated resource recovery practice based on a combination of aquaculture and agriculture, and provides livelihood support to a large, economically underprivileged population of around 20,000 families which depend upon the various wetland products, primarily fish and vegetables, for subsistence (Kundu, 2010). In addition it provides habitat for water birds and a natural wastewater treatment system (Kundu et al., 2008).

The fish ponds receive raw sewage from Calcutta on a batch basis and fishermen have developed appropriate operational techniques. Raw sewage is screened and then allowed to flow into the ponds. After 12 days the ponds' contents are agitated with nets and sticks to facilitate oxidation and mixing. After another 13 days the ponds are ready to be stocked with fish. Thereafter, sewage is applied for 3 hours in the morning for 7 days a month at an estimated rate of 130 m^3 sewage/ha/day, the purpose of which is to fertilize the ponds. They are then stocked with a polyculture of fingerlings at a total density of 3.5 fish/m^2 and total initial stocked weight of 869 kg. Intermediate harvesting is started after 120 days and ponds are drained after 300 days, in March and April (Pescod, 1992). The system currently produces over 15,000 MT per annum of fish from its 264 functioning aquaculture ponds, and subsistence farmers produce nearly 150 MT of vegetables on the land (Kundu, 2010). This meets around 10-20 percent of the total fish demand of Kolkata (Pescod, 1992).

4.8.3.2 Policy and Institutional Arrangements

Although the area is vast it has declined over the years due to urban expansion and land reclamation. In 1945, the area of sewage-fed fish ponds was about 7,300 ha but by 2003 this had declined to 5,842 ha (Kumar, 2010). The decline in pond area has reduced the ability of the wetlands to treat wastewater (Kumar, 2010).

The encroachment and general deterioration of the EKW led to protests and court action and, in August 2002, the EKW area was listed under Article 8 of the Ramsar Convention as a "Wetland of International Importance" and was described by Ramsar as "one of the rare examples of environmental protection and development management where a complex ecological process has been adopted by the local farmers for mastering the resource recovery activities" (Kundu, 2010; Kundu et al., 2008).

The East Kolkata Wetlands (Conservation and Management) Ordinance, 2005 came into force on the 16th of November 2005 and on the 31st of March 2006, this ordinance was passed into the East Kolkata Wetlands (Conservation and Management) Act 2006, which allowed the State Govt. to the East Kolkata Wetlands management Authority (EKWMA) under the chairmanship of Chief Secretary to the Government of West Bengal. This Authority consists various departments (Environment, Urban Development, Irrigation & Waterways, Fisheries, Forest, Municipal Affairs, Land and Land Reforms, Panchayat and Rural Development), the West Bengal Pollution Control Board, District Magistrates, Kolkata Metropolitan Development Authority (KMDA), Kolkata Municipal Authority (KMC), Institute of Environmental Studies and Wetland Management (IESWM), local NGOs and cooperatives. In addition, expert committees have been formed around: Sewage and Fisheries; Land Management Hygiene, Sanitation and Welfare; and Biodiversity Conservation. The EKWMA has authority to prevent encroachment and abate pollution, as well as to develop an action plan for the EKW (Kundu et al., 2008).

Despite all this, Kumar (2010) reports serious problems with the management of the EKW: '*The current institutional arrangements are not effective limiting implementation of the East Kolkata Wetlands (Conservation and Management Act), 2006. There is, on an overall, focus on patch management with engineering measures ignoring interlinkages with hydrological processes and biodiversity. Involvement of multiple agencies with sectoral approaches limits adoption of a holistic management approach and strategy. Absence of appropriate monitoring and evaluation mechanisms limits assessment of impacts of implementation of action plans*' (Kumar, 2010).

4.8.4 Mirzapur, Bangladesh - Treated Wastewater in Aquaculture

4.8.4.1 Reuse Situation

In 1989, a local NGO, the Project in Agriculture, Rural Industry Science and Medicine (PRISM-Bangladesh), began a collaboration with the Kumudini Welfare Trust to treat wastewater from the Kumudini Hospital Complex, Mirzapur, Tangail district. The wastewater was received from the kitchens, bathrooms and laboratories of the hospital as well as school and domestic wastewater from some 2,350 people with a per capita production of 100 l/day. When the project began there was already a WSP on the premises but it did not function well and was a cost to the hospital. The purpose of the project was to improve the quality of the effluent and to generate an income that could sustain the WSP (UNEP-DTIE-IETC, 2000; Patwary and Domingo, 2013).

The system consists of a 0.2 ha anaerobic pond with an HRT of 2-4 days and a 0.7 ha plug flow lagoon constructed as a 500 m long serpentine channel with seven bends, in which duckweed was grown. The HRT in the plug flow pond is estimated at 21-23 days. Duckweed harvested from the 0.7 ha wastewater treatment pond is fed daily to three adjacent fish ponds, each 0.2 ha (UNEP-DTIE-IETC, 2000). The WSP achieves BOD_5, nitrogen (N) and phosphorus (P), and FC reduction rates of 90-97 percent, 74-77 percent and 99.9 percent respectively. The quality of the effluent is so high (< 102 FC/100 ml) that it could be used for unrestricted irrigation of vegetables according to WHO guidelines for wastewater reuse (UNEP-DTIE-IETC, 2000; WHO, 2006).

Not only is the system effective in terms of treatment, it is also cost effective and makes a sufficient income to cover all costs and an average net profit before taxes of about USD 1,000 annually. Furthermore it does not charge user fees or subsidies (Patwary and Domingo, 2013). This income is derived from the sale of duckweed-fed fish and livestock (Skillicorn and Patwary, 2013). The wastewater treatment system produces 220-400 tonnes fresh weight of duckweed/ha/year (about 17-31 tonnes dry weight/ha/year) and fish production varies from 10-15 tonnes/ha/year. Fish yields are relatively high because of frequent harvesting, and the addition of other feed besides duckweed, such as oil cake and rice bran (UNEP-DTIE-IETC, 2000).

4.8.4.2 Policy and Institutional Arrangements

Contracts exist between three stakeholder groups:

- the Kumudini Welfare Trust, a non-profit family trust managed by an outside board of directors, with one of its representative member being nominated by the Government of Bangladesh;
- PRISM-Bangladesh, a non-profit Bangladeshi NGO in charge of developing and maintaining the wastewater system; and
- the public who generate the wastewater and are involved in producing and utilizing the products (Skillicorn and Patwary, 2013).

The project has been through a number of management structures from its inception, which appears to have been influenced by project donors. Initially it was well structured and guided by PRISM through a Plant Management Committee, which liaised closely with local authorities. The PMC included representatives of several government departments, and community leaders, NGOs, prominent businessmen and Khulna University of Engineering and Technology (KUET) were invited to meetings. A Community Committee was also established (Parkinson, 2005). Currently PRISM continues to support group formation, mobilization, training and credit management around duckweed cultivation for fish production and wastewater treatment (PRISM, nd).

4.8.5 Bangalore, India – Urban Recycling for Municipal and Industrial Use

4.8.5.1 Reuse Situation

Currently in Bangalore two main methods of municipal wastewater recycling take place. The first is driven by the Bangalore Water Supply and Sewerage Board (BWSSB) and recycles municipal wastewater that enters BWSSB sewers. The second involves onsite recycling in larger apartments, residential complexes, campuses and commercial properties, and is required by law by the Karnataka State Pollution Control Board (KSPCB).

The treatment and reuse of municipal wastewater by the BWSSB has taken place for many years although it still remains only a relatively small part of the wastewater generated. Currently there are 14 STPs, of which four provide tertiary treatment for reuse: Vishabhavathi (60 MLD), Yellahanka (10 MDL), Cubbon Park (1.5 MLD) and Lalbagh Park (1.5 MLD). The STPs in Cubbon Park and Lalbagh Park produce water that is used for irrigation within the parks. Vrishabhavathi Valley (V-Valley) was designed to provide treated water to Bidadi power station, while Yellahanka was intended to supply Bangalore International Airport Limited (BIAL) along with various industries in the area (BWSSB, 2015). There is a suggestion that only 7 MLD of the treated wastewater is actually used due to constraints such as lack of infrastructure to deliver water to potential uses, and the availability of alternative, cheaper supplies (McKinsey and CII, 2014). However this has not escaped the notice of the BWSSB, which is actively implementing plans to raise awareness of reuse, and intends to develop the pipeline infrastructure.

There are also a number of STPs that treat water for disposal into lakes and rivers with the intention of augmenting water levels. In the future there are plans for indirect potable reuse: wastewater would be treated to tertiary level and released into the Tavarakere wetlands, 7 km upstream of a water extraction point (Nataraj, 2015).

In addition to the central STPs there are probably several hundred small scale, private STPs in Bangalore, of which only a small proportion are considered to be operational (Shankar and Yathish, 2012). Similarly to municipal wastewater treatment and use, on-site recycling is currently limited but appears to be gaining ground due predominantly to the water shortages being experienced in Bangalore and the cost of alternatives such as tanker water. There is also increasing pressure from the KSPCB to introduce and implement STPs, and the law states that no wastewater is to be disposed of from those premises that are required to have on-site treatment (‘zero discharge’) (Kodavasal, 2011b).

4.8.5.2 Policy and Institutional Arrangements

Despite the currently low levels of water reuse, the situation in Bangalore is interesting because of the variety of systems operating and the institutional arrangements that exist. There are two main agencies, the BWSSB and the KSPCB, that are actively pursuing a water reuse agenda for the city with plans, projects and legislation. In addition there is strong international donor support (Temasek Foundation, 2012).

4.9 Chapter Summary

As has been demonstrated there are a considerable number and variety of wastewater use activities taking place around the world. These differ in many factors including the level of treatment of the wastewater, the use to which it is being put and the management regime. In countries with strong institutional setups and/or severe water shortages there is an increasing level of formality to water reuse, for example in Singapore and Tunisia. In other countries practices are more traditional and less formal. In most cases they fill an important gap, usually in water or nutrient supply but also in wastewater treatment, for example in the East Kolkata Wetlands.

The many examples provided in this landscape analysis undoubtedly underestimate the extent and variety of wastewater use practices. There are many references, in journal articles and reports, to wastewater use in countries around the world, which have not been cited here because the information is very limited, or because the information may be outdated and more recent reports are not available to confirm whether the practice is current.

5 Wastewater Reuse in Bangalore

5.1 Introduction

This chapter forms the main body of the research and primary case study. The aim of the chapter is to thoroughly describe the RRR situation in Bangalore, especially the stakeholders and institutional arrangements. This will be used to identify critical institutional arrangements, including aspects of legislation, modes of implementation, stakeholders and attitudes, that contribute to the establishment or functioning of wastewater reuse systems, or which limit their feasibility or success.

Bangalore, the capital of the Indian state of Karnataka (Figure 5-1) was selected because of its interesting, and increasingly challenging, water and wastewater management context, as well as the existence of what appeared to be exciting and promising water reuse systems. This chapter starts by providing some background on the physical and socio-economic conditions in Bangalore and describing the main water and wastewater flows and management systems. The purpose of this is to provide a basic understanding of the action arena within which the institutional analysis takes place.

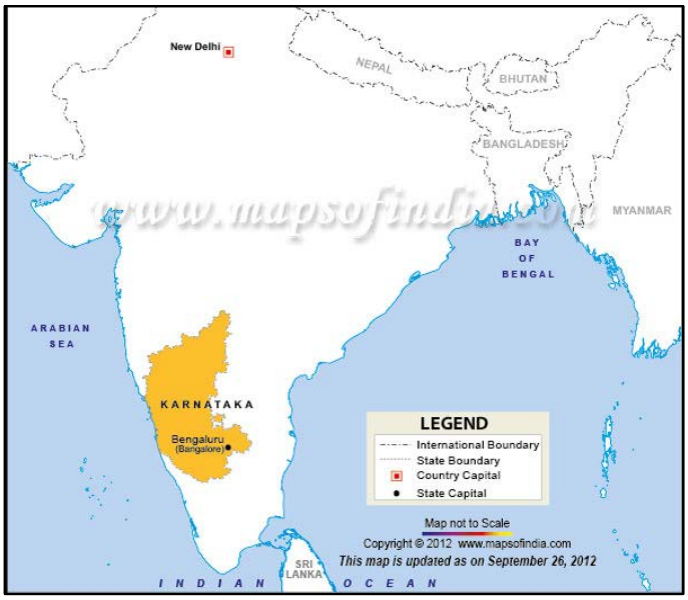


Figure 5-1. Map of India depicting Karnataka State
Source: Maps of India (2012)

The chapter then describes institutional arrangements at the national level, principally government ministries and departments, and policies and legislation that govern or influence state and city water, sanitation and wastewater use.

The next section moves the discussion to an initial analysis of the local level stakeholders and legislation that governs or affects their actions. Detailed stakeholder analysis begins with an interest and influence matrix and an examination of the relationships between stakeholders, how they implement, or fail to implement, policies and legislation. The section draws on literature and interviews conducted for this study, and culminates in a table highlighting the stakeholder roles, attitudes and actions that have a positive or negative effect on wastewater reuse in Bangalore.

5.2 Study Location

Bangalore comprises 27 districts of which three, Bangalore Urban district, Bangalore Rural district and Ramanagar district, form the **Bangalore Metropolitan Region (BMR).** The BMR is the largest metropolitan area of any city in India covering over 8,000 km^2. Within the BMR is the **Bangalore Metropolitan Area (BMA)** (800km^2) and five other planning areas. The **Bruhat Bangalore Mahanagara Palike (BBMP**, sometime translated as the Greater Bangalore City Corporation) area is part of the BMA (Figure 5-2).

Other terminology use to describe Bangalore is the **Greater Bangalore Region (GBR)** (741km^2), which is akin to the BBMP area, and comprises Bangalore Urban District and parts of Bangalore Rural District). It was formed in 2006 when the Urban Development Department (UDD), constituted[6] the BBMP, merging the then Bangalore City Corporation Area (226km^2) with eight Urban Local Bodies (ULBs) and 111 Villages of Bangalore Urban District (Figure 5-3; Sudhira et al., 2007; Kelkar et al., 2012). This study focuses on the BMA area but it should be noted that not all government stakeholders are confined to this boundary, due to its relatively recent creation, and that certain statistics are reported for other areas. Furthermore, some of the reuse systems cross local planning authority boundaries. Every attempt has been made to clarify when an area other than the BMA is being discussed.

[6] Gazette notification vide No. UDD/92/ MNY/2006, dated 2.11.2006.

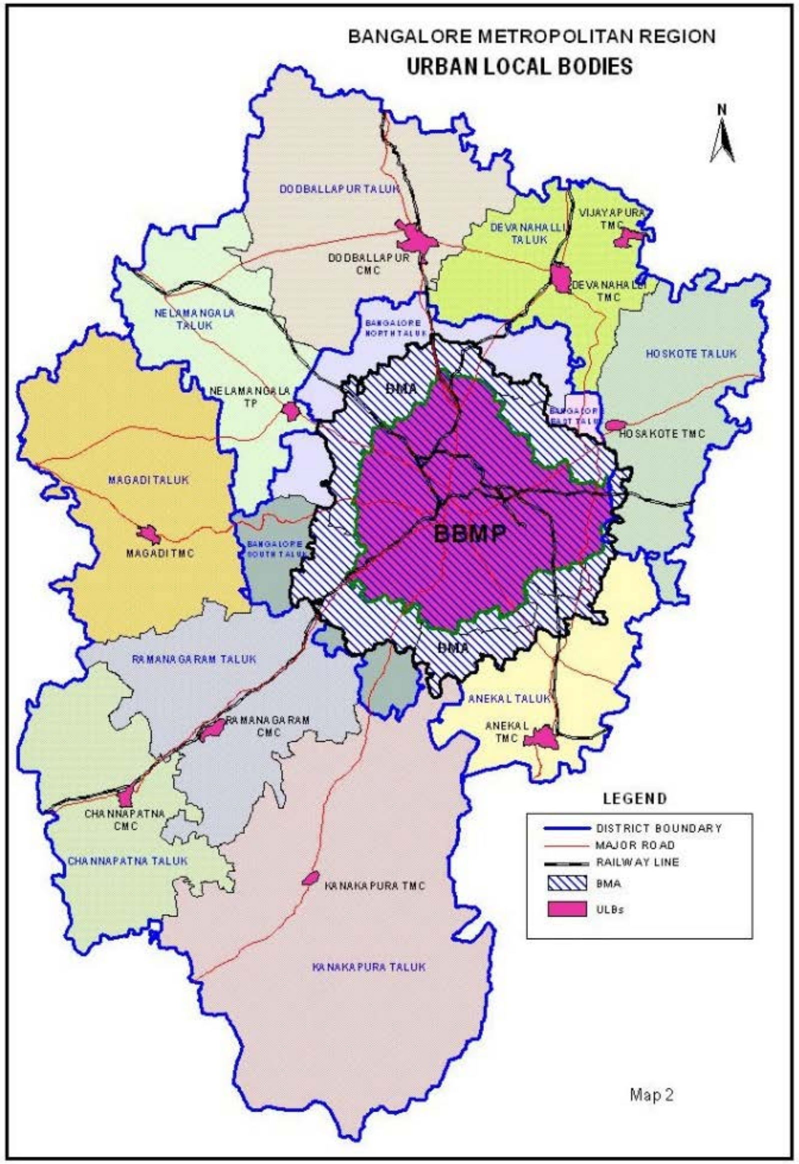


Figure 5-2. Depiction of BMR, BMA and BBMP area
Source: GOK (2008)

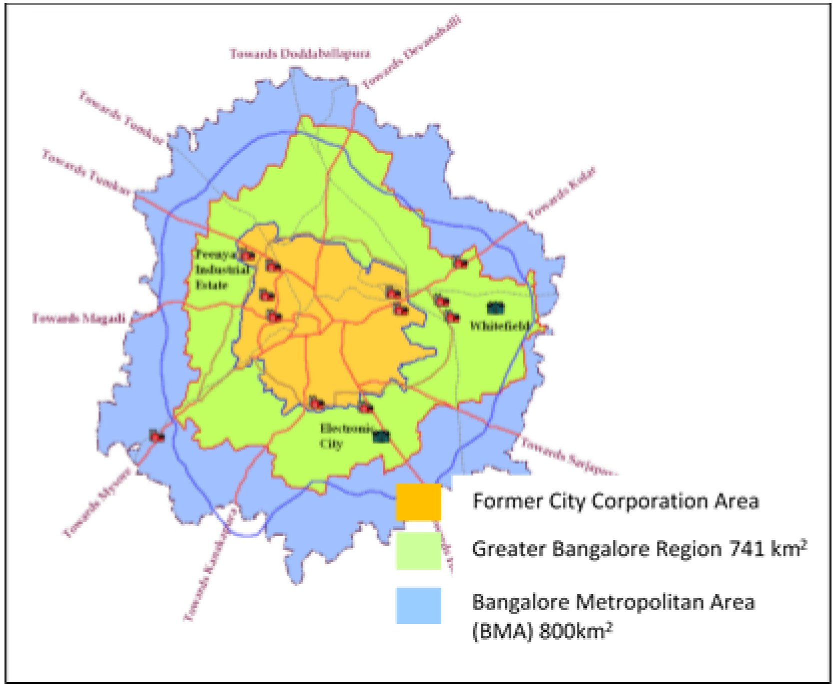


Figure 5-3. Depiction of the geographical areas within the BMA
Source: Sudhira et al. (2007)

In Bangalore, as in so many other cities, water supply is reaching its limits but demand continues to grow as the population rises and lifestyles change. There is also increasing demand for improved sanitation and wastewater management solutions. The WSS landscape in Bangalore is complicated by the increase in the geographical boundary of Bangalore in 2006, which extended the jurisdiction of key government organizations.

Unless unconventional sources of water and novel forms of wastewater management are identified, of which wastewater reuse will inevitably be a component, the authorities will not be able to meet their commitment to WSS, and people and the environment will suffer. Existing studies estimates that if the total quantity of storm water discharged annually (467 MLD) was to be protected and conserved, it could meet the requirement of around 2.3 million people or nearly 24 percent of the city's population (Hegde and Chandra, 2012; 2013). Furthermore, Hegde and Chandra (2012; 2013) calculate that if the total sewage load, around 721 MLD, was treated to drinking water standards and 70 percent of this was made available, it could serve another 2.6 million people. Combined they could serve just over 50 percent of the urban population. At present there are some interesting examples of treated domestic wastewater being used to supply industries, and to recharge lakes and groundwater. There are also a number of WWTU systems within apartments, residential complexes, campuses and commercial premises.

5.3 Bangalore Water Supply Context

The context for wastewater reuse is largely set by the water supply situation in Bangalore. The city is located in the watershed of two principal river basins, Arkavathi to the West and South Pennar to the East. North of the city is a ridge and river valley, known as the Hebbal series. Three principal valleys - Vrishabhavathi, Koramangala and Chellaghatta run in a north-south direction across the metropolitan area and a further five minor valleys drain the fringes of the city so that Bangalore naturally drains without the need for pumping (BWSSB, 2013).

The Bangalore Water Supply and Sewerage Board (BWSSB) supplies water to Bangalore from the Arkavathi River and the Cauvery River (Figure 5-4; Box 5-1). The Arkavathi is over exploited and in years of low rainfall is essentially dry. The result has been conflict with neighbouring States over greater use of the Cauvery River, which has led to caps being placed on each State's water entitlement through the Cauvery Water Disputes Tribunal. The total planned supply of surface water is just over 1,400 MLD but the BWSSB admit that the reality is far below this. Prior to the expansion of the Cauvery Water Supply Scheme (CWSS) the BWSSB reported that supply was 900 MLD compared to a demand of 1,300 MLD (BWSSB, 2013) and the gap between demand and supply continues to increase (BWSSB, 2013). The difficulties in obtaining water are resulting in high, unsustainable costs associated with lifting and transporting the water. Water from the Cauvery River must be transported some 100 km and lifted 300 m (Figure 5-4). The expansion of infrastructure to distribute this water is another major challenge and many households are not connected, especially in areas newly added to the BMA.

Figure 5-4. Schematic of water sources supplying Bangalore City
Source: CSE (2012a)

Box 5-1. History of water supply development in Bangalore

- 1896: 36 MLD from the Arkavathi River via Hesaraghatta Reservoir.
- 1933: 135 MLD of water from the Arkavathi River via Tippagondanahalli Reservoir (or T G Halli).
- Treated Water was supplied under the Cauvery Water Supply Scheme (CWSS).
  1974 – CWSS Stage I – 135 MLD
  1983 –CWSS Stage II – 135 MLD
  1993 – CWSS Stage III – 270 MLD
  2002 – CWSS Stage IV Phase I– 270 MLD
  2008 – CWSS Stage IV Phase I – 100 MLD augmented
  2012 – CWSS Stage IV Phase II – 500 MLD supplying seven city municipal councils (CMCs), Yelahanka, Byatarayanapura, Bommanahalli, Mahadevpura, K R Puram, Rajajeshwarinagar and Dasarahalli and one town municipal council (TMC), Kengeri (CMIE, 2012)
  Total – 1410 MLD[7]

Source: BWSSB (2013)

[7] Slightly different figures are provided by Kelkar and Thippeswamy (2012) of 150, 150, 314, 315 and 540 MLD for each stage. The total figure being 1469 MLD compared to 1410 MLD. Furthermore, the figures given in Box 5-1 are the design figures and current supply levels are below this (CPHEEO, 2005).

Groundwater is also important in Bangalore which receives 35 MLD from 7,000 BWSSB borewells, 106 MLD from 105,500 private borewells registered with BWSSB, and an estimated 200 MLD from over 200,000 unregistered private borewells. The total supply is around 341 MLD (Jacob, 2012). By contrast the groundwater recharge calculated by Hegde and Chandra (2012) for the Department of Mines and Geology, Bangalore, is just 90 MLD. As a result, the three aquifer systems that serve Bangalore city are classified as "Over Exploited", and the aquifer systems serving rural Bangalore are "critical" (Jacob, 2012; CGB, 2012).

At present, the BWSSB is variously estimated to provide around 1,120 MLD from surface water and 35-70 MLD from groundwater; a further 300 MLD is estimated to be supplied from private wells (Jacob, 2012; Narain et al., 2012; GOK, 2009; in Di Mario, 2014). Whatever the actual figure, it is widely acknowledged, both within and outside the BWSSB, that there is a considerable gap between supply and demand, even with the relatively recent expansion of pumping capacity from CWSS (BWSSB, 2013). According to Kelkar and Thippeswamy (2012) demand for freshwater had already outstripped supply in the Greater Bangalore Metropolitan Area in 2001 and by 2036 demand will be 1.7 times the available supply (Table 5-1).

Table 5-1. Projected water demand and availability in Greater Bangalore Metropolitan Area

Year	Population (millions)	Demand (MLD)	Available supply (MLD)	Shortfall (MLD)	Shortfall as a percentage of demand (%)
2001	5.4	870	540	310	35.6
2007	7.5	1219	840	379	31.1
2015	8.8	1720	1500	220	12.8
2021	10	2125	1500	615	28.9
2036	12.5	2550	1500	1050	41.2

Source: Kelkar and Thippeswamy (2012); Kelkar et al. (2012).

Water for human consumption is not the only issue. Bangalore’s environment is being drastically modified by water use and encroachment of wetlands which impacts wildlife, the communities that traditionally utilized wetlands, as well as the wider urban population. Bangalore was once endowed with numerous wetlands that were used for irrigation and domestic purposes, as well as drainage. However, since 1973, more than 70 percent of the wetlands in the BMR have been lost due to infrastructure development and formation of residential areas. In 1985, there were 51 healthy wetlands in Bangalore city but by 2008 this had declined to 17 (DFEE et al., 2008). A study by Nagendra et al. (2011) of the 35 lakes in Mahadevpura in the east of Bangalore city, found that 23 have become dysfunctional, seven are ‘extremely polluted', seven are ‘heavily polluted, drying' and nine are ‘completely dry' (Figure 5-5).

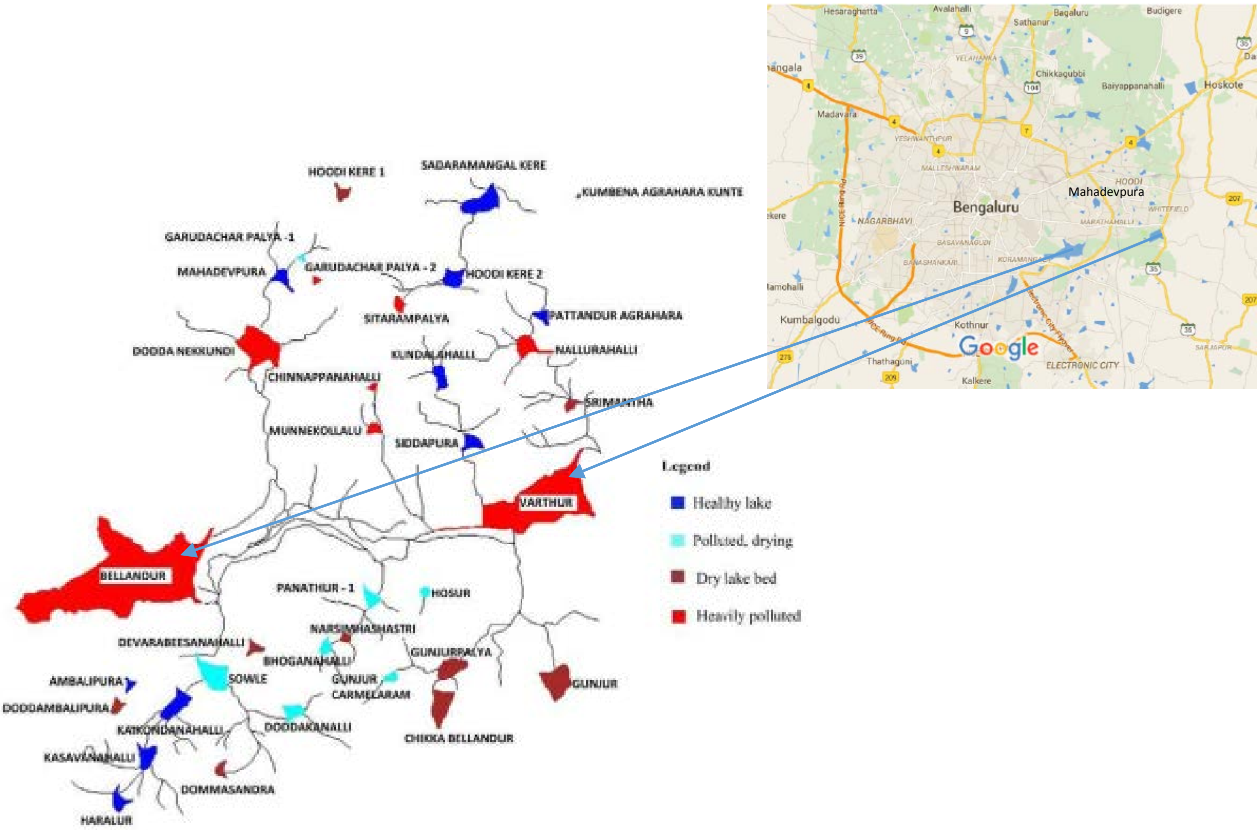


Figure 5-5. Status of lakes in Mahdevpura
Source: Nagendra et al. (2011); Google (2016)

5.4 Wastewater Management and Reuse Context in Bangalore

Not only does water supply pose a serious problem for the municipal authorities, so too does managing the wastewater that is generated. The first step in the research process was to identify the flows of wastewater and the management and reuse systems that were present in the city. A schematic was developed with project partners and stakeholders to show all the water sources utilized in Bangalore, the main water users and wastewater producers, and the ways in which wastewater is processed and used. Figure 5-6 shows how fresh water is delivered by BWSSB or through private means to various users in the city (e.g. industries, households, businesses). The waste is then processed on site (green arrows), in BWSSB STPs (black arrows) or disposed to the environment, returning eventually to the water cycle or being used untreated by farmers (black arrows). Wastewater treated in private STPs may be used on site or disposed of to the environment, also returning ultimately to the water cycle (green arrows). New laws have made it possible to share or sell this water whereas previously this was forbidden. Wastewater treated in BWSSB STPs flows to the environment and is also used by park authorities, farmers, fishermen and other users of receiving waters.

The wastewater management and reuse systems depicted in Figure 5-6 include:

- **Planned reuse from municipal STPs** – BWSSB is responsible for WWT and some of this water is sold to industries or used in public areas such as parks.
- **Wetland regeneration, groundwater recharge and fisheries -** Recharge results from formal WWT and "disposal" into urban lakes and from unplanned, unregulated disposal of untreated wastewater**.** The benefits can include wetland regeneration, groundwater recharge and improvements in fish numbers and quality, leading to livelihoods benefits, however the outcome depends on management and water quality.
- **Planned reuse from private STPs -** on-site wastewater treatment and use for non-potable domestic purposes such as flushing, gardening and car washing.
- **Wastewater irrigation -** use of wastewater that has been allowed to flow into irrigation tanks after a period of attenuation. Also informal irrigation either directly from drains or indirectly from polluted streams.

Descriptions were prepared for each as part of the research process and an example for Jakkur Lake is provided in Annex 4. The descriptions included flow diagrams and details such as the treatment process, quantities of wastewater treated, quantities of treated water utilized (where known), the stakeholders involved or affected, relevant policies and other institutional aspects that required further research.

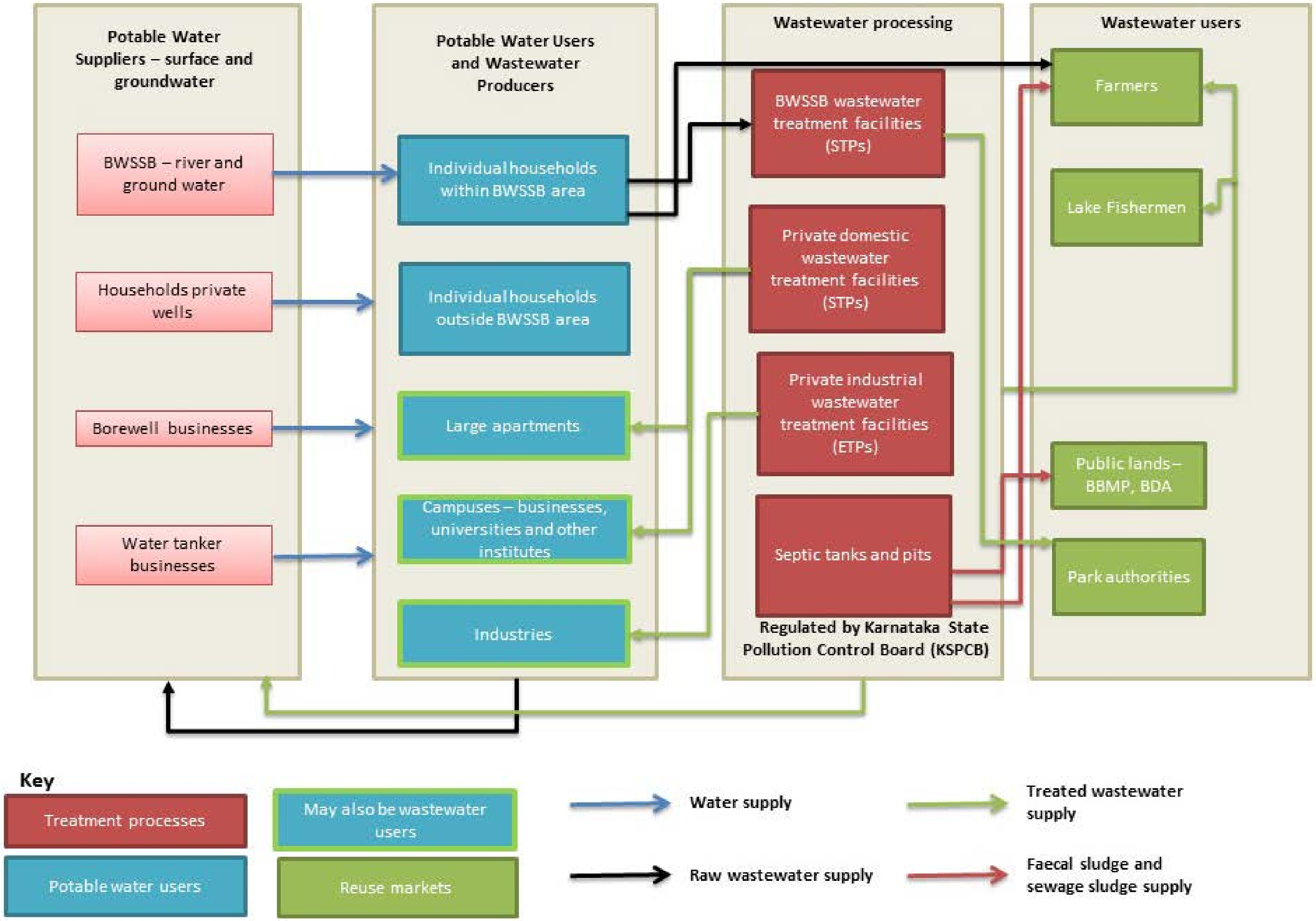


Figure 5-6: Waste streams, stakeholders and reuse
Source: modified from Krishnamurthy et al. (2015)

5.4.1 Planned Reuse from Municipal STPs

An underground sewer was built in Bangalore in 1922 and extended over the century; however it still serves only 40 percent of the BMR (BWSSB, 2013; CAG, 2011). In 1964 sewage treatment was introduced but only 47 percent of the sewage reaches the STPs (BWSSB, 2013; CAG, 2011). According to the Comptroller and Auditor General of India (CAG, 2011), the total quantity of sewage generated in the city is 1,200 MLD, the treatment capacity is 463 MLD but only 120 MLD of this is actually treated (Figure 5-7).

There are now 14 municipal STPs in the city with a combined design capacity of 721 MLD. Figure 5-8 shows the location of these STPs and Table 5-2 describes each of them, including their treatment capacity and purpose (i.e. disposal or use). The quantity actually treated is only 418 MLD but this is not insignificant, being equivalent to the first three stages of the CWSS. Of the 14 STPs, seven were designed for reuse purposes, potentially reusing 138 MLD (20 percent of the total wastewater treated). There were a range of reuses planned including irrigation of city parks, sale to industries and surface water recharge (Table 5-2). Sale to wastewater to industry is being actively pursued by the BWSSB as seen in the descriptions of the two main central STPs in Yelahanka and Vrishabhavathy (Box 5-2 and Box 5-3).

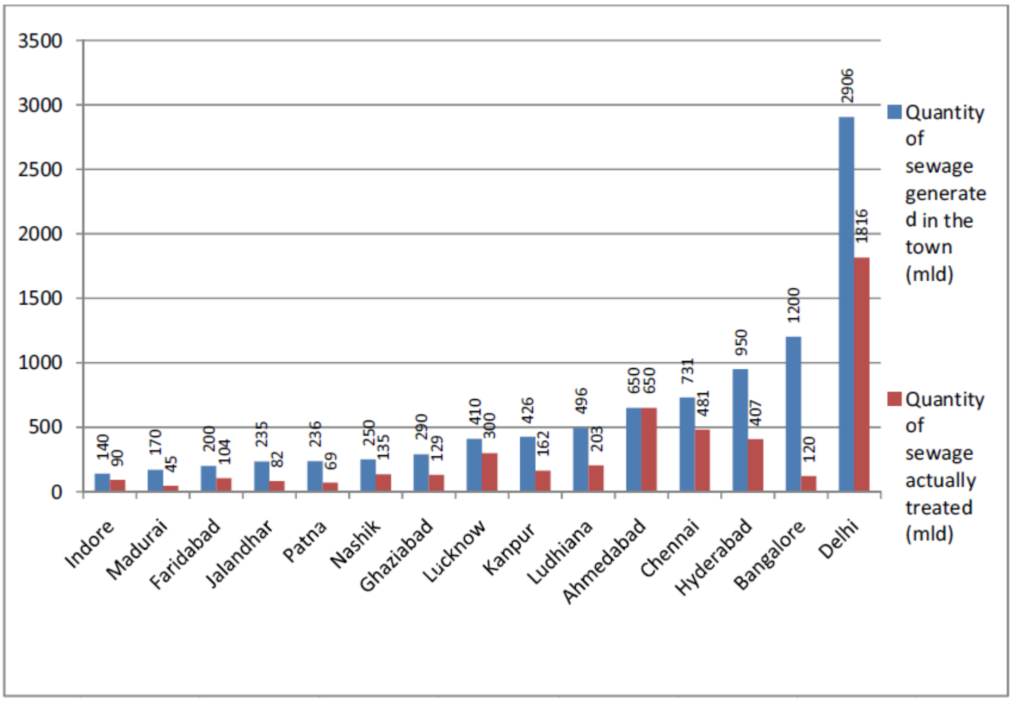


Figure 5-7. Quantity of sewage generated (MLD) and treated (MLD) in cities in India.
Source: CAG (2011)

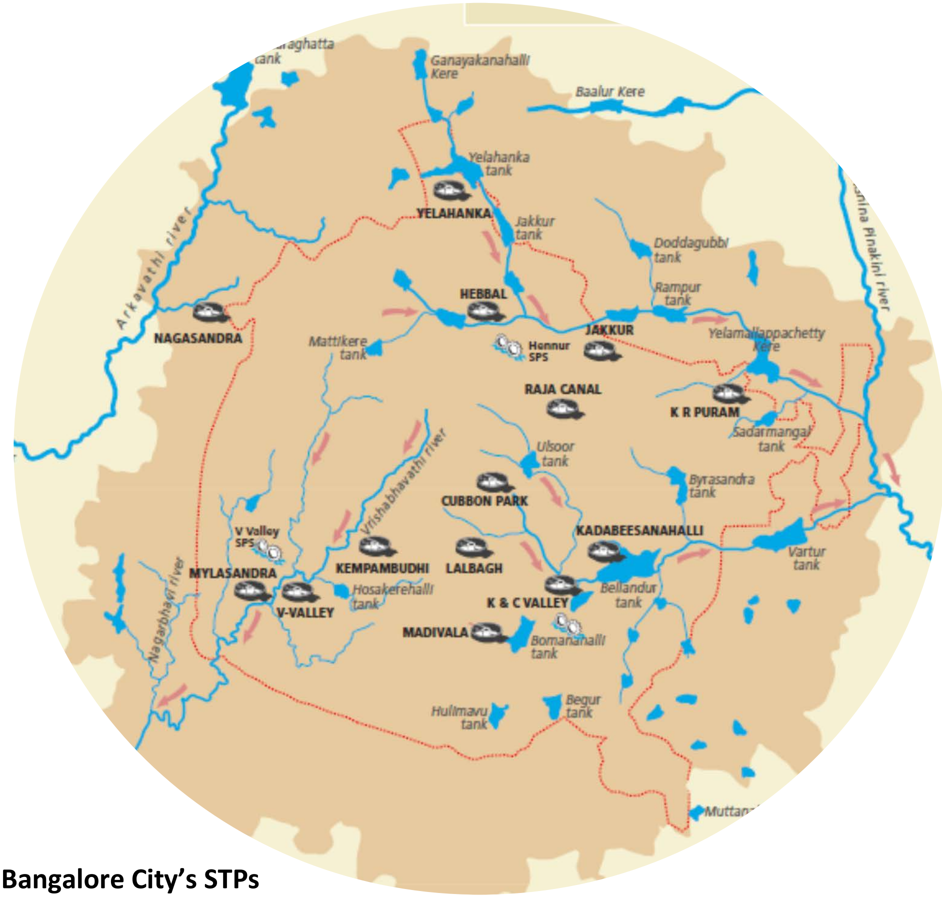


Figure 5-8. Location of Bangalore City's STPs
Source: CSE (2012b)

Note: STP locations are shown in bold upper-case text and white symbols within black ellipses.

Table 5-2. Sewage treatment plants, capacity and planned reuse

Treatment plant	Capacity (MLD)	Reuse (MLD)	Disposal (MLD)	Details
Koramangala and Challaghatta (K&C) Valley treatment plant	248		248	*Activated sludge (AS) and extended aeration (EA).* Primary sewage treatment plant (STP) established 1974; upgraded to secondary level in 1990. Under Cauvery Water Supply Scheme (CWSS) Stage IV Phase I, another 30 MLD capacity STP was established and EA adopted. 55 MLD capacity added 2006.
Vrishabhavathi valley (V-Valley) treatment plant	180	60	120	*Trickling filter and tertiary treatment.* Treats wastewater from the western part of the city. In 2004 tertiary treatment plant of 60 MLD added to **supply a new power plant** near Bidadi.
Hebbal valley treatment plant	60	60		*Activated Sludge.* Treats wastewater generated in the Northern part of the city. Treated wastewater **released to Nagavara lake**.
Madivala water reclamation plant	4	4		*Upward flow anaerobic sludge blanket (UASB), oxidation ponds and wetland.* The treated wastewater is released into a wetland system which **replenishes the Madivala lake** in the Southern part of the city, which lacked a freshwater inflow.
Kempambudhi reclamation plant	1	1		*EA*. Built to replenish Kempambudhi lake in the southern part of the city, which lacked a fresh water inflow.
Yelahanka Tertiary treatment plant	10	10		*AS, filtration and disinfection.* The authorities wanted to supply treated wastewater to the Bangalore International Airport Limited (BIAL). BWSSB established a tertiary waste stabilization pond near New Town, Yelahanka. It supplies **BIAL, Bharth Electronic Limited, Indian Tobacco Company, Rail Wheel Factory and Indian Air Force.**
Mylasandra	75		75	*EA.* Established under CWSS Stage IV Phase I downstream of V-valley STP. The treated wastewater is **released to V-valley.**
Kadabesanahalli	50		50	*EA*. Established under CWSS Stage IV Phase I to treat wastewater generated in the east of the city.
Krishnaraja (KR) Purum	20		20	*UASB.* Established under CWSS Stage IV Phase I to treat wastewater from the eastern part of the city.
Jakkur	10		10	*UASB.* Established under CWSS Stage IV Phase I to treat wastewater from the northern part of the city.
Raja canal	40		40	*EA.* Treats wastewater from the north eastern part of the city.
Nagasandra	20		20	*EA.* Built on Tumkur Road to treat the wastewater generated in the western part of the city.
Cubbon Park	1.5	1.5		*Tertiary – membrane and disinfection.* Established to address water shortage in Cubbon Park in the centre of the city. The treated water is supplied through a **sprinkler system.**
Lalbagh	1.5	1.5		*EA, filtration and UV disinfection.* Lalbagh, the largest park in Bangalore, suffered from a shortage of water. The STP was established to supply water through a **sprinkler system.**
Total	721	138	583	

Source: Adapted from BWSSB (2013).

Box 5-2. Yelahanka Tertiary Treatment Plant

Yelahanka Tertiary Treatment Plant (TTP) has a 10 MLD capacity and recycling facilities. The overall project cost approximately INR 4,000 million (USD 62.7 million), of which INR 240 million (USD 3.9 million) was the cost of the TTP. The project was funded through the Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC) and Housing and Urban Development Corporation Limited (HUDCO) under the Megacity scheme[8] and the Indo-French protocol[9]. It was commissioned in 2003. Industries ear-marked to receive treated wastewater are ITC Wheel and Axle Plant and the International Airport at Devanahalli. The wastewater is treated in an activated sludge plant followed by sand filtration and chlorination. It is then pumped to the end user (the airport plus a number of industries en route) through a 300 mm pipe which cost INR 85 million (USD 1.4 million) to install. The sludge is thickened, dewatered, dosed with lime and disposed of.

Source: BWSSB (nd)

Box 5-3. Vrishabhavathy Tertiary Treatment Plant

Commissioned in 2003 the 60 MLD TTP cost around INR 350 million (USD 5.5 million) and was funded through KUIDFC/HUDCO under the Megacity scheme and the Indo-French protocol. It was designed and constructed by ONDEO Degremont. The scheme was designed to sell recycled water to Karnataka Power Corporation Limited and Pulikeshi Power Corporation for their power generation plants at Bidadi and Kumbalgod industrial areas respectively. The treatment system involves biofiltration through an aerobic attached growth trickling filter, high rate clarification, biological treatment (FLOPAC) and chlorination. The excess sludge is digested and dried.

Source: BWSSB (nd)

The BWSSB also plans to recycle and reuse sewage for indirect potable use with wastewater flows from the Vrishabhavathi Valley (V-Valley) STP. The treated water will be discharged into the Arkavathy River and flow to a water treatment plant on the Thippagondanahalli (TG) reservoir that serves Bangalore city. However, the BWSSB acknowledges that public acceptance is a big challenge and in 2012 the BWSSB signed an MoU with Singapore Cooperation Enterprise (SCE) and the Singapore-based Temasek Foundation (TF), to aid in public outreach and stakeholder acceptance (Box 5-4).

[8] Government of India Centrally Sponsored Scheme of Infrastructural Development in Mega Cities, see http://www.kuidfc.com/website/webpage.nsf/6dfb1eea694920ff65256e2c00360da2/8fafa349c38587f465256fa9003d6b7c/$FILE/Megacity%20Guidelines.pdf

[9] By lateral funding from the French Government to the BWSSB in 1995 of 50 Million Francs.

Box 5-4: Temasek Foundation, press release, 9 October 2012

Singapore Cooperation Enterprise and Temasek Foundation (TF), Singapore, today announced a new initiative that will assist the BWSSB in building the capabilities of its key government officials to develop and implement alternative sources of water through recycling and reuse methods. The 24-month programme will be supported by TF with a grant of SGD 756,890 (USD 600,000) and co-funded by BWSSB with an amount of SGD 263,346 (USD 210,000). The programme aims to provide advisory and capacity building activities to assist BWSSB to:

a) Achieve an in-depth understanding, through workshops and discussions, of the benefits and challenges of integrated wastewater management and water supply, and the policy action required to implement wastewater recycling and reuse strategies;
b) Create a joint development strategy report, feasibility study and preliminary scheme design;
c) Develop strategies to raise public awareness and acceptance of recycled wastewater by sharing Singapore's experience in managing the implementation of NEWater;
d) Build the capabilities of 160 BWSSB officials with the knowledge and skills to manage, operate and maintain recycling and reuse plants.

Source: Temasek Foundation (2012)

BWSSB has prepared a detailed project plan to treat 335 MLD of wastewater and release it into the Arkavathi River and wetlands at Tavarekere, 7 km upstream of a proposed water treatment plant. Once treated the water would be included in the mains supply to Bangalore. The project is still awaiting funding and, as stated in 2013, a major impediment remains public opinion (Nataraj, 2015).

5.4.2 Wetland Regeneration, Groundwater Recharge and Fisheries

There are thousands of open wells and borewells across Bangalore providing some 341 MLD to households and commercial premises (Jacob, 2012; CGWB, 2013). According to the Centre for Science and Environment (CSE), the demand-supply gap is estimated to be around 585 MLD and can be assumed to be filled by groundwater (CSE, 2006a). Many of these wells are utilized by the owners to reduce domestic water bills, to meet requirements when the BWSSB supply is inadequate or to undertake productive activities. In a number of cases well owners lease their wells out or sell their water to tanker operators who sell the water on to urban consumers. The cost to households is high, especially in low income, poorly served areas, but it is often their only option.

The formal treatment and disposal of urban sewage results in a large quantity of treated effluent entering open water bodies including urban lakes. In some cases this leads to unplanned groundwater recharge. The benefit of this recharge is felt by the households who live near the receiving waters and can make use of greater supplies of groundwater, and those individuals who sell groundwater or use-rights. Jakkur Lake is a well-documented example of this, and brief details are shown in Figure 5-9 and Box 5-5. However, care must be taken where untreated wastewater is entering lakes. The CGWB (2013) has observed that open wells and borewells around polluted tanks, lakes and rivers are polluted, for example near Vrishbhavathi River.

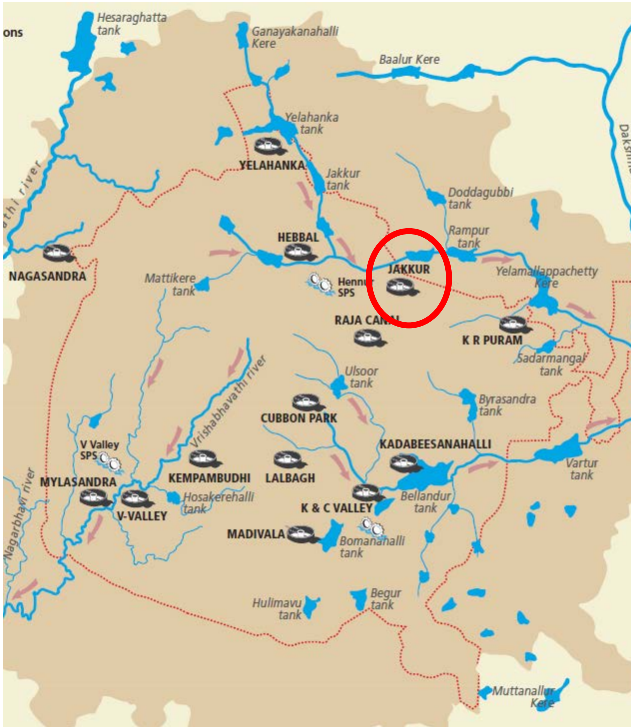


Figure 5-9: Location of Jakkur Lake
Source: Centre for Science and Environment, 2011.

A comprehensive rejuvenation project was undertaken for Jakkur Lake at the cost of INR 215 million (USD 3.37 million). The lake was de-watered, de-silted, and all sewage inflows were diverted to a 10 MLD sewage treatment plant (McKinzie & Company, 2014). Currently the STP receives only 5 MLD and the treated wastewater flows through a constructed wetland before entering the lake itself. The result has been an increase in biodiversity, fishing and groundwater recharge.

The lake is owned by the Bangalore Development Authority (BDA) but leased to and managed by the Lake Development Authority (LDA). Rights to fish in the lake are leased by the Fisheries Department (FD) to a fishing contractor. He in turn employs a number of people to fish the lake. The fish are sold locally.

Box 5-5. Jakkur Lake – rejuvenation and additional benefits
Source: Interviews conducted for this study

Hegde and Chandra (2012) estimate that currently just 1 percent of the total sewage discharged goes to recharge aquifers. If managed properly there is the potential for this to be increased. As part of an IWRM strategy for Bengaluru, McKinzie & Company (2014) propose a programme of lake regeneration to improve groundwater supplies. They calculate that, of Bangalore's 187 lakes, 38 which have already been cleared of encroachment can be prioritised for restoration and rejuvenation. Lakes with an area of over 30 acres can have a local STP to stop the inflow of sewage; smaller lakes can be restored by routing the flow of sewage to the nearest STP. These 38 lakes could increase Bangalore's water availability by 180 MLD.

Figure 5-11. Jakkur Lake and wetland used for fishing, grazing and bathing

Figure 5-10. Open well near Jakkur Lake used to supply water to a tanker operator

5.4.3 Wastewater Irrigation

Farmers in peri-urban areas make use of wastewater flowing to their fields. In some cases this wastewater has been treated prior to use but in many instances it flows directly into drains and streams from which it is diverted or pumped to agricultural land, providing irrigation and nutrients. As well as informal, unplanned use, there are examples of official, planned wastewater use where the sewage is directed to tanks as a means to augment the irrigation water. Two examples of this are in Byramangala tank and Yele Mallappa Shetty Kere (YMSK) (Box 5-6 and Box 5-7), which have proved so successful that there are plans for other tanks to be rehabilitated with sewage flows in the Hoskote area, but to date these have not been implemented, apparently due to a water sharing dispute with Tamil Nadu (Khanna, 2014).

Box 5-6. Byramangala Tank

Byramangala tank receives water from Vrishbhavathy Valley (V-Valley) which carries one third of the sewage flows from urban Bangalore (around 600 MLD). It is highly polluted with industrial effluents and urban waste. V-Valley has the largest number of farmers using wastewater for irrigation, although the practice is limited to areas along the river. Byramangala tank is used to irrigate around 1,774 ha, on which farmers grow paddy, sugarcane, jowar, babycorn and fodder grass. Upstream some farmers have been lifting water to use in agriculture.

Source: Information gathered from interviews for this project

Box 5-7. Yele Mallappa Shetty Kere

There are 51 major tanks; 28 medium tanks; and 44 small water bodies in Yele Mallappa Shetty Kere (YMSK) watershed, in the north of Bangalore. The tank receives sewage flows from the northern part of the city, particularly Jakkur, Yelahanka, KR Puram and Hebbal. In 1990, a plan was put forward by the Minor Irrigation Department to supplement the water in Doddakere tank, in Hoskote (within YMSK), Bangalore Rural District, with excess flows of sewage. This was intended to support agriculture in the 1,960 acre command area, which was suffering from water shortages and to help deal with the excess flows of sewage. The original proposal was to pump 265 litres/sec of water into the Doddakere tank for 40 days. The pumping finally started in 2011 and has continued ever since. In addition to supporting irrigation with surface water, the system is also replenishing the aquifer. Farmers are utilizing groundwater and the municipality has drilled around 200 borewells to supply drinking water to local towns, which benefits some 60,000 people. The water quality has been tested and is within standards for potable water. This is accounted for by the fact that the water flows 8 km through various tanks and wetlands before reaching Doddakere tank and therefore natural processes purify the water. Despite the recharge benefits, the goal of the scheme remains only to augment the shortage of water in Hoskote's Doddakere tank.

Source: Information gathered from interviews for this project; Raghunandan (2012)

5.4.4 Planned Reuse from Private STPs

Given that only around 3.4 million of the 8.5 million population is served by piped sewers the remaining 60 percent of the city's inhabitants (5.1 million people), rely on on-site sanitation with off-site disposal or private STPs. A study by Shankar and Yathish (2012) identified some 612 private STPs around the city in apartments (331), tech parks (123), hotels (42), hospitals (49), commercial and retail complexes (44), educational institutions (15) and residential layouts (7) (Table 5-3; Shankar and Yathish, 2012). These provide treatment in areas that BWSSB does not cover, in order to comply with national and State environmental laws. According to a report released by the Karnataka State Pollution Control Board (KSPCB), these private STPs have a total capacity of around 113 MLD (Table 5-4) and currently operate at 75 percent of their capacity (Shankar and Yathish, 2012). Other sources estimate the number to be much higher, at around 2,000, of which the majority lie in disrepair and are not functioning (Ananth Kodavasal, pers. comm., 17 July, 2013).

Table 5-3. Number of private and BWSSB STPs in Bangalore (BBMP and non-BBMP urban areas)

Property type	Anekal	Sarjapura	South	East	West	M.Pura	B.Halli	Yelahanka	PR Nagar	Dasarahalli	Total
Apartments	1	14	4	6	15	90	132	53	10	6	331
Tech Parks	0	0	4	21	0	49	36	12	1	0	123
Hotels	0	6	0	2	6	15	11	2	0	0	42
Hospitals	0	2	12	13	9	5	3	3	3	0	49
Commercial	1	0	2	5	5	25	6	0	0	1	44
Layouts/ gated communities	0	0	0	0	0	4	1	2	0	0	7
Educational institutions	2	4	1	0	0	0	6	2	0	0	15
BWSSB STPs	0	0	1	1	1	1	3	4	2	1	14
Total	4	26	24	48	36	189	198	78	16	8	626

Source: Shankar and Yathish (2012)

Table 5-4. Treatment capacity of BWSSB and private STPs (in 1,000 L/day)

Property type	Anekal	Sarjapura	South	East	West	M.Pura	B.Halli	Yela-hanka	PR Nagar	Dasara-halli	Total
Apartments	77	2,166	654	445	5,375	11,294	22,541	6,073	1,243	2,000	52,003
Tech Parks	0	0	955	1,115	0	8,750	9,017	4,120	300	0	24,257
Hotels	0	311	0	2,750	2,210	1,811	1,195	260	0	0	8,537
Hospitals	0	625	1,820	2,576	1,958	1,601	475	415	275	0	9,745
Commercial	130	0	300	1,565	1,829	6,612	830	0	0	50	11,316
Gated communities	0	0	0	0	0	300	185	410	0	0	8,95
Educational institutions	270	230	300	0	0	0	935	525	0	0	2,260
Sub Total	612	3,332	4,029	8,451	11,372	30,368	35,178	11,803	1,818	2,050	109,013
BWSSB STPs	0	0	1,500	1,500	1,000	20,000	306,000	120,000	255,000	20,000	721,000
Total	612	3,332	5,529	9,951	12,372	50,368	34,1178	131,803	256,818	22,050	834,016

Source: Shankar and Yathish (2012)

Where private STPs exist, the quality of the treated water allows for non-potable use such as flushing and gardening. This can only make use of around 30-75 percent of the treated wastewater, making disposal inevitable (Shankar and Yathish, 2012; Kodavasal, 2011b) and suggesting that more treated wastewater is available for use if a means of sharing and supply can be developed.

5.4.5 Water Recycling from Effluent Treatment Plants

Treatment and use of industrial effluent also takes place in Bangalore and is required under various environmental laws, but the treated wastewater is typically reused on site because of the economic value of water (Kumar, 2013). This form of recycling, though hugely important, is not discussed in detail here because this study focuses on domestic wastewater.

5.4.6 Situation Analysis Summary

A number of wastewater reuse systems are already functioning in Bangalore of which some are formal and some informal providing non-potable domestic water, lake regeneration, groundwater recharge, water for industry and irrigation. Most operate sub-optimally and there is scope to improve the systems or expand the quantity of wastewater used.

5.5 National Stakeholders and Institutional Context

Although the case study was of Bangalore and reuse systems within it, the institutional arrangements cannot be analysed in isolation from the wider context of national level institutions. This section therefore briefly reviews the main government organizations, policies and legislation that operate nationally, including constitutional responsibility for water and wastewater, and other relevant sectors along the sanitation chain - water reuse and environmental legislation, the sanitation sector, agriculture, aquaculture and irrigation. The policy and stakeholder review was far ranging and included other policies and sectors that are not discussed here, for example river management and forestry. This section focuses only on the sectors and government stakeholders found to have direct involvement with wastewater use. The stakeholders discussed in this chapter are depicted in Figure 5-12.

The main policies and pieces of legislation that were identified as relevant to this study, and which are described in more detail below, are provided in Table 5-5. Many more documents that could potentially influence water reuse were reviewed, for example the Inter-State Water Disputes Act, 1956 and the River Boards Act, 1956, but they were deemed to have less of a direct impact than others and have therefore been omitted from the list and analysis.

5.5.1 Constitutional Responsibility for Water and Wastewater

Water and wastewater management in urban areas in India is largely devolved to local government under the 73rd and 74th Amendment to the Constitution, although policies are set at the national level. The constitution defines the organisation, powers and limitations of each level of government and devolves responsibility to the States for local government, agriculture, water (including water supplies, irrigation and canals, drainage and storage), fisheries and industry, among other things.

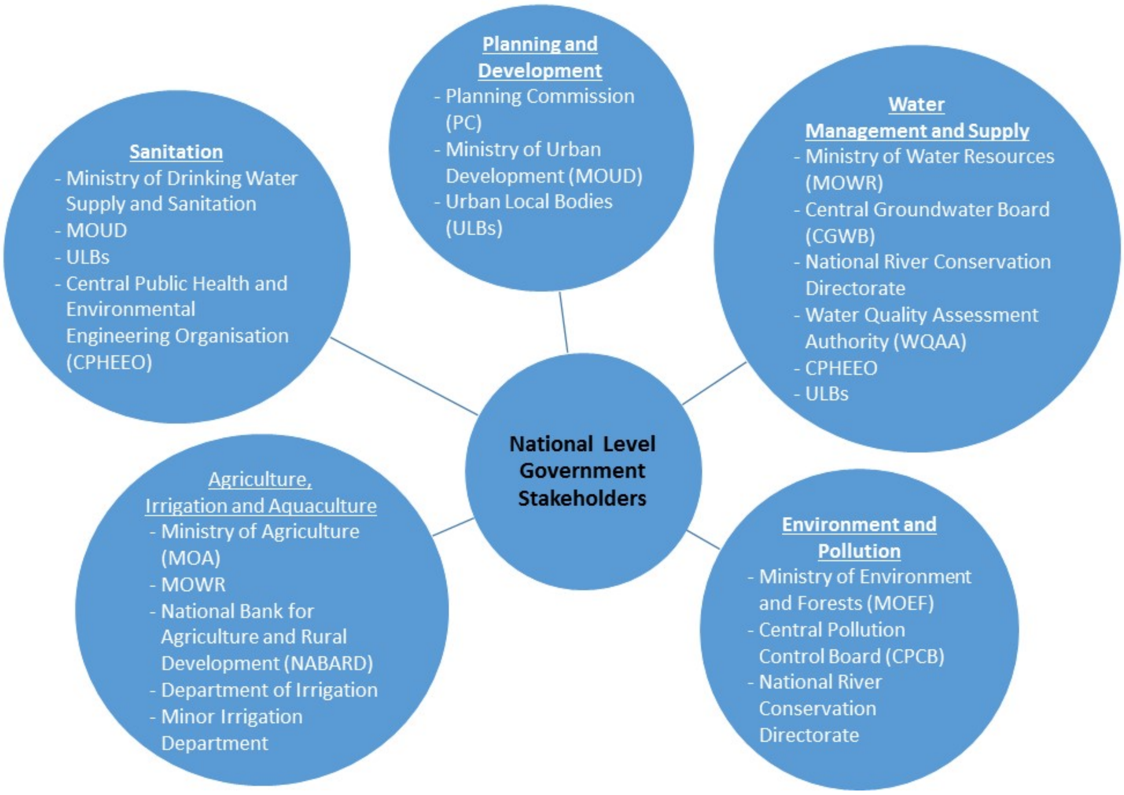


Figure 5-12. Schematic of relevant national government stakeholders
Source: Author (2015)

At national level, the main agencies responsible for water and sanitation are the **Ministry of Water Resources (MOWR)** and the **Central Ground Water Board (CGWB),** a subordinate office of the MOWR. The **Planning Commission (PC)** of the Government of India makes assessment of the country's resources and formulates plans for their effective and balanced utilization (MOEF, 2009; PC, 2009). In rural areas the **Ministry of Drinking Water and Sanitation (MDWS)** has the task of ensuring access to facilities but for urban areas responsibility for sanitation lies with the **Ministry of Urban Development (MOUD)**.

Table 5-5. List of national policies and legislation relating to wastewater use

	WSS	Reuse
National Policies and Plans		
National Urban Sanitation Policy (NUSP), 2008	√	Y
National Water Policy, 2002 and 2012	√	Y
Policy Statement for Abatement of Pollution, 1992	√	S
National Environment Policy, 2006	√	S
National Policy for Farmers, 2007	√	N
National Livestock Policy, 2013		N
Draft National Water Framework Bill, 2013	√	Y
National Legislation		
The Constitution (74th Amendment) Act, 1992	√	S
Water (Prevention and Control of Pollution) Act, 1974, amended 1988	√	S
Water (Prevention and Control of Pollution) Rules, 1975	√	S
The water (Prevention and Control of Pollution) Cess Act, 1977	√	S
Environment (Protection) Act, 1986	√	S
• Environment (Protection) Rules, 1986	√	S
• Municipal Solid Wastes (Management & Handling) Rules, 2000		SW
Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act, 1993	√	N
The Fertilizer (Control) Order, 1985		SW
Fertilizer Control (Amendment) Order, 2003 and 2013.		SW
National Plans, Programmes and Guidance		
PC's Eleventh Five Year Plan	√	Y
National River Conservation Plan (and National Lake Conservation Plan)	√	
Jawaharlal Nehru National Urban Renewal Mission	√	S
The Manual on Sewerage and Sewage Treatment, 1993	√	S
Septage Management in Urban India, 2012	√	Y
Inter-ministerial Task force on Integrated Plant Nutrient Management		SW
National Mission on Sustainable Habitat	√	Y
Guidelines for Intensive Aquaculture in Ponds and Tanks		N
Guidelines for Fisheries Development in Reservoirs (RFD)		N

WSS: Water supply and sanitation. √ = contains elements related to WSS. Y = currently mentions reuse. S = has elements that are potentially supportive of reuse but may not mention it directly. N = does not currently mention reuse but has the potential to do so (i.e. it is relevant to the sector). SW = nutrient recovery from solid waste but does not include faecal sludge.
Source: India Sanitation Portal (2013); CAG (2011); MOEF (2009); MOEF (2003).

The **MOWR** is responsible for planning, policy formulation, coordination and guidance in the water resources sector, including groundwater, minor irrigation, command area development and inter-basin transfers. They also provide infrastructural, technical and research support for sectoral development; give financial assistance; and mediate disputes (MOWR, nd). Their role in relation to wastewater reuse relates predominantly to formulating relevant policies, particularly where reuse would impact on water bodies within a basin (as opposed to recycling on-site), where reuse is for agriculture (e.g. through minor irrigation schemes), and where reuse may result in the need for new sharing agreements (e.g. in water "swops"). Nationally, responsibility of management and development of ground water rests with the CGWB, a subordinate office of the MOWR.

The **Planning Commission**, established in 1950, is tasked with developing long term strategic plans for the country and sectoral targets. It works to develop an *integrated approach to policy formulation*, for example across rural health, drinking water and environmental protection. The PC also plays a mediatory role between the States and Ministries of the Central Government. The aim is efficient utilization of resources through appropriate self-managed organizations (PC, 2009). Their responsibility extends to the allocation of resources to implement the plans, and the monitoring and adjustment of plans as they progress (*ibid*). The Water Management and Irrigation chapter of the PC's Eleventh Five Year Plan calls for the treatment of all municipal wastewater, and recommends the convergence of the management of water, which is currently through a number of Ministries and Departments. The Plan also recommends that attention be given to *"wastewater and sewage treatment and its reuse for non-potable purposes and industries"*, which is currently limited (PC, 2008a; p 402) and advocates recycling and reuse of sewage and industrial effluent after treatment (PC, 2008a, p 404; PC, 2008b, p 177). To achieve this they suggest incentives in the form of a rebate on the water cess (tax), concessions in customs and excise duty on equipment and machinery, and tax holidays for agencies dealing with planning, developing, and operating reuse treatment plants as well as users of treated sewage and trade effluents.

5.5.2 Water Reuse and Environmental Legislation

Wastewater reuse is supported in principle by the **National Water Policy (NWP), 2002,** which advocates recycling and reuse of treated effluents, and non-conventional methods for utilisation of water such as through artificial recharge of groundwater (MOWR, 2002, 3; 6). The **NWP, 2012** (MOWR, 2012, 6), states that "recycle [sic.] and reuse of water, including return flows, should be the general norm", and promotes a properly planned tariff system to incentivize reuse and recycling (**MOWR, 2012**, 7). It also encourages the reuse of primary treated urban effluents from kitchens and bathrooms, in flushing toilets (**MOWR, 2012, 10**).

The **National Environment Policy (NEP), 2006**, makes explicit provision for reuse and recycling of wastewater in its action plan for addressing water pollution, calling for the development of regulatory systems and incentives, and the implementation of reuse and recycling of sewage and wastewater from municipal and industrial sources by public agencies as well as public private partnerships (PPPs) (MOEF, 2006; 38). The policy also supports research and development (R&D) of low cost technologies for sewage treatment, making specific mention of the East Kolkata wetlands as the sort of model to be followed for bio-processing of sewage to yield multiple benefits.

The **Water (Prevention and Control of Pollution) Act, 1974,** amended in 1988, was enacted to restore water quality and address pollution. It established the Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCBs), including KSPCB. The Act lays down a system of consent for the establishment of industries and processes that are likely to discharge sewage or trade effluents. It also controls the construction or alteration of waste outlets (Chapter V, Section 25) and makes everyone responsible for preventing and policing the incorrect disposal of wastewater (Chapter V, Section 24).

The process for consent requires applications to the SPCB and an inspection. The SPCB may grant its consent with certain conditions, such as specification of the point of discharge, or nature, composition, temperature, volume or rate of discharge of the effluent. If consent is not sort and processes are started, the SPCB can apply retrospective conditions (Chapter V, Section 25). The penalty for contravention includes prison terms and fines (Section 43 and 44). The Act, 1974, foresees a balance of strategies to ensure compliance including: education and assistance; monitoring and inspection; communication and outreach. However, according to CAG (2011), there is little evidence of enforcement. This sentiment is echoed by Mukherjee and Chakraborty (2012) who feel that there is no lack of adequate legislation on pollution control in India, just a lack of enforcement.

The **Water (Prevention and Control of Pollution) Cess Act, 1977**, (last amended in 2003) was enacted to provide for the levy and collection of a cess (or tax) from industries and local authorities consuming water (Section 3 (2)). This cess is collected to augment the resources of the CPCB and the SPCBs for the prevention and control of water pollution. Entities that install STPs or ETPs are entitled to a rebate of 25 percent of the cess (Section 7), which provides an incentive for WWT.

The **Environment (Protection) Act, 1986**, provides for the protection and improvement of the environment including water, air and land. The Act is implemented and enforced by the Ministry of Environment and Forests (MOEF) and the CPCB. General measures within the Act include:

- a nation-wide programme for the prevention, control and abatement of pollution;
- standards for emission or discharge of environmental pollutants;
- restrictions on areas in which industries, operations or processes can be carried out;
- safeguards for the prevention of accidents which may cause environmental pollution;
- examination of manufacturing processes, materials and substances that are likely to cause environmental pollution;
- inspection of premises and equipment for the prevention, control and abatement of pollution; and
- preparation of relevant manuals, codes or guides (Article 2).

The Act gives power to persons appointed by the Central Government under the Act to: close, prohibit or regulate any industry, operation or process; and to stop the supply of services (Article 5). The Act also entitles the Central Government to make rules around: quality of air, water or soil for various purposes; and the maximum allowable limits of concentration of a range of environmental pollutants for different areas (Article 6). It also makes provisions for detecting and prosecuting violations including prison and fines.

The **Environment (Protection) Rules, 1986,** were written by the Central Government in accordance with the powers conferred by the Environment (Protection) Act, 1986. The Rules give general standards for discharge of environmental pollutants in effluent (Schedule VI) and for specific industries, operations and processes (Schedule I). The general standards specify the quality of effluents that can be disposed of into inland water bodies, public sewers, irrigated land and coastal waters and include some 39 parameters of which a handful of key parameters are reproduced here (Table 5-6). The Act 1986, also allows for the CPCB or any SPCB to specify more stringent standards for specific industries, operations or processes depending upon the quality of the receiving system (Section 3). Compliance must be achieved within one year or less depending on local conditions.

It is notable that the standards do not include a parameter for microbial quality. It would appear that the Environmental Rules, 1986 did originally contain a figure for FCs, of 1,000 MPN/100ml for inland water and irrigation, and 10,000 for MPN/100ml for public sewers and marine coastal areas. These were, however, omitted by Rule 2(d)(i) of the Environment (Protection) Third Amendment Rules, 1993 vide Notification No. G.S.R. 801(E) dated 31.12.1993. There is also no mention of helminth eggs in the Rules, even for disposal of effluent to land for irrigation.

Table 5-6. Environment (Protection) Rules, 1986, Schedule VI, Selected Discharge Standards

Parameter (mg/l max unless stated otherwise)	Inland surface water	Public sewer	Land for irrigation
Suspended solids	100	600	200
pH (pH units)	5.5-9.0	5.5-9.0	5.5-9.0
Oil and grease	10	20	10
Total residual chlorine	1.0	-	-
Ammonical nitrogen (as N)	50	50	-
Total Kjeldahl Nitrogen (as NH3)	100	-	-
Free ammonia (as NH3)	5.0	-	-
Biochemical Oxygen Demand (BOD) [3 days at 27^{o}C]	30	350	100
Chemical Oxygen Demand (COD)	250	-	-
Dissolved Phosphates (as P)	5.0	-	-

Source: MOEF, 1986

In addition to effluent standards, the CPCB also utilizes the concept of 'designated best use' to manage water quality (Annex 5). Under this system, the quality of any water body should be at the highest level for the designated uses, which are:

A. Drinking Water Source without conventional treatment but after disinfection
B. Outdoor bathing (Organised)
C. Drinking water source after conventional treatment and disinfection
D. Propagation of Wild life and Fisheries
E. Irrigation, Industrial Cooling, Controlled Waste disposal (MOUD and JICA, 2013a).

Other standards exist, such as those published by The Bureau of Indian Standards, which recommends water quality parameters for different uses in the standard IS 2296:1992 (Annex 6); and guidelines are available to evaluate the quality of water for irrigation, which can be classified in five classes depending upon its chemical properties (sodium, SAR, EC, RSC) (Annex 7).

The prevention of water pollution is the responsibility of the **MOEF** and the **CPCB**, which is a statutory organisation under the MOEF. The Ministry coordinates India's environmental policies and programmes. Their focus includes conservation of natural resources including lakes, rivers and biodiversity, and the prevention and abatement of pollution. The MOEF's objectives are supported by a set of legislative and regulatory measures including the Environment Protection Act, 1986; the Water (Prevention and Control of Pollution) Act, 1974; the Water Cess Act, 1977; the Air (Prevention and Control of Pollution) Act, 1981; the National Conservation Strategy and Policy Statement on Environment and Development, 1992 (MOEF, 1992a); Policy Statement on Abatement of Pollution, 1992 (MOEF, 1992b); and the National Environment Policy, 2006 (MOEF, 2013; MOEF, 2006).

The MOEF's Pollution Control Division handles matters connected with the CPCB; litigation and court cases relating to environmental acts; bilateral programmes and projects on pollution control; reimbursement of Cess proceeds to SPCBs; water quality monitoring; and all matters relating to pollution of rivers which are not covered under the National River Conservation Programme (NRCP) (MOEF, 2013).

The **CPCB** was constituted under the Water (Prevention and Control of Pollution) Act, 1974 and entrusted with the powers under the Environment (Protection) Act, 1986. The CPCB is mandated to advise Central Government on environmental matters and to support and guide SPCBs in the task of implementing environmental legislation and monitoring compliance with standards specified in the Environment Protection Rules and Act (MOEF, 2000). The CPCB must also instigate a nation-wide programme for the prevention, control or abatement of pollution; co-ordinate the activities of the SPCBs and resolve disputes; raise mass awareness of pollution issues; collect and publish pollution data; and set quality standards for water bodies (CPCB, 2008).

The **National River Conservation Directorate**, also under the MOEF, is implementing the Centrally Sponsored Schemes of the National River Conservation Plan and National Plan for Conservation of Aquatic Eco-systems for conservation of rivers, lakes and wetlands in the country. Their work includes pollution prevention and abatement, including sewage treatment, and water body conservation. This is achieved through the implementation of sustainable conservation plans, and governed with application of uniform policy and guidelines (MoEFCC, 2016).

The **Water Quality Assessment Authority (WQAA),** constituted in 2001 is tasked, under Section 5 of the Environment (Protection) Act 1986, with various aspects of wastewater management, treatment and reuse, and directing government agencies in:

- standard methods for water quality monitoring;
- ensuring the proper treatment of wastewater to restore the water quality of water bodies to meet the designated-best-uses;
- promotion of recycling and reuse of treated sewage and trade effluent for irrigation;
- maintaining minimum discharge for sustenance of aquatic life forms in riverine systems;

- utilizing self-assimilation in critical river stretches to minimize the cost of effluent treatment;
- providing information to pollution control authorities to facilitate allocation of waste loads;
- reviewing the quality of national water resources and identifying "Hot Spots" for improvement in water quality; and
- interacting with relevant authorities under the Environment (Protection) Act, 1986 for matters relating to management of water resources.

WQAA has also been corresponding with the National Environmental Engineering Institute (NEERI) on a 'Desk Study on Artificial Recharge to Groundwater by Treated Wastewater through Soil Aquifer Treatment' (MOWR, 2015)

5.5.3 Sanitation

In addition to wastewater management and environmental pollution, the MOUD has fairly recently published the **National Urban Sanitation Policy (NUSP), 2008**. This focuses specifically on the management of human excreta and associated public health and environmental impacts, although the policy acknowledges the need for an integrated solution that takes account of solid, industrial and hazardous waste, drainage and drinking water supply (NUSP, 2008). The policy was approved in 2008 and in 2009 the 1st Round National Rating of 423 cities was undertaken and State sanitation strategies and city sanitation plans were developed.

The NUSP's vision is that through affordable sanitation, all Indian cities become sanitized, healthy and liveable. It aims to target behaviour change and to introduce total sanitation with safe disposal and no open defecation (Gayathri, 2013). This is currently a long way from being reality: great strides have been made in the provision of toilet facilities but much less progress has been made in waste conveyance and treatment, with just 37 percent of the excreta generated in urban India being safely disposed of (MOUD, 2008; WGUIWSS, 2012).

Key policy areas that the NUSP believes need addressing are:

- **Poor Awareness**: previously low priority; inadequate understanding of health links.
- **Occupational Hazards**: little attention paid to hazards faced by sanitation workers.
- **Fragmented Institutional Roles and Responsibilities**: gaps and overlaps at all levels.
- **Lack of an Integrated City-wide Approach**: piece-meal planning, no account taken of the full cycle of safe confinement, treatment and safe disposal.
- **Limited Technology Choices**: limited options, not cost-effective, questionable sustainability.

- **Reaching the Un-served and the Poor**: constrained by tenure, space or economics. Individual toilet provision should be prioritised.
- **Lack of Demand Responsiveness**: sanitation provided by public agencies in a supply-driven manner, with little regard for demands and preferences of households.

Several of these aspects have a bearing on reuse. A policy goal is the sanitary and safe disposal of 100 percent of human excreta and liquid wastes from all sanitation facilities through the proper functioning of network based sewers, the proper disposal and treatment of sludge, and the recycling and reuse of treated wastewater for non-potable applications wherever possible (MOUD, 2008).

Implementation at the state and city level is through State Level Sanitation Strategies and City Sanitation Plans. The NUSP gives the States freedom to make use of existing provisions in municipal and other Acts; amend municipal Acts and frame relevant bye-laws and regulations, such as building and construction codes; create their own system of incentives, charges and punitive actions; and promote partnerships with public, private and NGO agencies for provision, management and maintenance of sanitation facilities (MOUD, 2008).

Although financing for Sanitation Strategies and Plans is not certain, the National Government has schemes that can be made use of such as the MOUD's **Jawaharlal Nehru National Urban Renewal Mission (JNNURM) Urban Infrastructure and Governance (UIG)** component, and the **Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT)**. These have a time span of 7 years (2005-12) with a budget of INRS 1,000,000 million (USD 15,323 million) of which the share of the central government is INRS 500,000 million (USD 7,660 million). At present some 122 sewerage and 39 storm water drainage project have been funded under the JNNURM of which 35 and 29 have been completed respectively (JNNURM, 2014). The policy, however, stresses that the emphasis will be on improving the efficiency of existing sanitation infrastructure and service delivery (MOUD, 2008).

Responsibility for Sanitation Plans lies with the ULBs although involvement is also required from the SPCBs, who set discharge standards, the State Health Departments who define public health outcomes, public health engineering departments (PHEDs) and parastatals who are responsible for sanitation management processes and infrastructure, and urban development departments who ensure service delivery standards (NUSP, 2008). To date only five Sanitation Plans have been published and there is no publically available plan for Bangalore (SSWM, nd).

The **Manual Scavengers and Construction of Dry Toilets (Prohibition) Act, 1993** prohibits the employment of a person to manually carry human excreta or to construct or maintain a dry latrine (GOI, 1993). The Act does not specifically cover septic tanks and sewers, although it is implied, and the MOUD in its Advisory Note on Septage Management in Urban India, under the NUSP, recommends that cleaning of septic tanks and sewers needs to be carried out using mechanical devices that obviates the need for manual scavenging (MOUD, 2013). Unfortunately the National Advisory Council (2011) believes that the practice of manual scavenging is still common practice.

The NUSP was developed by the **MOUD,** the apex body for urban development, which is assigned the business of water supply, sewage, drainage and sanitation relating to urban areas under the Government of India (Allocation of Business) Rules, 1961 (Chatri and Azia, 2012; MOUD, 2013). The **Central Public Health and Environmental Engineering Organisation (CPHEEO)** is the Technical Wing of the MOUD and develops policies, strategies and guidelines on WSS which it provides to the State Governments and Municipal Corporations. The CPHEEO plays a vital role in processing schemes proposed for external funding agencies and institutional financing. It acts as an advisory body at Central level for the State agencies and ULBs in implementation, O&M of urban WSS projects and helps them to adopt the latest technologies in these sectors. They also provide training to Public Health Engineers. In collaboration with the United Nations Development Programme (UNDP) and the Japan International Cooperation Agency (JICA), CPHEEO has published: the Manual on Water Supply and Treatment, Third Edition, 1999 ; the Manual on Sewerage and Sewage Treatment, Third Edition, 2013; and the Manual on Operation and Maintenance of Water Supply Systems, 2005 (CPHEEO, nd). They are intended to provide guidance to Public Health Engineering Departments, Water Boards and municipal bodies on basic norms, standards and developments in the field (CPHEEO, 1999). They are widely used but are not legally binding.

5.5.4 Agriculture, Aquaculture and Irrigation

Agriculture, aquaculture, irrigation and fertilizer policies and legislation predominantly focus on increasing productivity and efficiency, supporting rural communities, poverty reduction and fertilizer regulation. Elements of agricultural policy cover the use of unconventional water but this is only a small part and there is no explicit mention of wastewater use. If anything, the emphasis on the quality and safety of agricultural products restricts the scope for wastewater use. There is a call in the **National Policy for Farmers, 2007**, for integrated water management, which could potentially open up the discussion for the inclusion of wastewater, but as yet that is not even mooted.

The **National Policy for Farmers, 2007** encourages the use of organic manure and production of bio-fertilizers to improve soil health but does not mention human excreta. It also states that water quality needs to be addressed, and recommends water harvesting, aquifer recharge and water use efficiency, but does not mention wastewater use. It supports inland aquaculture by providing space for ponds but makes no mention of recycled water being utilized for this purpose. The **National Livestock Policy, 2013** covers improved animal husbandry practices, management of manure through composting and biogas and the establishment of stakeholder steering committees (DADF, 2013). There is no evidence as to whether the use of wastewater for fodder production is supported or not as there is no mention of it in the policy. The **Guidelines for Intensive Aquaculture in Ponds and Tanks** (NFDB, nd, a) provides for financial support to farmers interested in investing in intensive aquaculture in existing and new ponds and tanks. No mention is made of water quality. The **Guidelines for Fisheries Development in Reservoirs** (NFDB, nd, b) do not mention water quality either. The **State Government (Department of Fisheries)** is the main agency for implementation of the **Reservoir Fisheries Development Programme**, identifying reservoirs, leasing the reservoirs and monitoring. They retain 75 percent of the income and the remainder is given to the **National Fisheries Development Board** (NFDB, nd, b).

Irrigation is a state subject and only overseen at the national level through the policy formulation of the **Ministry of Water Resource (MOWR).** Elements of the Water Policy, the Water (Prevention and Control of Pollution) Act, 1974 and the Environment (Protection) Rules, 1986 are relevant to irrigation, particularly effluent discharge standards which were discussed previously. Key elements are that the **Water (Prevention and Control of Pollution) Act, 1974** prevents the discharge of sewage or effluent in excess of standards into open water bodies, groundwater and onto land, which implies that wastewater irrigation is forbidden. The **Environment (Protection) Rules, 1986,** specify the quality of effluents that can be disposed to inland water bodies, public sewers, land for irrigation and coastal waters and allows for the CPCB or any SPCB to specify more stringent standards for certain receiving waters. The **National Water Policy (NWP), 2012,** emphasises better demand management, water use efficiency and improved water application but makes no mention of the use of recycled or non-conventional water for irrigation. **The Draft National Water Framework Bill, 2013** establishes governing principles for protection, conservation and regulation of waters and the preservation of water quality includeing 'recovering, to the extent possible, water for some uses from waste'.

The policies and legislation around fertilizer management were reviewed because of the nutrient content of wastewater and the possibility of businesses that combine wastewater recycling and the sale or use of faecal sludge from septic tanks or sewage sludge from STPs. There are several pieces of fertilizer legislation but none appears to cover manure from sanitary waste. The focus is mainly on ensuring fair prices and quality, and covers business registration, marketing and quality specifications as set out in the **Fertilizer (Control) Order (FCO) 1985** and **Fertiliser (Control) Amendment Order, 2003**. The FCO covers organic fertilizer, manure, compost from city waste and vermicompost but organic manure is not a large part of the legislation. The promotion of organic fertilizer is largely the domain of agriculture policy. In 2013, the **Fertiliser Control (Amendment) Order** was passed, altering specifications for the content of organic fertilizers and organic manure. It stipulates that the source of organic manure is any plant biomass, animal biomass or animal excreta, but human excreta is not listed. The **Inter-ministerial Task Force on Integrated Plant Nutrient Management,** of the MOUD and Ministry of Agriculture (MOA), suggests incentives for composting, based on the recommendation by the Indian Council of Agricultural Research (ICAR) that the bio-degradable portion of city garbage should be converted to compost but, similarly to the FCO and Amendment Order, 2013, it does not include human excreta (MOUD, 2005).

Responsibility for all aspects of agriculture in India is that of the **Ministry of Agriculture (MOA)**, which consists of the three departments: the **Department of Agriculture and Co-operation (DAC);** the **Department of Agricultural Research and Education (DARE)**; and the **Department of Animal Husbandry Dairying and Fisheries (DADF)** (previously the Department of Animal Husbandry and Dairying (DAH&D)).

The **DAC's** role includes all agricultural matters as long as it does not impinge on the role of DARE. This includes development of fertilizer and other agricultural industries, extension and education, on-farm water management, supporting agricultural marketing, soil conservation schemes and administration of the Fertilizer Control Order (FCO), 1985 (DAC, 2014; DAC, 2012). The **DAC** is also responsible for supporting State extension programmes, and working with farmers, NGOs, and other stakeholders operating at district level and below. They run a number of programmes on soil health and organic farming, providing support for expansion of organic fertilizer production and use, and including subsidies through the **National Bank for Agriculture and Rural Development (NBARD)** (DAC, 2014; DAC, 2012).

Livestock development really falls to the States but the Central Government supports their efforts through the **DADF**. The **National Fisheries Development Board (NFDB)** within DADF, is tasked with developing aquaculture including the use of less utilized water resources (NFDB, 2007).

5.5.5 Summary of National Institutional Context

Several ministries are responsible for various aspects of water and sanitation but at different scales or locations, for example the MOWR coordinates basin-level water management while other ministries are responsible for rural or urban WSS (MDWS and MOUD). Their role is limited to policy formulation, planning and budget allocation while responsibility for implementation is devolved to ULBs. The MOWR and the PC support the notion of wastewater reuse and recommend various incentives.

Several national policies are relevant to wastewater use (Table 5-5) but two are critical in that they explicitly support wastewater use, these are: the National Water Policy 2002 and 2012; and the National Environment Policy, 2006. In addition, the MOUD's National Mission on Sustainable Habitat, 2010, explicitly endorses wastewater use after treatment for various uses, including groundwater recharge, and proposes the introduction of more sewage treatment and reuse demonstration projects as well as community systems. By contrast, the policies around agriculture, livestock and fisheries do not make mention of wastewater reuse or recycling, although they are supportive of IWRM and water use efficiency. Some legislation, such as the Water (Prevention and Control of Pollution) Act, 1974 prevent the discharge of sewage in excess of standards to water bodies and land, and therefore effectively prevents the use of untreated wastewater in agriculture or aquaculture but do not forbid reuse after adequate treatment. These policies and elements of relevance to RRR are given in Table 5-7.

Table 5-7. Water and wastewater related policy

Policy/legislation and main feature	Selected elements relevant to RRR
National Water Policy (NWP), 2002 *Supports recycling and reuse*	• Supports recycling and re-use of treated effluents (MOWR, 2002, 3; 6). • States that "effluents should be treated to acceptable levels and standards before discharging them into natural streams" (p. 7). • Advocates the polluter pays principle (p. 7). • Is supportive of private sector involvement (p. 7). • Seeks greater understanding and knowledge of recycling and reuse (p. 8).
National Water Policy (NWP), 2012	• States that "recycle [sic.] and reuse of water, including return flows, should be the … norm" (MOWR, 2012, 6). • Advocates a properly planned tariff system to incentivize reuse and recycling (p. 7).

Policy/legislation and main feature	**Selected elements relevant to RRR**
Supports recycling and reuse	Provides for “the use of economic incentives and penalties to reduce pollution and wastage” (p. 3). • Encourages the reuse of urban water effluents from kitchens and bathrooms, after primary treatment, in flush toilets (p. 10). • Aims to combine water supply bills and sewerage charges, and to integrate water supply and sewage treatment schemes (p. 10). • Places water for sanitation as a top priority along with drinking water. • Provides for third party inspection and punitive measures (p. 8).
National Environment Policy (NEP), 2006 *Endorses treatment and use of wastewater and low cost technologies for treatment and multiple reuse benefits (*MOEF, 2006)	• “Prepare and implement action plans for major cities for addressing water pollution, comprising regulatory systems relying on an appropriate combination of fiats and incentive based instruments, projects implemented through public agencies as well as public-private partnerships for treatment, reuse and recycle [sic] …, of sewage and wastewater from municipal and industrial sources, before discharge to water bodies” (MOEF, 2006; p. 38). • Support for research and development of low cost technologies for sewage treatment e.g. East Kolkata wetlands as a model for bio-processing of sewage for multiple benefits. • Development of PPP models for wastewater treatment. • Enhancing the capacities of municipal authorities for recovery of user charges. • Takes explicit account of groundwater pollution in pricing of agricultural inputs.
Water (Prevention and Control of Pollution) Act, 1974, amended in 1988 *Creates an enabling environment for wastewater treatment (WWT) and RRR*	• Establishes the Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCBs). • Lays down a system of consent whereby no industry, process, treatment, or disposal system that is likely to result in the discharge of sewage or effluent into a stream, well, sewer or onto land, can be established or extended without the consent of the SPCB. • Makes provisions for regulating all new or altered discharge outlets (Chapter V, Section 25, 26). • Prohibits discharges in excess of standards (Chapter V, Section 24). • Stipulates penalties for violations including fines and prison terms (Chapter V, Section 43 and 44).
The **Water (Prevention and Control of Pollution) Cess Act, 1977**, last amended in 2003	• Provides for the levy and collection of a cess on water consumed by specified industrial activities and every local authority (Section 3 (2)). • Augments the resources of the CPCB and the SPCBs. • A 25% rebate is offered as an incentive for WWT (Section 7).
The **Environment (Protection) Act, 1986** *Regulates emissions*	• Provides for the protection and improvement of the environment including water, air and land. • Lays down standards for emission from various sources. “Chapter III: Prevention, Control and Abatement of Environmental Pollution” is “that no person carrying on any industry, operation or process shall discharge or emit or permit to be discharged or emitted any environmental pollutant in excess of such standards as may be prescribed” (Article 7). • Requires the preparation of manuals, codes and guides on pollution prevention

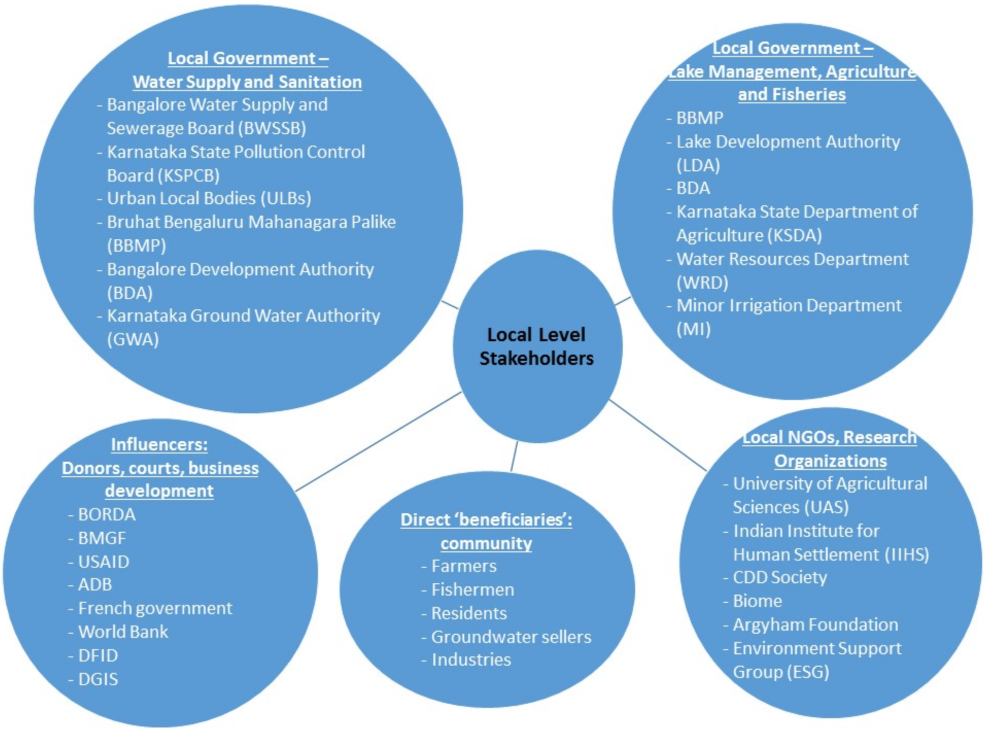
Policy/legislation and main feature	Selected elements relevant to RRR
	and abatement (Article 2). • Gives power to Central Government appointees to close, prohibit or regulate violators (Article 5).
The **Environment (Protection) Rules, 1986** *Sets discharge standards*	• Gives general standards for discharge of environmental pollutants for effluents (Annex VI) and wastewater generation standards for specific industries (Annex VII), which specify the quality of effluents that can be disposed to inland water bodies, public sewers, land for irrigation and coastal waters. The standards include some 39 parameters, see Annex 6 for a subset of these. • Allows for the CPCB or any SPCB to specify more stringent standards for certain processes or receiving waters after recording reasons for these standards in writing (Section 3).
National Urban Sanitation Policy (NUSP), 2008 *Focuses on the management of human excreta and associated public health and environmental impacts. Supports reuse of treated wastewater.*	• Vision - "All Indian cities and towns become totally sanitized, healthy and liveable and ensure and sustain good public health and environmental outcomes for all their citizens ....". • Goals are to: target behaviour change; achieve open defecation free cities; achieve total sanitation with safe disposal of 100% human and liquid waste; and the development of state sanitation strategies and city sanitation plans for every state (Gayathri, 2013). • A specific policy goal is the sanitary and safe disposal of 100 % of human excreta and liquid wastes from all sanitation facilities through the proper functioning of network based sewers, the proper disposal and treatment of sludge and the recycling and reuse of treated wastewater for non-potable applications wherever possible. • Implementation is through State Level Sanitation Strategies and City Sanitation Plans (CSPs). States are free to make use of existing provisions in municipal Acts or to amend them and frame relevant bye-laws and regulations, such as building and construction codes (NUSP, 2008). • Financing is uncertain but schemes exist that can be tapped into.
"Septage[10] Management in Urban India", 2012 (WSP, 2012) *Supports implementation of the NUSP.*	• Notes that institutional mechanisms for inspection, monitoring, and other regulatory measures are non-existent, or not effectively enforced (Water and Sanitation Programme, 2012, 9) • Advises ULBs to formulate their own bye-laws and rules for management of septage (p 23). • Suggests that long term plans should consider PPPs for both collection and treatment. Recommends using composted SS as a soil amendment to reclaim land, for landscaping or horticulture. • SS for agriculture or use that may involve human contact (e.g. at parks or playgrounds) is only recommended after analysis. SS must conform to USEPA standards and SS and wastewater to WHO (2006b) guidelines.
The **Manual on Sewerage and**	Makes reference to relevant Indian Standards and Codes of Practice notified by the Bureau of Indian Standards. These take the form of recommendations. The most

[10] Septage here refers here broadly to not only faecal sludge removed from septic tanks but also that removed from pit latrines and similar on-site toilets (Water and Sanitation Programme, 2012).

Policy/legislation and main feature	Selected elements relevant to RRR
Sewage Treatment (1993) *Supports implementation of the NUSP and provides guidance for engineers.*	relevant include the following: • IS 1172:1993 – Basic requirements for water supply, drainage, and sanitation. • IS 12314:1987 – Code of Practice (COP) for sanitation with leach pits for rural communities. • IS 2470 (Part 1):1985 – COP for installation of septic tank: design criteria and construction. • IS 2470 (Part 2):1985 – COP for installation of septic tank: secondary treatment and disposal of septic tank effluent. • IS 5611:1987 – Code of Practice for facultative waste stabilization ponds. • IS 10261:1982 – Requirements for settling tanks for WWT. • IS 13496:1992 – General requirements for suction machines for cleaning sewers, manholes and so on (Water and Sanitation Programme, 2008) • Currently this manual is under revision and provides guidelines on construction of septic tanks, and brief guidelines on septage management. Advisory note on septage management in urban India (2013) provides strategies and guidelines for the national level septage management. Some of the states have already developed septage management guidelines for the state. This national advisory note is currently being revised to incorporate reuse. • Advisory note on reuse of treated wastewater is also being developed
The PC's Eleventh Five Year Plan, Water Management and Irrigation Chapter	• Calls for: treatment of all municipal wastewater; the convergence of the management of water; attention be given to *"wastewater and sewage treatment and its reuse for non-potable purposes and industries"*, which is currently limited (PC, 2008a; p 402); recycling and reuse of sewage and industrial effluent after treatment (PC, 2008a, p 404; PC, 2008b, p 177). • Suggests incentives in the form of a rebate on the water cess, concessions in customs and excise duty on equipment, and tax holidays for agencies planning, developing, and operating reuse wastewater treatment plants (WWTPs) and users of treated sewage and trade effluents.
Manual Scavengers and Construction of Dry Toilets (Prohibition) Act 1993 *May support FS extraction and use.*	• No person shall: (a) engage in or employ another person to manually carry human excreta; or (b) Construct or maintain a dry latrine (GOI, 1993). • Those who violate the Act will be punished and people previously employed in this way must be supported to find alternative employment. • The definition of manual scavenging as per the Act, 1993 does not specifically cover manual cleaning of septic tanks and sewers, though it is implied, and the Ministry of Urban Development (MOUD) in its Advisory Note on Septage Management in Urban India, under the NUSP, recommends that cleaning of septic tanks and sewers needs to be carried out using mechanical devices that obviates the need for manual scavenging (MOUD, 2013). • National Advisory Council (2011) suggests that the practice of manual scavenging is still common practice.

5.6 Karnataka State and Bangalore Institutional Context

Based on the waste streams and reuse case studies outlined in section 5.3, a stakeholder analysis was performed and all stakeholders identified (see Figure 5-13), combining consideration of their structure, roles and effectiveness, and the policies and legislation that are relevant to them in the context of WWTU. The stakeholders are grouped and a summary of the stakeholders in each group is provided at the end of the relevant sub-sections. An overall summary of the stakeholders is given in Annex 8. A list of the relevant local level policies and legislation is provided for easy reference in



(Table 5-8).

Figure 5-13. Local level stakeholders
Source: Author (2015)

Table 5-8. List of state and municipal policies and legislation relating to reuse

	WSS	Reuse
State Policies, Laws and Strategies		
State Water Policy, 2002	√	N
Notification_05122015_4975 Directions Under Section 33(A) of the Water (Prevention & Control of Pollution) Act, 1974 regarding treatment and utilization of sewage	√	Y
Karnataka Urban Drinking Water and Sanitation Policy , 2003	√	N
Karnataka Municipal Corporation Act, 1976	-	-
Karnataka Municipalities Act, 1964	√	-
Karnataka Urban Water Supply and Drainage Board Act, 1973	√	N
Karnataka Ground Water (Regulation and Control of Development and Management) Act, 2011	√	-
Karnataka Town and Country Planning Act, 1961	√	-
Integrated Agribusiness Development Policy, 2011	√	Y
Karnataka Agricultural Policy, 2006	√	Y
City Legislation and Plans		
The Bangalore Development Authority Act, 1976	√	-
Bangalore Master Plan, 2015 (2007)	√	-
Bangalore Water Supply and Sewerage Act, 1964	√	-
The Bangalore Water Supply (Amendment) Regulations, 2012	√	Y*
The Bangalore Sewerage (Amendment) Regulations, 2012	√	N**

Note: many of these Acts have been updated several times. Y = currently mentions reuse. S = has elements that are supportive of reuse but may not mention reuse directly. N = does not currently mention reuse but has the potential to do so. *Supports reuse of treated wastewater for non-potable purposes. **Prohibits irrigation with effluent.

Source: Directorate of Town and Country Planning (2015); India Sanitation Portal (2013); CAG (2011); MOEF (2009); MOEF (2003); WRD (2002)

5.6.1 Local Government

5.6.1.1 Urban Planning and Management

Local government comprises various categories of **Urban Local Bodies (ULBs)** established under the Constitution of India. The categories of ULBs range from City Corporations for urban areas with populations of over 300,000 to Town Panchayats for populations of 10,000-20,000. The number and type of each in Karnataka is given in Table 5-9.

Table 5-9. Urban local body categories and numbers of each in Karnataka

Classification	Population of Urban Area	Number in Karnataka
City Corporations	300,000 and above	8*
City Municipal Councils	50,000 to 300,000	43
Town Municipal Councils	20,000 to 50,000	94
Town Panchayat	10,000 to 20,000	68
Notified Area Committees		6

*Includes the BBMP.

Source: DAM (2014); UDD (2011)

The ULBs are made responsible for such things as urban planning; regulation of land-use and construction of buildings; water supply; public health and sanitation; urban forestry and protection of the environment; slum improvement; urban poverty alleviation; urban amenities (parks, gardens, playgrounds, public conveniences); and regulation of slaughter houses and tanneries (GOI, 1992). In addition, the ULBs have a number of obligatory, special and discretionary functions which include: cleaning public places and sewers; constructing and maintaining urban infrastructure such as latrines, privies, urinals, drains, sewers, drainage works, sewage works, washing places, drinking fountains, tanks, wells and dams; obtaining a proper and sufficient supply of water to prevent danger to health; vaccinations; providing receptacles for removal of night-soil; prevention of epidemics, promotion of public health, and WSS beyond the limits of the municipality (DMA, 2014). In Karnataka the Municipal bodies are governed by the Karnataka Municipalities Act, 1964 and the Karnataka Municipal Corporation Act, 1976.

The **Karnataka Municipalities Act, 1964** is for City Municipalities, Town Municipalities and Town Panchayats and sets out the obligatory functions of the Municipal Council. It includes provision of water supply for domestic, industrial and commercial purposes; maintenance of drains and sewage disposal; and responsibility for public health, sanitation, solid waste management and fire services. Specific guidelines for the implementation of these functions are not present within the Act (EMPRI, 2003).

The Karnataka Municipal Corporation Act, 1976, gives authority to the **Bruhat Bengaluru Mahanagara Palike (BBMP)**, the administrative body responsible for the civic and infrastructural assets of the Greater Bangalore Metropolitan Area. The BBMP comprises the Executive Council, with an appointed Commissioner and Joint Commissioners for each of the eight administrative zones; and the Legislative Council with an elected Mayor and 198 Corporators (council members), one for each ward (Shankar and Yathish, 2012). The BBMP is responsible for, among other things: approving building construction plans and giving completion certificates; cleaning of public streets and areas; collection, removal, treatment and disposal of sewage and solid waste; construction, maintenance and cleaning of drains, public toilets and other similar facilities; and the "preparation of compost" from sewage and solid waste (Karnataka Municipal Corporation Act, 1976). On paper, many urban functions are the responsibility of city government, as per the 12th Schedule of the Constitution but in practice decentralization has been slow (Connors, 2005) and many of their mandated function out are in fact implemented by '*certain semi-autonomous corporations and parastatal agencies which are not accountable to the local government'* (Idiculla, 2015).

The **Bangalore Development Authority (BDA)** is the principal planning authority in the BMA. It is a regulatory body required to prepare and oversee a "Comprehensive Development Plan" (CDP), as well as WSS planning, and land-use plans and allocation (BDA, nd). Their mission is to "Plan, regulate, control, monitor and facilitate urban development in … BMA, to ensure sustainable and orderly growth" (BDA, nd). No authority or person may undertake development within the BMA without the permission of the BDA. They have a Land Acquisition Department, a Town Planning Department and an Engineering Department. The BDA is required to plan sites for the processing of solid waste, and has initiated a number of "Eco-commitment projects" including lake restoration work of which two, in Lalbagh Park and Cubbon Park, include WWTU for irrigation of the parks.

5.6.1.2 Municipal Wastewater Management and Treatment

Responsibility for providing adequate water supplies to urban domestic and commercial customers within the BMA and for making suitable arrangements for the safe transport and disposal of sewage and faecal sludge lies with the BWSSB (Kelkar et al., 2012), however it is not responsible for urban drainage, which falls to the BDA.

The BWSSB was created in 1964, at the request of the World Bank, to manage the CWSS on a commercial basis and, under the Bangalore Water Supply and Sewerage Act, 1964, it took over responsibility for water and sewerage provision from the Bangalore City Corporation (BWSSB, 2013; Smitha, 2002) as well as treatment, which was introduced in 1964 (BWSSB, 2013). The BWSSB has full responsibility for 'all public sewers, all sewers in, alongside or under any public street within the BMA, and all sewage disposal works (GOK, 1964, p. 28).

The BWSSB is responsible for giving permission to connect to the sewers to all households and bulk water users (e.g. apartments) within the BMA, that are not generating trade effluent. The users, under the Bangalore Water Supply and Sewerage Act, 1964, have the responsibly to apply to connect. They must adhere to the terms and conditions set by BWSSB (GOK, 1964, Chapter V). Details of requirements for water and sewerage users and disposal rates are given in The Bangalore Sewerage (Amendment) Regulations, 2012 (BWSSB, 2012b), which updates the Bangalore Sewerage Regulations, 1974. The rates for disposal vary according to the size of the premises and whether they receive a BWSSB water supply (Annex 9).

Despite regulations the reality is that only 45 percent of the population of Bangalore is connected to sewers, which covers just 40 percent of the BMR (CAG, 2011, relayed in the Daily News and Analysis (DNA) on Tuesday 15th March 2011)[11]. In theory this should increase with the recent publication of the **Notification_05122015_4975 Directions under Section 33 (A) of the Water (Prevention & Control of Pollution) Act, 1974 Regarding Treatment and Utilization of Sewage**, which makes it mandatory for all local authorities to set up sewage collection and treatment systems (KSPCB, 2015).

Currently, only 47 percent of the sewage generated reaches a treatment plant (CSE, 2012b). Kelkar and Thippeswamy (2012) identify 12 STPs in Bangalore (not including Cubbon Park and Lalbagh Park) with a total treatment capacity of 718 MLD, which is twice the quantity of wastewater actually treated (350 MLD). They calculated that a similar quantity (346 MLD) flows untreated to the valleys and waterways (Table 5-10).

Table 5-10. Summary of wastewater treatment capacity and reuse in Bangalore

Number of treatment plants	12*
Total installed capacity	718 MLD
Quantity treated	350 MLD
Treated effluent flowing into valleys	346 MLD

*Does not include the treatment plants in Cubbon Park and Lalbagh Park

Source: Kelkar and Thippeswamy (2012)

The BWSSB does, however, have a number of reuse STPs (as discussed in the previous section) and is motivated to undertake reuse because of the increasing difficulty and cost associated with providing fresh water to the urban population, especially given the expansion of the city and the growth in industrial zones that are not served by the current water distribution network. The BWSSB reports that the cost of water supply is approximately 16 INR/kilo litre (although experts estimate it to be

[11] http://www.dnaindia.com/bangalore/report_over-half-of-bangalore-s-sewage-flows-into-storm-water-drains-lakes-report_1520311

more like 85 INR/KL)[12] (BWSSB, 2013; Vishvanath, 2014). This is substantially more than the cost paid by consumers which, since the increase in 2013, ranges from 7-45 INR/KL (previously 6-36 INR/KL) for domestic consumers and 50-87 INR/KL (previously 36-60 INR/KL) for non-domestic consumers (BWSSB, 2014; Meera, 2014). Although the total cost of providing treated wastewater could not be established, BWSSB sources state that it is much lower than the cost of providing fresh water from the CWSS. It has been estimated that the cost of treating the wastewater is around 10-12 INR/KL (~0.25 USD/KL) (Kumar, 2011; cited in CSE, 2012b). The revenue derived by BWSSB from the sale of treated wastewater is estimated to be around 4 million INR/KL (65,600 USD/KL) per year, which should stimulate further investment (Ravindra, 2013). Such an income would be important because BWSSB derives all its annual revenues from water tariffs which are politically determined and remained unchanged from 2005 to 2013. This created a major financial shortfall. Vishvanath (2014) estimates that BWSSB's costs are more than INRS 800 million (USD 12.15 million) a month while its revenues are barely INR 500 million (USD 7.59 million).

Water reclamation and reuse is firmly on the current agenda of the BWSSB, as can be seen in The Bangalore Water Supply (Amendment) Regulations, 2012 (BWSSB, 2012a) and in recent projects which show that the BWSSB is seeking novel ways of augmenting water supply. For this purpose they have established the New Initiatives Division. Under the projects designed to supply treated water to industries the BWSSB build and operate the STPs or they contract out the operation to management companies. The industries pay to receive a regular supply of treated water of adequate quality for their purposes at a cost that reflects the level of infrastructure provided. The cost to industries if secondary treated water is supplied by tanker is 10 INR/KL (0.16 USD/KL) or 15 INR/KL (0.25 USD/KL) if supplied by pipe. The latter requires industries to bear the cost of pipeline construction. Tertiary treated water costs 15 INR/KL (0.25 USD/KL) and 25 INR/KL (0.41 USD/KL) for tanker and piped water respectively. The higher costs of a piped supply reflect the convenience and continuous nature of the supply. By comparison non-domestic tariffs for the supply of fresh water were 36-60 INR/KL (0.59-0.98 USD/KL) at the time of data collection, depending on the quantity consumed, making the use of treated wastewater a financially interesting option (BWSSB, 2012a).

The income derived from the sale of treated wastewater does not have to cover capital investments, for which the BWSSB receives direct contributions from government departments such as the BDA, the BBMP and the KSPCB. It also receives loans from donors and agencies such as the Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC). However, Connors (2005)

[12] Unpublished figures obtained from the BWSSB for this project put the cost in the range of 26-46 INR/KL

believes that for this reason the BWSSB will never initiate an expansion programme without the required funds. Connors (2005) describes the BWSSB as “a traditional, publicly owned water utility struggling to cope with insufficient funds, rotating leadership, explosive population growth, expanding urban boundaries, hiring and promotion constraints, high water costs, and political interference, primarily in the setting of tariffs”. At present the BWSSB has over 1,000 staff vacancies ranging from accountants and engineers to sanitary workers, which must be putting enormous strain on the system (BWSSB, 2013).

Significant new legislation has recently been published by the KSPCB (2015), requiring all local authorities and concerned agencies to meet certain new wastewater management criteria and to submit a time-bound action plan for setting up a sewage collection, treatment and disposal system. Critically, ‘Secondary treated sewage should be mandatorily sold for use for non-potable purposes such as industrial purposes, railways and bus cleaning, flushing of toilets through dual piping, horticulture and irrigation. No potable water to be allowed for such activities. They will also digest methane for captive power generation to further improve viability of STPs’. Furthermore, ‘Local authorities shall enforce dual piping system in new housing constructions for use of treated sewage for flushing purpose’ (KSPCB, 2015).

5.6.1.3 Environmental Management and Pollution Monitoring

Monitoring and enforcement of water pollution and effluent standards, and consent to discharge effluent, including hazardous, biomedical and municipal waste, are the responsibility of the KSPCB in accordance with the Water (Prevention and Control of Pollution) Act 1974, the Water (Prevention & Control of Pollution) Cess Act, 1977, the Water (Prevention & Control of Pollution) Cess Rules, 1978, the Environment Protection Act, 1986, and the Municipal Solid Wastes (Management & Handling) Rules, 2000 (KSPCB, 2004). The KSPCB, which has 44 regional offices, one in each district of the state, regulates wastewater quality from industrial, commercial and residential premises but not from individual households. Instead it regulates BWSSB discharges and STP effluent.

Based on the Water (Prevention and Control of Pollution) Rules, 1976, the Environment (Protection) Rules, 1986, and State byelaws, residential properties over 20,000 m^3 within the built-up area of the BWSSB sewered area and properties of over 5,000 m^3 outside the sewered area, as well as commercial establishments of more than 2,000 m^3, are required to have onsite STPs (Table 5-11). They must treat and reuse their wastewater onsite, conforming to State treatment and reuse standards (Table 5-12).

Table 5-11. Properties that require STPs and consent forms

Area	Type and size	Requirement
BWSSB sewered areas	Residential apartments, built-up area < 20,000 m^2	Must obtain permission from, and pay fees to, the BWSSB for disposal into the sewer
	Residential apartments, built-up area > 20,000 m^2	Must have an on-site STP
Outside BWSSB area (unsewered)	Residential apartments, built-up area > 5,000 m^2	Must have an on-site STP
	Commercial establishments > 2,000 m^2	Must have an on-site STP

Source: Shankar and Yathish (2012)

Table 5-12: KSPCB urban reuse standards

Parameter	Previous standard	Urban reuse standard (2012)	Effluent discharge standards for STPs (2015)
pH	6.5-8.5	6.0 -9.0	6.0-9.0
BOD (mg/L)	< 20	< 10	< 10
COD (mg/L)	-	-	< 50
Total suspended solids (TSS) (mg/L)	< 30	-	< 20
Oil & grease (O&G)	<10	-	-
Turbidity (NTU)	Not specified	< 2	-
E. Coli	Not specified	NIL	-
Residual Chlorine (ppm)	Not specified	> 1	-
NH_4-N (mg/L)	-	-	< 5
N-Total (mg/L)	-	-	< 10
Faecal Coliform (MPN/100 ml)	-	-	< 100

Source: Kodavasal (2011a); KSPCB (2015)

The reuse standards or 'urban reuse norms' as they are commonly known[13], were apparently issued by the KSPCB in 2012 and created considerable discussion because they were so stringent (Table 5-12) (Shankar and Yathish, 2012). A subsequent direction issued by the KSPCB (2015), clarified the standards and required all existing and future STPs, to meet the revised standards.

[13] These norms are mentioned extensively in the newspapers and in documents commissioned by the KSPCB, for example Shankar and Yathish (2012) and Kodavasal (2011a) but the original source, KSPCB Memorandum No.3080, Dated: 16.8.2012, has not been obtained to confirm this.

State legislation issued by KSPCB, is in accordance with national legislation and is enforced and monitored through a system of applications for consent, which are explained in Box 5-8.

Box 5-8. Types of consent

- Consent for establishment (CFE) has to be obtained prior to establishment of an industry, operation or a process. It includes STPs in residential complexes. In 2015 the State Level Environmental Impact Assessment Authority, Karnataka (SLEIAAK) further directed the KSPCB to only issue CFEs after submission of a copy of the Environmental Clearance certificate, due to violations that were arising.
- Consent for operation (CFO) has to be obtained prior to commissioning a building and for continuation of discharge of emission and effluents. It is based on their intended activities and related effluent management and treatment facilities.

Source: KSPCB (2004); SLEIAAK (2015)

Industries are responsible for managing the quality of their effluent in accordance with the Water (Prevention and Control of Pollution) Act, 1974. Compliance is monitored and enforced by the KSPCB through spot checks and the official consent process. Where violations of the law are identified criminal cases are filed (MOEF, 2003) but in reality the KSPCB is stretched considerably and many industries are inadequately or infrequently inspected.

5.6.1.4 Groundwater Regulation and Management

As mentioned in section 5.3, there are thousands of open wells and borewells across Bangalore providing some 341 MLD to households and commercial premises (Jacob, 2012; Central Groundwater Board, 2012). Groundwater is regulated under the Karnataka Ground Water (Regulation and Control of Development and Management) Act, 2011, which is designed to control the extraction of groundwater and to prevent over exploitation (MOWR, 2011). It is implemented by the **Karnataka Ground Water Authority (GWA)**, which was only constituted in 2014, and comprises several organizations including the Department of Mines and Geology, the Department of Water Resources, the Minor Irrigation Department, the CGWB, KSPCB, the DOA, farmers representatives, the Karnataka Urban Water Supply and Drainage Board (KUWSDB) and BWSSB. The Authority can notify areas where extraction should be restricted (Article 10.2) and take steps to protect aquifers (Article 10.6). Bangalore Urban and Bangalore Rural districts have both been notified due to over abstraction and water shortages. Anyone wishing to dig a well in the notified area must apply to the GWA for a permit (Article 11.1). Any existing user of groundwater within a notified area must apply for a certificate of registration. The BWSSB, has been entrusted with recording registrations of all borewells in the BBMP area, for the Department of Mines and Geology, which heads the GWA.

Despite the creation of the GWA and the enactment of the Karnataka Ground Water Act, 2011, there is still very little control over the quality of water extracted from wells and borewells. The GWA and the Act are primarily concerned with over exploitation of aquifers and the registration and monitoring of the number of borewells and the quantity of water extracted. They are not responsible for ensuring the quality of the groundwater or the use of that water, although the issuance of permits for drilling does include consideration of the quality of the water and the intended use (Karnataka Ground Water Act, Section 11.4).

This consideration of water quality has implications in locations where groundwater is being recharged by wastewater. Where the recharge is from treated wastewater but is incidental or unplanned, the BWSSB and KSPCB are responsible for ensuring the quality of the effluent but not the groundwater; and in terms of water supply the BWSSB is only responsible for the quality of the water provide through its piped system and its own borewells, not private wells (Deputy Chief Engineer, BWSSB, pers. comm., 17 July, 2013). Where the recharge is from untreated wastewater there will be no regulation of water quality as there is no legal requirement to monitor well water quality (although permits are issued on the basis of quality and planned use).

5.6.1.5 Lakes, Fisheries and Agriculture

Lake management is the responsibility of a complex mix of organizations including the **Lake Development Authority (LDA)**, the **BDA**, the **Karnataka Forestry Department (KFD)** and the **BBMP** (Table 5-13). As the BBMP have proved to be more effective than others at lake restoration the Government issued an Order dated 19/04/2010 to put a further 95 lakes under their (Patil Committee, 2011). However the **Karnataka Lake Development and Conservation Authority (KLDCA) Bill, 2014**, has recently been enacted. This will create a new authority with greater power and will incorporate the LDA. The new KLDCA will have regulatory control over all lakes in Mangaluru, Hubballi–Dharwad, Mysuru, Belagavi, Tumakuru, Davangere, Ballari, and Kalaburagi corporations, and will have the power to remove encroachments, penalise or jail encroachers with fines and jail terms, and even officials who have “not acted or failed” to remove encroachments (RAO, 2015).

Table 5-13. Responsibility for lakes across the BBMP area

	Number of lakes restored or being restored			
Custodian	**Restored**	**In Progress**	**Proposed**	**Total**
Bruhat Bangalore Mahanagara Palike (BBMP)	13	18	98	129
Bangalore Development Authority (BDA)	7	6	31	44
Lake Development Authority (LDA)	9	-	2	11
Karnataka Forest Department (KFD)	2	0	3	5
Total	31	24	134	189

Source: Patil Committee (2011)

The government organization responsible for fisheries management in Bangalore is the **Fisheries Department (FD)**, within the **Animal Husbandry and Fisheries Department (AHFD)**[14], under the **Karnataka State Department of Agriculture (KSDA)**. Their role includes augmentation of fish production through the development and management of inland water resources; creation of employment in rural areas; and activities to improve the socio-economic conditions of fishermen and the nutritional status of the general public. Their functions include the provision of fishing rights for tanks on lease, tender or auction; licensing of fishing in reservoirs or rivers; assistance in post-harvest and marketing; and supply of fish culture and feed (AHFD, 2009).

In addition there has been constituted, under The Karnataka Inland Fisheries (Conservation Development and Regulation) Act, 1996 (published in 2003), a State Inland Fisheries Advisory Board that includes the Minister in charge of Fisheries, the Finance Department, the Irrigation Department and a Fisheries Cooperative Societies representative. Their role encompasses the welfare of fishermen, training, extension and propagation of inland fisheries.

Under the Government of Karnataka there are a number of departments that deal with aspects of agriculture and aquaculture all of which have various responsibilities related to developing their sector, improving marketing, providing guidance and extension, and supporting the poorest, but none has specific responsibilities or roles related to water supply or wastewater use.

The **KSDA** was created mainly to provide agricultural extension services and technologies including advice on integrated nutrient management and micro-irrigation to preserve water resources (KSDA, no date; 2013a; 2013b). The KSDA also has the role of improving agricultural water use efficiency. One element of the policy goals of KSDA, as set out in the Karnataka Agricultural Policy, 2006, is the need to create wastewater recycling facilities, as espoused by the President of India in his mission

[14] Also known as the Department of Animal Husbandry and Fisheries (DAHF).

statement for agricultural prosperity (KSDA, 2007). Structures are planned to utilize wastewater, but this appears to relate to excess canal water rather than domestic wastewater, and no other mention is made of wastewater use. The policy includes the recycling of agricultural wastes and application of green manure (KSDA, 2007). The Integrated Agribusiness Development Policy, 2011, also supports the development of bio-compost plants, using urban domestic waste (KSDA, 2011) but there is no mention of wastewater or faecal sludge use.

The **DAHF** is in charge of schemes for the development and improvement of livestock, animal health and dairy development (AHFD, 2009). Nothing in their remit relates directly to water reuse (for example for irrigation of fodder crops). The **Karnataka Milk Federation (KMF)** is the Cooperative Apex Body in the State of Karnataka representing organisations of milk producers. It implements a range of dairy development activities to produce quality milk, ensure a market and make milk products available to the urban market. It also provides inputs and disseminates knowledge (KMF, 2013). The **Karnataka Co-Operative Poultry Federation Limited (KCPF)** plays a similar role to the KMF in the poultry sector. They also protect consumers by monitoring and controlling diseases in the poultry population and maintaining the quality of the product (KCPF, 2013).

Although the KSDA has some responsibility for on-farm water efficiency, water supply and management fall to the MOWR with responsibility devolved to the States which formulate laws and plans for development of water resources for water supply, irrigation and hydropower (MOWR, 2013). Irrigation schemes are divided into major, medium and minor, depending on the Cultivable Command Area (CCA) (previously it was based on the financial cost of the scheme). Major projects have a CCA of > 10,000 ha; medium projects 2,000-10,000 ha; and minor projects <2,000 ha (MOWR, nd). Management of the CCAs falls to the **Water Resources Department (WRD)** which is responsible for obtaining surface water for irrigation and drinking, and plans, implements and monitors irrigation projects (WRD, 2013). Within the WRD is **Minor Irrigation (MI)** which, like the WRD, undertakes fairly typical irrigation work such as constructing and rehabilitating tanks and canal banks, and flood control work (Minor Irrigation, 2011). There is no mention in their remit or goals of wastewater use.

Crucially, for water reuse, The Bangalore Sewerage (Amendment) Regulations, 2012, state that for *'Irrigation with sewage or industrial effluents: - Direct disposal of sewage or industrial effluents for irrigation of crops to be used for human consumption or for washing of cattle is prohibited*' (BWSSB, 2012b).

5.6.1.6 Summary

Significant attributes of the main local government stakeholders are provided in Table 5-14, along with relevant legislation where salient.

Table 5-14. Role and key activities of state and city level government organizations

Stakeholder	Role and norms of behaviour	Governing legislation
BBMP	**Administrative body responsible for the civic and infrastructural assets of the BMA**; approving building construction plans and giving completion and occupancy certificates; sewage, drains and sanitation in public places. The BBMP Health Department implements sanitation works such as the cleaning of drains. Also lake management and restoration.	Karnataka Municipalities Act, 1964; Corporation Act, 1976; Solid Waste (Management and Handling) Rules (2000)
BWSSB	**Parastatal responsible for water supply and sewerage in the BBMP area**. Must make suitable arrangements for the safe transport and disposal of sewage and faecal sludge. It has a 'New Initiatives Division' which is looking at RRR issues and has projects to supply treated wastewater to industries. Is actively undertaking treatment and recycling, selling treated wastewater to industries and augmenting surface water. Regulations state direct disposal of sewage or industrial effluents for irrigation of crops to be used for human consumption or for washing of cattle is prohibited' (BWSSB, 2012b).	State Water Policy, 2002; Bangalore Water Supply and Sewerage Act, 1964 Notification I The Bangalore Water Supply (Amendment) Regulations, 2012; Notification II The Bangalore Sewerage (Amendment) Regulations, 2012
KSPCB	**Regulating agency for water, wastewater, environmental and public health issues**. Monitors and enforces water pollution and effluent standards, and consent to discharge effluent. Also established and monitors compliance with reuse norms. Enforces: Water (Prevention and Control of Pollution) Act, 1974, 1988; Water (Prevention and Control of Pollution) Rules, 1975; Water (Prevention and Control of Pollution) Cess Act, 1977; Environment (Protection) Act, 1986; and Environment (Protection) Rules, 1986; Solid Waste (Management and Handling) Rules (2000), and state level legislation arising from these. Interacts with BWSSB, BBMP, BDA (in Masterplan) and Health Dept.	National environmental legislation (see left column) and State level byelaws and circulars. The Karnataka State Board for the Prevention and Control of Water Pollution (Procedure for Transaction of Business) and the Water (Prevention and Control of Pollution) Rules, 1976, known as the 'Karnataka Water Rules', 1996
BMRDA	**Land use planning and allocation**: An autonomous	BMRDA Act 1985

Stakeholder	Role and norms of behaviour	Governing legislation
	body created under the BMRDA Act 1985 to plan, coordinate and supervise the orderly development of the BMR.	
BDA	**Land use planning and allocation**: Regulatory body required to prepare a "Comprehensive Development Plan" and to oversee planning and development of infrastructure including water supply and sewerage and for allocation of land for such purposes. Responsible for urban drainage and operates STPs in Cubbon Park and Lalbagh Park, which receive wastewater from the BWSSB network and are used to irrigate the parks. Also involved in lake management and restoration.	
LDA	**Protection and restoration of lakes:** Autonomous regulatory, planning and policy body for protection, conservation, reclamation, restoration, regeneration and development of lakes in Karnataka.	
GWA	Constituted in 2014 to **prevent exploitation of groundwater** through a borewell permit system. Made up of several organizations including KSPCB and BWSSB.	Karnataka Ground Water (Regulation and Control of Development and Management) Act, 2011
KSDA	Provide **agricultural extension** and input services. On-farm water efficiency (including reuse schemes). Provision of fishing rights and assistance with marketing. **DAHF** livestock improvement, animal health and dairy. **KMF** represents milk producers. **KCPF r**epresents poultry farmers.	Integrated Agribusiness Development Policy, 2011 Karnataka Agricultural Policy, 2006. The Karnataka Inland Fisheries (Conservation Development and Regulation) Act, 1996.
KUIDFCL	Main arm of Karnataka Government for **financing urban infrastructure development projects** and interface with external lending agencies.	
KFD	Lake management and restoration.	
WRD	National department but has no equivalent operating locally. Responsible for obtaining surface water for irrigation and drinking. Minor Irrigation Department (MID) under WRD and performs the same tasks for smaller command areas. National body works at all levels. No local equivalent.	

5.6.2 Research Organizations and Non-Governmental Organizations

In addition to local government departments, there are a wide variety of other stakeholders engaged in aspects of wastewater reuse or who could influence the sector (Figure 5-13), which are described here.

5.6.2.1 Universities

There are several universities in Bangalore, of these, the University of Agricultural Sciences (UAS), Department of Soil Science and Agricultural Chemistry, has been undertaking research on the impact of urine use on crops since 2006. One of the aims of this work is to develop guidelines for the safe use of wastewater, excreta and urine (Argyham, no date). The work was funded by Arghyam, the Stockholm Environment Institute (SEI) and UNICEF. They are currently also undertaking a study to characterize faecal sludge to determine its potential uses and benefits in agriculture. The UAS shares its findings with farmers by inviting them to annual farmer fairs.

According to a professor at the university interviewed for this study, funding has not been easy to obtain for research into RRR, and therefore not many government departments have been interested in this area of work. The DOA are not interested as a rule but there are some individuals who are. There has, however, been increasing interest from certain donors such as the Bill and Melinda Gates Foundation (BMGF) which is funding work on septage management (see the section on donors).

The **Indian Institute for Human Settlements (IIHS)**, is a national education institution, based in Bangalore, committed to the equitable, sustainable and efficient transformation of Indian settlements. It has also been designated a National Resource Centre (NRC) by the Ministry of Housing and Urban Poverty Alleviation (IIHS, 2013). IIHS has been working on an Anglo-Dutch project to future proof India's cities. This project includes a water, sanitation and reuse component (Atkins, 2014). It is further discussed in the donor section below.

5.6.2.2 Consortium for DEWATS Dissemination (CDD) Society

The Consortium for DEWATS[15]Dissemination (CDD) Society aims to address the challenges posed by increasing quantities of wastewater produced in urban and peri-urban areas in South Asia through the provision of decentralised basic needs services. They work extensively with several of the major stakeholders including the BWSSB, the KSPCB, research organizations (e.g. IWMI), NGOs (e.g. Biome,

[15] Decentralized Wastewater Treatment (DEWATS)

see below) and donors (including the German Federal Ministry for Economic Cooperation and Development (BMZ); the BMGF; and the EU). Their projects include supporting city governments to implement relevant policies and guidance, such as the septage management advisory note for decentralized sanitation infrastructure; and dissemination of knowledge of decentralized urban sanitation (CDD Society, 2014). Their latest project, the 'Nexus Project', aims to close the sanitation loop and link sanitation to health, food, water and energy by improving the overall sanitation situation and increasing the supply of food by using nutrient-rich wastewater for food production (CDD Society, 2015).

5.6.2.3 Biome Environmental Solutions and Rainwater Club

Biome Environmental Solutions (Biome) is a Bangalore-based design firm focused on ecology, architecture and water. It was created in 2008 by the merger of Chitra K. Vishwanath Architects and Rainwater Club. It offers environmentally conscious architecture solutions including wastewater cycling and recycling, and advocating reuse of appropriate waste streams within the household for flushing and gardening (Biome Environmental, 2009a; Rainwater Club, 2008).

5.6.2.4 Environment Support Group

Environment Support Group (ESG) is a Public Charitable Trust that works with a variety of environmental and social justice initiatives to proactively address environmental and social justice issues and concerns. They have worked on solid waste management, hazardous waste and lake management (ESG, 2015). It is well known for its environmental and human rights campaigns and for the public interest litigation (PIL) lodged by its trustees and staff.

5.6.2.5 Arghyam Foundation

Arghyam is a charitable foundation based in Bangalore that grants funds to organisations that implement and manage groundwater and sanitation projects in India. It also undertakes some of its own research. For example, it has been testing a decentralised WWT technology known as Soil Biotechnology (SBT) in the grounds of ACCEPT Society, an AIDS hospice on the outskirts of Bangalore that was struggling with wastewater management and water supply. The system treats wastewater to standards that are acceptable for irrigation and other reuse purposes that do not involve direct human contact (Arghyam, 2013). Another project funded by Arghyam was the 'Monitoring exercise in Integrated Urban Water Management (IUWM) at Rainbow drive layout, Bangalore', which was implemented by Biome and the Rainbow Drive Resident's Welfare Association (RWA). The project investigated the factors that led the RWAs to seek alternative water and wastewater management options, which included rainwater harvesting, groundwater augmentation and wastewater treatment and use (Arghyam, nd).

The Foundation is also involved in advocacy, awareness and consultation projects, including one with the State government and Janasahayog, which works with slum dwellers. The project is a consultation process between the State and citizens which aims to improve awareness of the water situation and to democratize water governance (Arghyam, nd).

5.6.2.6 Summary

The research organizations and NGOs identified as being active in the wastewater use arena are summarized in (Table 5-15).

Table 5-15. Summary of research organizations and NGOs

Stakeholder	Role (with respect to water and wastewater)
Universities	University of Agricultural Sciences (UAS), Department of Soil Science and Agricultural Chemistry undertaking research on nutrient use from excreta and urine.
CDD Society	Decentralised sanitation. Active network and good coordination between government and non-government stakeholders.
Biome	Environmentally conscious architecture solutions including wastewater cycling and recycling.
Environment Support Group	Environmental and social justice advocacy and legal challenges.
Arghyam Foundation	Provides funds for water and sanitation projects including decentralized wastewater treatment and integrated water management, which involves treatment and use.

5.6.3 Business Development and Financing Stakeholders

Although many of the reuse systems identified in Bangalore are either established by the government, taking place within multiple occupancy residential properties, or are informal (i.e. use of untreated wastewater), it is necessary to look at the business development landscape to determine whether the environment is conducive to the establishment of reuse businesses, whether it is likely that private companies will enter the water reuse arena, and how local governments can fund their schemes.

5.6.3.1 Industrial Development

Bangalore is a city that is developing fast with much investment and entrepreneurial spirit. The new Industrial Policy 2009-14 of the **Commerce and Industries Department**, Government of Karnataka, is designed to promote development and provide incentives for entrepreneurs while protecting the underprivileged and safeguarding the interests of farmers and investors in the land acquisition process. Importantly for reuse, one element of the strategy is 'appropriate provisions for the protection of environment and to encourage energy & water conservation measures in industry/projects through go-green strategy' (GOK, 2009). Under the section on conservation of scarce resources, enterprises are encouraged to implement reuse and recycling of wastewater and to secure better waste management through innovative approaches. The Department of Science and Technology (DST), has created **"Technology business incubators"**. These provide services that can help enterprise engaged in reuse businesses to develop their model, improve their credibility and expand their enterprise (DST, 2002)

5.6.3.2 Urban Infrastructure Development

The financing markets and financial institutions in Karnataka, particularly Bangalore, are well developed. The landscape of financing for RRR enterprises includes government schemes and public financial institutions, which typically finance public projects, ULBs and sometimes PPPs. They include the **Karnataka Urban Infrastructure Development and Finance Corporation Limited (KUIDFCL)** and the **Housing and Urban Development Corporation Limited (HUDCO)**. The KUIDFCL provides assistance to ULBs, while HUDCO is finances development of residential properties and in 1990 added loans for infrastructure such as water supply and sanitation. HUDCO has a policy of insisting on sewerage schemes whenever water supply schemes are implemented, and funds on-site sanitation as well as community facilities. International funding for environmentally sustainable projects is channelled through HUDCO (HUDCO, nd).

The **Infrastructure Development Corporation (Karnataka) Ltd. (iDeCK)**, a joint venture between the Infrastructure Development Finance Company Limited (IDFC) and Housing Development Finance Corporation Limited (HDFC), is the nodal agency for infrastructure projects in Karnataka. The objectives include policy formulation, implementation, financing and management. They mobilize capital from investors and negotiate loans and have been involved in the development of water supply schemes in Karnataka and in the preparation of City Development Plans (iDeCK, 2013).

5.6.3.3 Financial Services and Corporate Social Responsibility

The financial services sector is well developed in Bangalore including private, nationalized and rural banks, micro-finance and credit cooperatives. There are also a growing number of **"social" investors** that may provide equity financing (Aavishkar, 2014; Sankalp Forum, 2015) and a range of **challenges and competitions** announced by various bilaterals, multi-laterals, industry associations and private foundations, which early stage RRR enterprises with adequate social impact can explore (Millennium Alliance, 2012; Sankalp Forum, 2015). Furthermore, many Indian corporations are implementing social responsibility programmes, funding action research and pilots for innovation.

5.6.3.4 Summary

The main stakeholders identified in the business development and financial services sector in Bangalore are listed in Table 5-16 with a brief outline of their roles.

Table 5-16. Summary of research, business development and financing stakeholders

Stakeholder	Role (with respect to water and wastewater)
Commerce & Industries Department	Developed the new Industrial Policy 2009-14 provides incentives for entrepreneurs. Water conservation and green strategies are emphasised.
Department of Science and Technology	Created technology business incubators for reuse businesses.
Karnataka Urban Infrastructure Development and Finance Corporation Limited (KUIDFCL)	Main arm of the State Government for financing urban infrastructure development projects. Provide support to ULBs
Housing and Urban Development Corporation Limited (HUDCO)	Provide financing for development of residential properties, including water and sanitation infrastructure.
Infrastructure Development Corporation (Karnataka) Ltd. (iDeCK)	Nodal agency for infrastructure projects. Involved in city development and water supply plans.

5.6.4 International Donors

5.6.4.1 Water Supply and Sewerage

Historically there have been several international donors funding wastewater management interventions, such as sewerage and STPs in Bangalore, these include:

- **AusAid**, which funded research into the state of waste and sanitation in Bangalore in 2000. This led to a lot of work being done on wastewater management in the city.
- The **Japan International Cooperation Agency (JICA)** and **Japan Bank for International Cooperation (JBIC)**, funded the Bangalore Water Supply and Sewerage Project (II-2) in 2005-

2006, which included awareness raising and slum improvement. They also funded the Bangalore City Water and Sewerage Development Project first phase from 1996. Within this **USAID** provided a guarantee for the bonds issued by the KUIDFC to finance the water distribution network (JICA, nd). JICA's contribution was INR 28,300 million (USD 464 million) of the total estimated cost of INR 33,837 million (USD 555 million). The scheme includes 13 water supply contracts and 16 sewerage contract packages (BWSSB, no date).

- The Greater Bangalore Water and Sanitation Project (GBWASP) 2003-2014 was implemented by the BWSSB, with support and funding from **USAID** and the **World Bank**. The Underground Drainage (UGD) component of the project is financed by the World Bank under the Karnataka Municipal Reforms Project (KMRP) (BWSSB, 2013).
- Under the **Indo-French protocol** 1995, 50 Million Francs was earmarked for BWSSB for water supply and sewerage, out of which 30 Million Francs was for V.Valley STP and 10 million for Yelahanka STP (BWSSB, no date).

5.6.4.2 Research, Social Development and Decentralised Schemes

International funding has also been provided for research and social development works, through local and international NGOs and universities. These include Global Communities, Caterpillar Foundation, and the RUAF Foundation, which worked on urban agriculture and wastewater use. Currently the **BMGF,** is providing funding for a range of projects including: the projects with the UAS and CDD Society outlined previously; transformation of non-piped sanitation systems in unserved areas with iDECK; and development of a tool for city-wide sanitation planning with the Center for Study of Science, Technology and Policy (CSTEP), ULBs, MOUD and GOI (BMGF, 2014). **BORDA** continues to fund DEWATS in Bangalore, principally through CDD Society.

The **UK Department for International Development (DFID)** and the **Netherlands Directorate-General for International Cooperation (DGIS)**, and the **Climate Development Knowledge Network (CDKN)** have funded action planning with the city authorities of Bangalore and Madurai. The project, Future Proofing Indian Cities, intends to create action plans that address future urban development needs, including WSS (Atkins, 2014). In Bangalore, the plan incorporates BWSSB's ambitions to increase the reuse of wastewater in Bangalore, which is contained within 'Theme 5: Water demand management', 'Project 10: Increase recycle and reuse of treated wastewater'. The outcome of this component is intended to be, 'Increased availability of water for supply within BWSSB distribution system. Conserving potable water and replacing its use with treated non potable water …' (Atkins, 2014).

5.6.4.3 Summary

The past and present international donors in the water reuse sector in Bangalore identified under this study are listed in Table 5-17 with an indication of the types of projects they have funded.

Table 5-17. Summary of international donors

Stakeholder	Role (with respect to water and wastewater)
AusAid, JICA, JBIC, World Bank, French Government	Historical donors to the WSS sector including sewerage and STPs.
Bill and Melinda Gates Foundation (BMGF)	Current donors funding research, social development, small-scale infrastructure including decentralized sanitation.
BORDA	DEWATS, mainly through CDD Society.
DFID and DGIS	Funding an action plan for Bangalore with BWSSB; includes plans for reuse and recycling of wastewater.

5.6.5 Other 'Influencers'

This section groups together several other stakeholders that may not be directly involved in wastewater management, treatment and use, but which have a certain level of influence, either due to vested interests in the sector or because of their roles as arbiters or in information sharing.

5.6.5.1 Courts and Civil Society

These two stakeholders have been grouped together for the discussion because of the combined role that they play through the actions of civil society groups bringing actions to court. There are several ways in which civil society groups affect change but this one has been shown to be particularly important in Bangalore.

The Lok Adalat, which roughly translates as the 'People's Court', which is established and mandated by the Legal Service Authorities Act, 1987, is a very useful avenue through which people can seek judgments on public interest litigation (PIL). Several PILs relating to environmental issues have been brought to the Lok Adalat over the past few years including lake encroachment and pollution. These cases have resulted in clarification of the implementation of specific rules. No PILs appear to have been brought regarding wastewater reuse to date, although there is ongoing litigation regarding pollution and degradation of lakes by BWSSB and other civic agencies. The initial proceedings were filed in January 2014 and have now been taken up by the KSPCB (Chetan, 2015).

There is no doubt that the courts play an important role in environmental issues and providing binding judgements, however, the process tends to be lengthy, slow and costly, which reduces the impact and may also discourage people from filing PILs in the first place. A case in point is that of Bellandur Lake, where the Bellandur gram panchayat approached the high court with a PIL in July 1999. Some three years later an environmental plan was published but by 2013 it is reported that no significant action had been taken (Ramesh and Krishnaiah, 2013). Although it should be noted that projects have been undertaken to rehabilitate lakes across the city.

Civil society groups also put pressure on the government and the public in other ways. In the case of the privatization of lakes, protests have been organized such as one by "**Hasiru Usiru**," in association comprised of several NGOs including ESG, Alternative Law Forum, Equations, CIVIC, Open Space and SICHREM (Staff Reporter, 2008) and others around Bellandur Lake (Ramesh and Krishnaiah, 2013).

5.6.5.2 The Media

The media have a strong environmental bent in Bangalore. A search for articles on sewage, sewage treatment, reuse and pollution reveal a number of articles, fora and blogs dedicated to these issues. A particularly good example is 'Citizen Matters Bangalore' which regularly posts articles and discussion pieces on legislation and high court judgements and shines a light on the activities of government officials as well as the private sector (Citizen Matters Bangalore, nd). The combination of the media, the courts and active citizens is potentially a powerful tool for action in relation to environmental issues, sanitation and water reuse.

5.6.5.3 Summary

The roles of these three stakeholder groups that do so much to influence the sector and shine a light on bad practice are summarized in Table 5-18.

Table 5-18. Summary of 'influencers'

Stakeholder	Role (with respect to water and wastewater)
Courts and the judiciary	Uphold laws and issue orders requiring action, especially on the part of government departments. Slow process and does not always bring results. Could have a negative impact if they were opposed to reuse.
Civil Society	Raise issues, lobby and demonstrate. Bring litigation to courts. Often move the debate forward, create interest in the media and can lead to action on the part of authorities or community members. Could have a negative impact if they were opposed to reuse.
The media	Active in raising the profile of issues in the public consciousness, for challenging government actions and for facilitating debate. Could have a negative impact if they were opposed to reuse.

5.6.6 Communities and Private Sector – Waste producers, processors and users

This section describes the roles and institutional arrangements a somewhat eclectic set of stakeholders. It covers all those directly involved in certain reuse systems - waste producers, users, processors or beneficiaries. Many of them have more than one role in the wastewater use systems, for example, apartment owners are waste producers, processors and users.

5.6.6.1 Residential and Commercial Complexes

As explained previously, large residential and commercial complexes[16] are required to treat their wastewater and make use of it on-site for non-potable purposes. The wastewater use system involves developers, residents, residents' welfare associations (RWAs), and STP designers and managers, in addition to the KSPCB. This on-site treatment offers benefits in the form of access to water and sewage facilities for properties outside the area covered by BWSSB, where high prices are paid for tanker water and where sanitation challenges can be considerable. However, there are problems with on-site systems, mainly arising as a result of lack of expertise to build and operate the STPs, as well as willingness on the part of owners/users to effectively manage the STP or use the water produced therein.

Real estate developers are required to build and install STPs typically hiring a Public Health Engineer (PHE) to assist with the design. The developer must apply for the CFE from the KSPCB. Once built, the developers hand over operation to the RWA who will apply for CFO. However, many developers have little knowledge of STPs and often fit inappropriate, poorly cited systems based on the wrong specifications, using cheap or inferior equipment. Furthermore they are not interested in developing separate greywater systems (which would benefit the users) because they are an additional cost to install and take up space that cannot be sold. In many cases private STPs are not functional and private companies will play the role of reviving or improving an inoperative plant. Treated water from the STP is reused within the premises for gardens, flushing toilets and cooling in air conditioning units.

Although STPs are required by law, and their installation was driven by compliance, they are increasingly being seen as an important investment in places where water supply is scarce and costly. The extent of the benefits depends on factors such as the source of freshwater (BWSSB piped supply, tanker or bore well), which influences the quantity available and its cost; and whether or not the premises have a dual piping system that facilitates reuse. If STPs are operated effectively and

[16] This includes large commercial developments (eg: malls); institutional campuses (eg: research and academic institutions such as IISc, hospitals); and business campuses (eg: Software development parks).

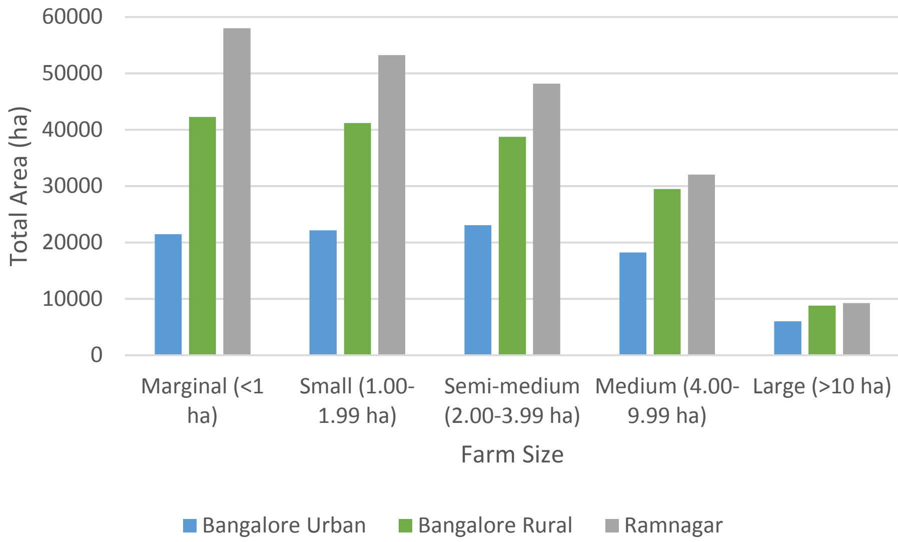
dual plumbing systems are in place the payback period is only 3-8 years, based on average costs of 20 INR/kL (0.3 USD/kL) for an activated sludge plant (the most commonly used in Bangalore) and dependent on size (Ananth Kodavasal, pers. comm., 17 July, 2013).

The benefit to the apartments is translating into growth in businesses that design, install, operate, consult on and rehabilitate STPs. The role that a water treatment professional chooses to play will depend on their skills, interests, finances and manpower.

5.6.6.2 Farmers

According to the Agriculture Census 2010-2011 conducted by the Department of Agriculture and Cooperation, Ministry of Agriculture, and reported by the KSDA, there are 76,278 farmers in Bangalore Urban District cultivating 90,928 ha. The total number of farmers, by class of landholding, for the three Districts that make up BMR are given in Figure 5-14.

In terms of irrigation the Agriculture Census, 2010-2011 does not record any area of land being irrigated by canals, tanks, lift irrigation, wells or 'other sources' in Bangalore Urban or Bangalore Rural Districts, it does, however, record net areas of 10,261 ha and 29,719 ha being irrigated by borewells in the two districts respectively. By contrast Ramanagar, being more rural, is irrigated by all sources except wells and 'other sources' (KSDA, nd, b). The reality is probably slightly different with small-scale urban and peri-urban agriculture being undertaken in areas not typically seen as agricultural and not counted in the census. These farmers will be impacted by wastewater flows and WWTU schemes, many of them benefitting from them. Several plans are in place to increase the number of treated wastewater irrigation schemes. One example is the ADB-financed project, facilitated by the KUIDFC, in Tumkur, about 80 km northwest of Bangalore, which sought to expand the district's water supply and sewerage system and channelled 24.75 MLD to an STP and diverted the treated water for irrigation purposes. Local farmers interviewed by the project appeared to be happy with the quality of the water for cultivating crops (ADB, 2012). The same approach is proposed as part of an IWRM strategy for Bangalore, in which the 38 lakes already being rehabilitated could be further improved, and would contribute an additional 180 MLD to the water available to Bangalore (McKinsey and CII, 2014).



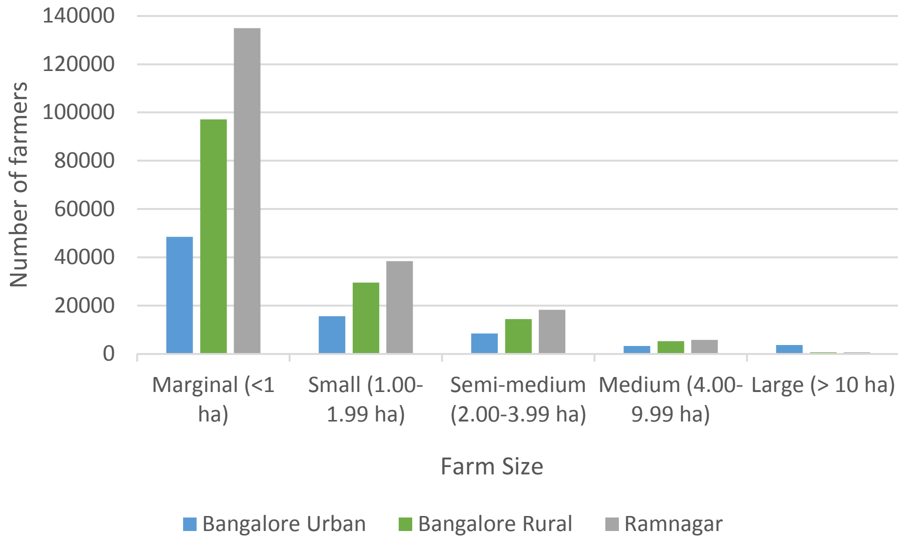


Figure 5-14. Number of farmers and agricultural area by farm size in Bangalore
Source: KSDA (nd, a)

5.6.6.3 Fishermen

There are estimated to be 633,000 inland fishermen in the State of Karnataka, where there are around 593,000 ha of water bodies, including rivers, tanks and lakes. The sector produced 19,795 million tons of fish in 2013-2014 with a value of INR 15,962 million (USD 241 million) (FD, 2014). It is difficult to obtain specific figures for Bangalore, however, there is anecdotal evidence that there are many commercial and subsistence fishermen across the city, but that a large proportion of these have lost their livelihoods as a result of encroachment and pollution of lakes (Ramesh and Krishnaiah, 2013).

These fishermen are required to obtain a licence under The Karnataka Inland Fisheries (Conservation Development and Regulation) Act, 1996 and the Assistant Director of Fisheries has the power to lease fishing rights for certain waterbodies. Likewise fish breeding can only take place if registered under the Act. Contravention of the Act can lead to a fine.

Research undertaken for this project found that the fishermen at Jakkur Lake were working for a fishing company based in Andhra Pradhesh, which had been sold the lease by the Fisheries Department. This demonstrates that where the catch is good there is considerable interest in obtaining fishing rights, and it is not only local fishermen who are involved.

5.6.6.4 Groundwater Users and Sellers

Due to the absence of a BWSSB supply in almost 50 percent of Bangalore and a limited supply even in those areas with piped water, many households are reliant on borewells or on tankers that supply borewell water (McKinsey and CII, 2014; DFEE et al., 2008; Connors, 2005). Some of the water supplied by tankers is done so by the BWSSB but in addition to that there are hundreds of private tanker operators. Latha et al. (2005) estimated that over 10 years ago there were some 100-120 tanker companies with more than 3,000 water tankers. Households purchasing water in this way range from the most to the least wealthy in the city. The biggest problem with this system is that there is no control over pricing and the already high costs, compared with piped water supplies or the cost of pumping from one’s own borewell, can rise at any time. The Bangalore Mirror reported that this can be as much as INR 1,500 (USD 22.65) per tanker (usually 4,000 l) at its peak and that there are about 15,000 private operators in the city (Kaggere, 2014).

In 2014 the situation became so severe that the BWSSB announced that it would operate 30 tankers, each with a capacity of 6,000 L, 24 hours a day, seven days a week, and would only charge INR 360 (USD 5.44). It appears that the motivation is to break the ‘tanker mafia’ that exists in Bangalore. "People shell out huge sums to buy water, but are not assured of either quality or quantity," said T Venkataraju, chief engineer, BWSSB. "They don't know if the water is pure or from where it is sourced” (Kaggere, 2014).

The potential for wastewater to be utilized for groundwater recharge exists, as discussed in previous sections. At present demand far outstrips supply and the tanker owner and borewell owners that were interviewed as part of this study were very pleased with the STP development and rehabilitation of Jakkur lake as it meant that the groundwater table had risen and they could supply more water, thus improving their incomes. It should be noted that whilst the tanker owners are seen as a 'mafia,' individual borewell owners, also benefit from leasing the rights to their wells and this can have a dramatic impact on their livelihoods. In time the impact on users could also be positive if more water is available either for them to pump or to purchase (at lower price) from tankers.

5.6.6.5 Industrial Users

A number of industries have established or are establishing themselves in areas where water supply, both piped water and groundwater, is extremely limited. Many of these industries are part of BWSSB schemes to treat and recycle water, or recycle within their own premises, as required under environmental law. The BWSSB systems have been described in previous sections including the cost of treated wastewater supply. Onsite systems are not discussed because the focus of this study is on domestic wastewater, as explained in the introduction.

5.6.6.6 Potential Wastewater Users - Residents of Bangalore

Although it was not possible to interview a large number of residents, it is clear from interviews with RWAs, government officials and civil society groups that there is a mixed perspective on reuse. Many of those who are currently reusing wastewater, such as farmers and fishermen, appear satisfied with the water because they have a regular supply, although in some cases they are dissatisfied with the quality. RWAs, who are obliged to use treated wastewater within their premises, are generally not opposed in principle but have problems with the stringent requirements and the management of the STPs. The wider community who have less involvement with wastewater reuse are in principle in favour, provided it is not for potable uses. They are willing for it to be used for industrial and to some extent agricultural uses.

5.6.6.7 Summary

Reuse is only possible with the engagement of wastewater producers and users. Their critical roles in the process and how they are affected by reuse are summarized in Table 5-19.

Table 5-19. Summary of community and private sector stakeholders

Stakeholder	Role (with respect to water and wastewater)
Residential and commercial complex owners/users	Generate wastewater, process it on-site and utilize the treated water. Legally bound to do this by KSPCB in accordance with Water Pollution Acts and Rules and the KSPCB CFO regulations. Increasingly seeing the benefits especially in areas suffering from water shortages and difficulties in handling faecal sludge. Arrangements for sharing costs and benefits between residents are critical.
Private sector - STP designers and managers	A growing number with varying degrees of skill and knowledge. They design and operate, or rehabilitate and operate STPs. Fees could not be ascertained in the study. They suffer from skills shortages and staff retention.
Real estate developers	Installation of STP and compliance with KSPCB CFE regulations. Often lack expertise or willingness to install appropriate systems.
Farmers	Utilize water that may be polluted with or deliberately augmented by sewage. Provides access to water that may otherwise not be available (e.g. Hoskote) but water quality can be questionable if not managed.
Fishermen	Obtain fishing rights from FD but many lakes are increasingly encroached or polluted. Some have been rehabilitated and fishing rights appear highly sought after (e.g. Jakkur Lake).
Groundwater sellers	Provide water to households and industries via tankers. They are unregulated and prices, as well as quality, can vary.
Industries	Those in water scarce areas are being supplied by schemes to treat and sell Bangalore's sewage. Some also recycle their own wastewater on site.

5.7 Chapter Summary

This chapter has described in detail the relevant policy and legislative areas that affect RRR in Bangalore, referring to national, state and local legislation. It can be seen that some are highly supportive of reuse, while others either ignore the issue, principally those on the potential reuse side, or criminalize certain aspects (for example reuse of untreated wastewater in agriculture). Some give great detail to facilitate implementation, while others make vague recommendations.

It has also introduced the stakeholders that work in or are influenced by the various sectors that intersect in the RRR arena, ranging from national policy makers, to local government implementers and regulators, civil society groups, farmers, fishermen, urban residents, industries and the media. All have a role to play in RRR with come having greater involvement and influence than others. Similarly some are affected more than others by the legislation and actions of other stakeholders.

The analysis of the stakeholders, legislation, current practices and the institutional arrangements that these form is analysed further in the discussion.

6 Wastewater Reuse in Hanoi

6.1 Introduction

This chapter outlines, in less detail than for Bangalore, the stakeholders, policies and legislation surrounding wastewater and its use in Vietnam. It starts by briefly introducing the water and sanitation context, and giving some examples of wastewater use in Hanoi. What follows is a description of government and non-government stakeholders in the sector, and key policies and legislation, primarily in the environment, water, agriculture and aquaculture sectors.

6.2 The Water and Wastewater Context

6.2.1 Study Location

This research is undertaken for Hanoi City, the capital of Vietnam and the second largest city, located in the north of the country. Hanoi's area has increased recently to 3,323 km^2 and now includes 10 urban districts, one town and 22 district towns (GSOV, 2014), due to the decision to merge a province, a district and four communes into the metropolitan area of Hanoi. Hanoi's administrative boundaries are shown in Figure 6-1.

6.2.2 National Water and Wastewater Context

Vietnam's population is growing at a significant rate especially in urban areas, putting pressure on water and sanitation provision. The current population is nearly 89 million with a population density of 268 persons/km^2. The urban population is expected to reach 41.6 billion by 2020, 40 percent of the population of Vietnam (ADB, 2010). Seven percent of the population lives in Hanoi (GSOV, 2014).

Sanitation coverage is reasonably good at 65 percent nationally and 88 percent in urban areas (AECOM and Sandec, 2010) but only around 10 percent of the urban wastewater is treated (Australian Aid and the World Bank, 2013). The main form of sanitation in large cities is septic tanks and double vault or pit latrines (Viet Anh, 2010a; Urban Solutions, 2009). In Hanoi, 80 percent of the households are connected to septic tanks but supernatant flows into the sewer or drain. This leads to very long emptying cycles of 10 to 15 years (Viet Anh et. al, 2011). However, management of the waste after initial containment is limited with less than 10 percent of urban wastewater being treated (WHO et al., 2011). The majority of the grey water is disposed of directly to drains or the sewer (WEPA and IGES, 2013). Nationally, there are 24 centralized WWTPs, in eight urban areas, treating about 670,000 m^3 day^{-1} (Tien, 2013 cited in WEPA and IGES, 2013). In addition it is estimated that there are several thousand decentralized WWTPs installed across the country, although the total treatment capacity is unknown (Viet Anh, 2010b)

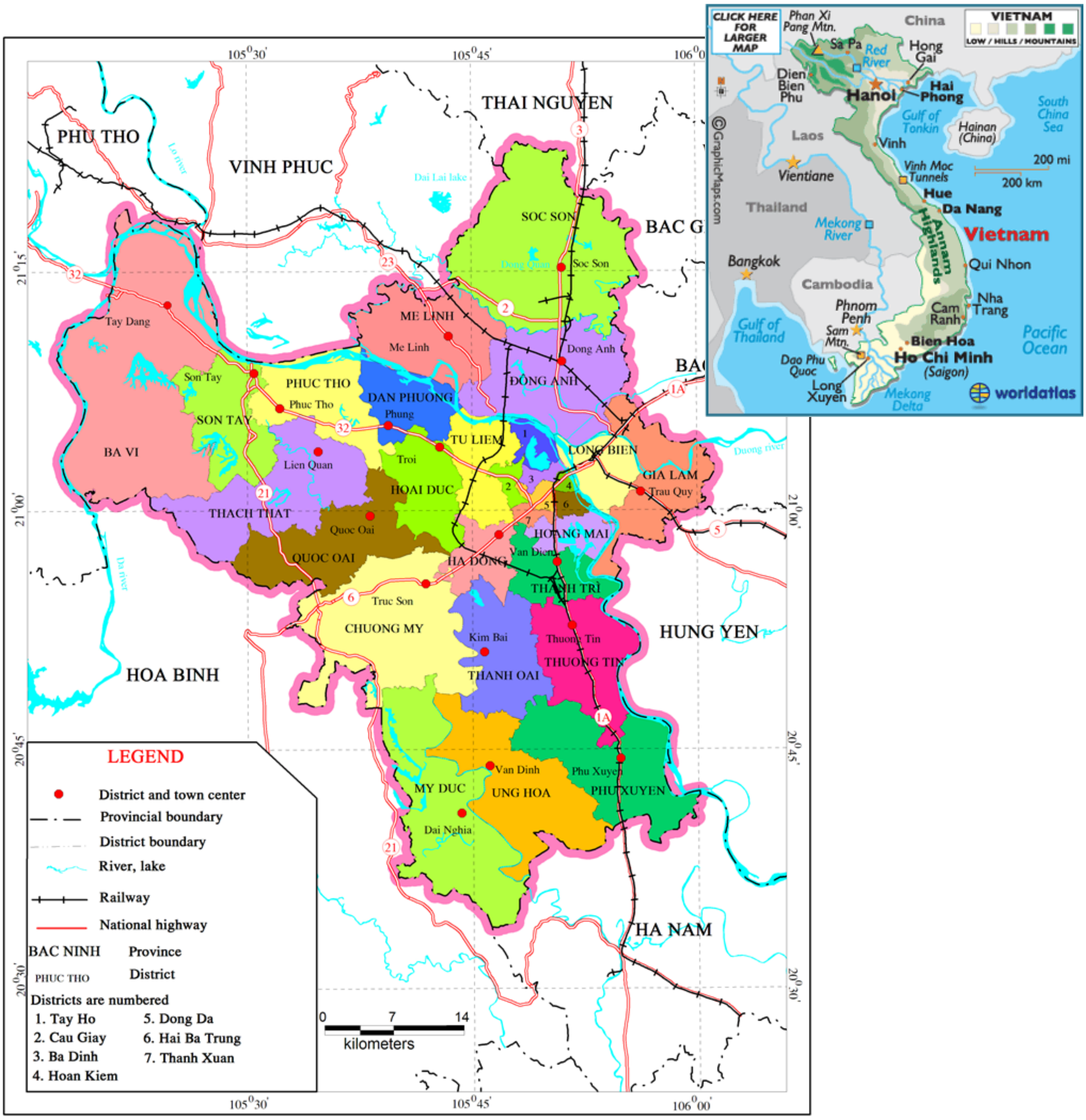


Figure 6-1. Administrative map of Hanoi in 2013
Source: Thuy (2014)

Water pollution is severe, emanating from urban areas and the many industrial clusters. Waterborne diseases are widespread, with hospitals registering 250,000 cases of diarrhoea a year and 44 percent of children have been infected with some kind of intestinal worm (UNICEF, 2006). The cost in terms of economic losses is estimated at USD 780 million each year or 1.8 percent of GDP (World Bank, 2008; in AECOM and Sandec, 2010).

Drainage coverage in major cities in Vietnam is about 70 percent but is as low as 10-20 percent in category IV and V urban areas. These systems usually receive not only drainage water but also wastewater from septic tanks and latrines. The wastewater carried often flows directly into open water bodies, and poor management contributes to flooding and pollution (WHO et al., 2011).

Water demand is high with 82 percent of the consumptive river water use in Vietnam being diverted to agriculture and a further 11 percent to aquaculture (ADB, 2010). Domestic demand is growing and infrastructure and resource management is not keeping pace. Sixty nine percent of the total urban population are served by pipe-borne water but there are delivery problems, leaks and water ingress, and the quality of the water does not reach the standards set by the Ministry of Health (WHO et al. 2011). In Hanoi, groundwater has been over exploited, so the city government has prohibited the construction of new wells. In future, the city will rely on surface water from the Da, Red and Doung Rivers (WHO et al., 2011), despite reports of high pollution levels by the Institute for Environmental Science and Development (VESDEC) (Nhien, 2014).

In addition to the water requirements of agriculture, the sector also consumes large quantities of fertilizer, amounting to over 10 million tons per year. Local urea production can meet this demand but is costly. Diammonium phosphate (DAP) use amounts to over 1.4 million tons annually of which 0.5-0.6 million tons is imported. All potassium fertilizer is imported but does not meet the annual demand of 400,000 tons (Ninh, 2012). Part of this demand could be met by wastewater.

6.2.3 Wastewater Use in Hanoi

Several examples of wastewater use have been reported for Hanoi, mainly in agriculture and aquaculture. Raschid-Sally and Jayakody (2008) estimated that 658,000 farmers use wastewater to irrigate 43,778 ha of land in Hanoi, for example in Tran Phu and Bang B, Hoang Lien commune, District Hoang Mai and Thanh Tri, Hanoi (Khai et al., 2007). Most of this reuse is unplanned, unofficial and indirect, taking the form of extraction from polluted water. A study of river water quality estimates that the total wastewater load received by the four main rivers that drain Hanoi is 315,000-355,000 m^3 day^{-1} (Dao et al., 2010). This gives an indication of the potential for reuse.

Thanh Tri District is a well-documented example of the use of wastewater in agriculture and aquaculture. It is a peri-urban district located in the south of Hanoi. Irrigation systems designed to take water from the To Lich River have been in use since the 1960s. Over the years the water quality has impacted crop yields and some farmers have converted to aquaculture in collaboration with the

Local Agriculture Cooperative (Huong et al., 2012). A field study on wastewater-fed aquaculture production in Thanh Tri, found that the total aquaculture area was 1,121 ha (19% of total farmed area) in 1995, an increase of 120 percent from 1985. More than 3,000 tonnes of fish are produced in this area annually – 10 percent of the total fish supply for Hanoi city (Hoan, 2001). A study in 2002 of Yen So commune, Thanh Tri District, showed that Kim Nguu River is used to supply water to around 185 ha of fish ponds. A further 25 ha of vegetables are irrigated by this river and water from the fish ponds flows onto paddy and vegetable fields (WHO et al., 2011). Aquatic vegetable and fish production can generate USD 5,760 ha^{-1} yr^{-1} and USD 7,200 ha^{-1} yr^{-1} respectively (Huong et al., 2012).

Of particular note in the Hoan (2001) study was that all the farmers interviewed displayed a strong willingness to obtain wastewater and improve their system of production, and that the long term use of wastewater had resulted in an effective system that had become part of the district development plans.

In terms of planned use, a number of WWT facilities have been developed, such as the Yen So Sewage Treatment Plant, the largest of its kind in Vietnam, which was handed over to Hanoi SADCO in 2012. It is capable of treating 200,000 m^3 of sewage per day, half of the total amount produced daily in Hanoi (Nhandan, 2013). There is also a 500 m^3 day^{-1} WWTU plant, developed by Odis. However, it is difficult to obtain information on the actual functioning of these plants (Odis, nd).

6.3 Administrative Setup

6.3.1 The Structure of the State System

Law making and law enforcement is undertaken at a number of levels in Vietnam. Understanding these levels is a first step in unravelling intuitional arrangements in Vietnam. At the highest level is the **National Assembly**. The legislative body for law making. The National Assembly, appoints the **President** (head of state) and the **Prime Minister** (head of government), the **Chief Justice** of the **Supreme People's Court of Vietnam**, the Head of the **Supreme People's Procuracy** of Vietnam and the 21-member **Government** (Cima, 1987; Embassy of Vietnam, nd). This hierarchy can be seen in Annex 10.

The **National Assembly** is responsible to the people and has the power to draw up, adopt, and amend the constitution and to make and amend laws. It also has the authority to establish and dissolve ministries and ministerial level agencies; to adjust the boundaries of the provinces and cities; and to legislate and implement state plans and budgets (ISOS, 2012; Wikipedia, 2014). The

National Assembly is convened twice a year and at other times is represented by the **Standing Committee of the National Assembly**. Their duties include: explaining and interpreting the constitution, laws, acts, and ordinances; promulgating ordinances; supervising the implementation of the constitution and laws, and the activities of the Government, the Supreme People's Court, and the Supreme People's Procuracy; and guiding the activities of **provincial People's Councils** (local legislative bodies). **The government** is the executive arm of the National Assembly and the highest administrative body of the Vietnamese state (Loan, 2010).

6.3.2 Local Level Organizations

The structure of the government system in Vietnam is such that many roles are devolved to lower levels, including Province, District, Municipality, Town and Commune. The country has 58 provinces and five cities, which are under direct central rule. Below that are Districts, Provincial Cities, towns, townlets, wards and communes (Figure 6-2). There are over 700 urban areas in Vietnam classified by administration (i.e. central government, provincial or district administration) and by hierarchy based on parameters such as population and level of infrastructure (Annex 11; Figure 6-2). Hanoi is classified as a national centre, along with eight other cities, and is under central government administration.

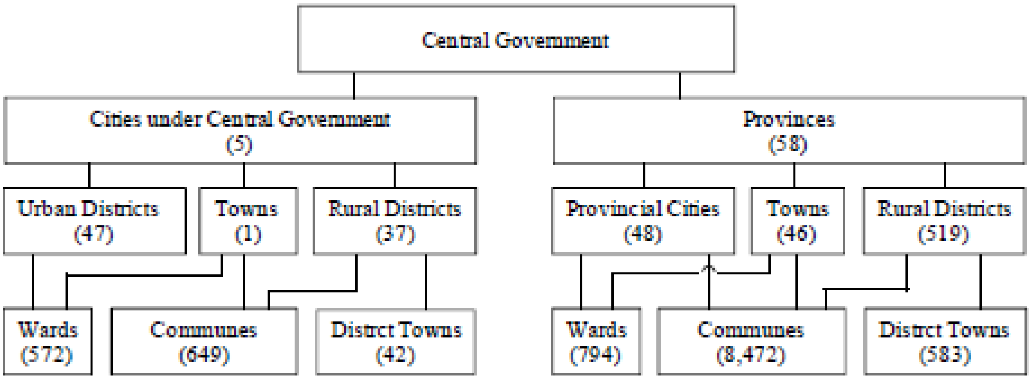


Figure 6-2. Administrative structure of Vietnam
Source: Nippon Koei and Yachiyo Engineering (2011)

People's Councils (PCs) are the elected state authority in each locality (e.g. Province, District and Commune) (Constitution, 2001, Article 119; Loan, 2010). People's Councils can pass resolutions on measures for: the implementation of the constitution and the law at local level; on the plan for socio-economic development; and the execution of the budget (Constitution 1992, Article 120). Revenue allocations and budgets for provinces, districts and communes must be approved by the provincial PCs.

People's Committees elected by the PCs, are the executive arm of the PCs and administrative bodies with responsibilities for implementing the constitution, laws and other legal documents adopted by national agencies and resolutions of the PCs (Constitution 1992, Article 123). The People's Committees work across almost all sectors and have departments mirroring all the main ministries (World Bank, 2006). A key component of Vietnam's reform program of the past two decades has been the process of devolving responsibilities to decentralized agents such as the People's Committees (ADB, 2009). They have established several organizations such as **Urban Environmental Companies (URENCOs)** to enable them to implement their responsibilities. The People's Committees have multiple roles throughout various areas of waste management including environmental protection of water bodies, and urban planning and infrastructure development, including WWT.

6.4 Stakeholders and Responsibilities

This section identifies the key stakeholders in water and wastewater management, including planning, monitoring, financial management and construction. It also considers those stakeholders who are engaged in (potential) reuse activities such as agriculture and aquaculture. The section is divided into government stakeholders at national and local level, and non-government stakeholders.

6.4.1 Ministries and National Agencies

National-level organizations responsible for water, wastewater and reuse sectors span a large number of ministries, bodies and committees.

The **Ministry of Construction** (MOC), constituted under Decree 62/2013/ND-CP, Defining the Functions, Tasks, Powers and Organizational Structure of the Ministry of Construction is responsible for construction, architecture, planning and urban technical infrastructure relating to drainage and wastewater management (MOC, 2009). The MOC is involved in sector development planning, policy formulation and regulations; it develops construction standards, rules and regulations; and administers and monitors major urban development projects (ADB, 2010). Under **Decision No. 1930/QD-TTg approving orientations for development of water drainage in Vietnamese urban centers and industrial parks up to 2025 and a vision towards 2050**, MOC is tasked with development of drainage; proposing priority projects for donor and state funding; studying models of concentrated and scattered WWT technologies; and promulgating technical regulations on sanitation facilities and drainage. These activities are to be undertaken in collaboration with other ministries and provincial PCs. They also coordinate with Ministry of Natural Resources and

Environment (MONRE) on an urban water supply and drainage database (No. 1930/QD-TTg, 2009) and with the Ministry of Health (MOH) to develop septic tank and septage reuse guidelines (AECOM and Sandec, 2010).

MOC is **specifically tasked with encouraging reuse** in **Decision No. 1929/QD-TTg Approving Orientations for Development of Water Supply in Vietnam's Urban Centres and Industrial Parks up to 2025, and a Vision Towards 2050**, which includes the aim: '*To encourage the rational, economical and safe use of clean water and to apply technologies of reusing water for different purposes*'. However, this is the only statement on reuse that can be found in the Decision.

Within the MOC is the **Technical Infrastructure Agency (TIA),** which consists of the **Division of Drainage Management and Wastewater Treatment**; and the Division of Solid Waste Management. The TIA's role includes urban water supply, drainage and industrial parks, including planning and establishing technical norms (MOC, 2009).

The **MONRE** is tasked with ensuring compliance with the Law on Environmental Protection (LOEP), 2014, and the Law on Water Resources (LOWR), 2012, including all aspects of water pollution. It is also responsible for developing the national water resources master plan with other ministries (Article 21). Under their purview are the **Environmental Impacts Assessment and Appraisal Department** and the **Department of the Environment**.

Vietnam Environment Administration (VEA) is a subsidiary body under MONRE, tasked with assisting with environmental management. Decision No. 25/2014/QĐ-TTg, regulating functions, duties, authorities and organizational structure of VEA, requires VEA to draft relevant legislation and plans in relation to environmental management, and oversee such things as pollution management, monitoring and remediation (VEA, 2014a). They are responsible for promoting recycling but no mention is made of wastewater reuse. Within VEA is the **Department of Waste Management and Environment Promotion,** and the **Department of Environmental Pollution Control** (VEA, 2014a).

They are an active organization working with NGOs and other government departments to develop a dedicated pollution law, as well as monitoring and reporting on polluters. In 2013 for example, they inspected 429 industrial zones nationwide and identified 157 enterprises committing violations of the LOEP, fining them a total of USD 1.57 million (Vietnam Environment, 2013). However, the enormity of the industrial wastewater problem seems to dominate their work. In 2012 the deputy chief inspector of the Ho Chi Minh City (HCMC) Department of Natural Resources and Environment (DONRE) reported that there were 10 environmental inspectors for 150,000 industries (Vietnam Environment, 2012).

The **Ministry of Agriculture and Rural Development (MARD),** within which are the: Agriculture Department; Department of Water Resources; Veterinary Department; and Plant Protection Department, is tasked with state level management of agriculture, forestry, irrigation, fisheries and fertilizers. Their role is defined in Decree No. 01/2008/ND-CP and Decree No. 86/2003/ND-CP defining the functions, tasks, powers and organizational structure of the MARD; Decree No. 202/2013/ND-CP on the management of fertilizers; and Decree No.178/2007/ND-CP on stipulation of functions, mandates, authorities and organization structure of Ministries (MOJ, nd a, b; MARD, nd).

In relation to **farming**, MARD must develop and submit plans, implement government programmes and strategies, disseminate information and raise public awareness about. They have an important role in overseeing crop and livestock masterplans, including safe production of agricultural products and improving fertility of agricultural land (MARD, nd). In the **fisheries** sector MARD performs a similar governance role, developing and overseeing master plans, regulating fishery exploitation, monitoring and ensuring conservation. It governs aquaculture activities based on approved plans (MARD, nd). The MARD is also required to oversee aspects of **water resources management** including river basin development, construction and use of irrigation works and rural water supplies. Their role extends to rural development including reducing poverty and hunger (MARD, nd). Of particular relevance to **wastewater use** is their role in food hygiene and safety systems, which involves: good manufacturing practices (GMP), good aquaculture practices (GAP), code of conduct (CoC), good hygiene practices (GHP) and hazard analysis critical control point/risk management (HACCP/RM) in production, processing and transportation. They also issue regulations and technical standards for food quality and safety, and safe production, preservation and processing (MARD, nd).

The **Ministry of Health (MOH)** has responsibility for ensuring food safety, disease prevention and environmental health under Decree No. 63/2012/ND-CP defining the functions, tasks, powers and organizational structure of the Ministry of Health. It must monitor, prevent and control infectious and occupational diseases, accidents and injuries, as well as hygiene, environmental and occupational health, and drinking water quality. The MOH develops and promulgates technical regulations on food safety during production and processing. They also coordinate with MONRE, MOC and others to issue regulations and standards on health related environmental protection.

The **Ministry of Planning and Investment (MPI)** advises the government on foreign direct investment (FDI) and how to attract overseas development aid (ODA). In collaboration with the MOF, it sets the criteria for allocation of development capital from the state budget. It also evaluates the effectiveness of its use and PPP investment projects (MPI, nd). Its role is defined under Decree No. 178/2007/ND-CP defining the functions, tasks, powers and organizational structures of the ministries and ministerial-level agencies. Under the MPI is the **Agency for Enterprise Development (AED),** which provides support to small and medium scale enterprises (SMEs) and regulatory information through its portal and the SME Technical Assistance Centres (TACs), as well as developing SME policies and 5-year plans (Business Portal, 2014). The AED is governed by Decree No. 90/2001/ND-CP on Supporting Development of SMEs.

The **Ministry of Finance (MOF**) decides, with other relevant ministries, on expenditure on infrastructure such as waste management facilities. It prepares and administers the budget, including those for externally funded projects, collects taxes and fees and manages State enterprises, assets and debts, as set out in Decree No 118/2008/NĐ-CP Defining the Functions, Tasks, Powers and Organizational Structure of the Ministry of Finance.

Two important non-ministerial organizations that operate at the national level are the **Vietnam Fatherland Front (VFF)** and the **Vietnam Women's Union (VWU)**. The VFF, an official organization with constitutional rights, collects opinions, petitions, and grievances through consultations with its network of mass organizations, and reports them to the National Assembly. The LOWR (2012, Article 5) requires them to mobilize people to participate in water resources protection. The VWU is involved in community work such as health education, microfinance and community mobilization.

6.4.2 Provincial and Local Government Stakeholders

6.4.2.1 Wastewater Management

Urban water supply, waste management and sanitation are managed by many agencies including MOC, MOH, MONRE and the Ministry of Science and Technology (MOST). The line ministries have their corresponding departments in the structure of the provincial government (ADB, 2010), within the PCs, which manage local level WSS (Figure 6-3).

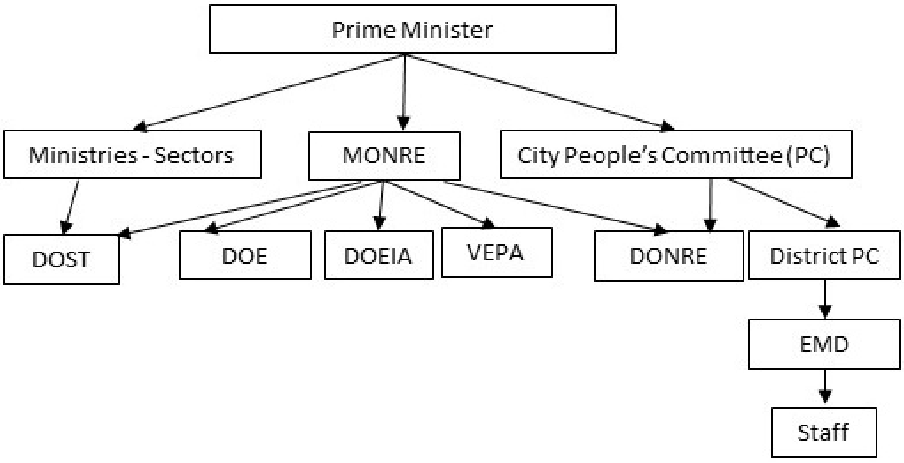


Figure 6-3. Organizations responsible for water and sanitation at national and local levels
Source: MOC and GIZ (2012)

Responsibility for WSS nationally is shared principally between the MOC in urban areas and the MARD and MOH in rural areas (for water supply and sanitation respectively). Water source development and water source protection are the responsibility of MONRE. Water quality and standards for drinking water and domestic water are the remit of MOH. Investment planning and investment decisions for the development of WSS are the responsibility of MPI, in co-operation with related ministries and agencies, as well as Provincial PCs, and when relevant, donors. The **MOC** assumes the prime responsibility for, and coordinates with concerned ministries and Provincial PCs, in realizing **urban water drainage plans and programs**.

People's Committees have perhaps the most extensive role covering environmental protection, waste management, urban infrastructure, planning and budgets. Of particular note is their remit under the LOEP (2005, 2014)[17]. At the provincial level, they exercise executive authority over all provincial functions including WSS and drainage development. They must organize the implementation of the Government's **Decree No. 88/2007/ND-CP on Urban and Industrial Park Water Drainage**; consolidate water drainage management in their respective localities; coordinate with other PCs on basin water management; encourage investment in urban centres; formulate, organize and oversee water drainage; and carry out communication activities on water drainage and environmental protection in accordance with **Decision No. 1930/QD-TTg.** Decisions on water tariffs are also made by Provincial PCs in accordance with the guidance given by MOC and MOF.

[17] See the Policy, Legislation and Implementation section for details.

Town PCs are usually responsible for administration of the town urban infrastructure and WSS services. Responsibility for developing and approving environmental protection planning for urban areas also lies with the Provincial and District PCs in accordance with the Law on the Construction (LOC) for urban centres and residential planning (LOC, 2008).

In the largest cities, drainage and WWT services are provided by **state owned enterprises (SOEs)** established by the PCs. These **URENCOs and urban public works companies (UPWCs)** operate in accordance with **Decree 56-CP on The State Public-Utility Enterprises, 1996** and the **Law on State Enterprises (LOE), 2003**. They supply public services in compliance with State policies and plans, and operate mostly on a non-profit basis. They are also involved in a range of other activities to meet local needs or to supplement company income. However, they have been criticized for lacking commercial orientation and rely largely on subsidies from PCs (ADB, 2010).

In Hanoi, and other big cities such as HCMC, **Sewerage and Drainage Companies (SADCOs)** are the centralized agencies with official responsibility for wastewater management, while URENCOs deal with solid waste (Cau et al., 2007). SADCOs are public utility enterprises under the **Department of Transport and Urban Public Works (DTUPW)** of the city authority (Figure 6-4) and are primarily responsible for provision of sewers and drains (Viet Anh et al., 2004; GHK International, 2005). In Hanoi, approximately 60 percent of the city's area is fully served by SADCO drains while local authorities are responsible for tertiary sewers in coordination with SADCO, due to the limited capacity of SADCO. SADCO also manages ditches, channels and rivers (GHK International, 2005). SADCO enterprises have clear organizational structures and well-established work procedures. Hanoi SADCO is divided into four operational units (enterprises), each with a specific responsibility in different districts (GHK International, 2005). Each enterprise operates as a line department under SADCO and their main tasks are:

- To maintain facilities for sewerage and drainage.
- To develop plans for effective management of the sewerage and drainage system.
- To repair and rehabilitate the existing sewerage and drainage system.
- To provide wastewater and environmental sanitation services for individuals and organizations.
- To cooperate with local (ward, district) authorities to raise public awareness and participation in management and protection of the sewerage and drainage system (GHK International, 2005).

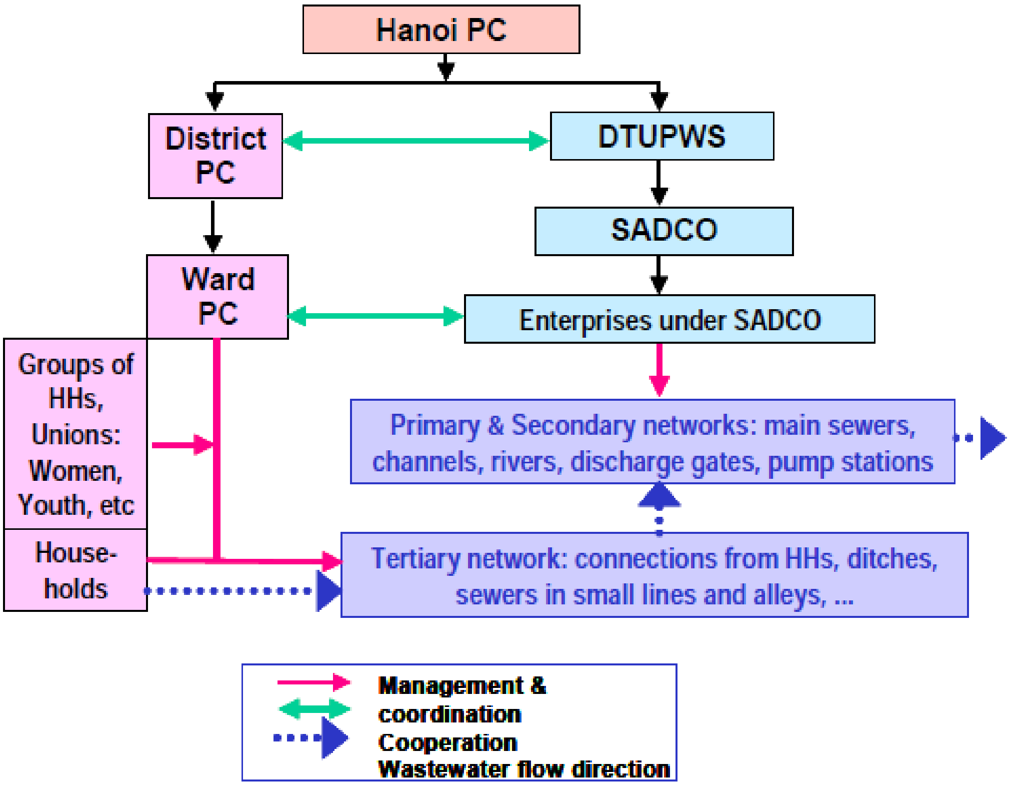


Figure 6-4. The relationship between SADCO and other stakeholders in wastewater management
Source: GHK International (2005)

Of SADCO's O&M expenses, 25 percent are covered by the surcharge on the water supply fee and the remaining funds come from the city government based on a yearly budget allocation. Additional sources of revenue at the commune/ward level include: labour fee based revenue and revenue from lease of ponds for fish farming.

The **DONRE** is responsible for monitoring and controlling wastewater discharged to receiving water bodies and for the Environmental Protection Fee according **to Decree 67/2003/ND-CP on Environmental Protection Charges for Waste Water** and **04/2007/ND-CP** (amending and supplementing a number of articles of Decree No. 67/2007/ND-CP) (MOC, 2009). The **Department of Finance (DOF)** is responsible for advising the City PCs to allocate budget for wastewater management. The Department of Planning and Investment (DPI) is responsible for advising the city PC on new investments and the extension of existing drainage or sewerage systems (MOC and GIZ, 2012). However, coordination has not been as it should be and there needs to be better joint planning and implementation by the organizations listed above (WHO et al., 2011).

6.4.2.2 Agriculture and Aquaculture

MARD performs state management functions for agriculture, forestry, fisheries, irrigation, water services and rural development nationwide, including state management functions with regard to delivery of public services in rural areas (ISC, nd). The provincial counterparts to the MARD are the Departments of Agriculture Development (DARDs), of which there are 63 (MARD, nd). They operate as local branches of MARD, in conjunction with provincial and municipal PCs (ISC, nd). Part of their role is to support small-scale irrigation infrastructure development, and assist in technical aspects and planning of irrigation and drainage schemes. At local level, there are Irrigation and Drainage Management Companies, Water User Associations and some Participatory Irrigation Management institutions (Wikipedia, 2016).

In the fisheries sector there are three administrative levels (central, provincial and district), there are also unions and associations which support the development of the fisheries sector, these are the Labour Union of Viet Nam's Fisheries Sector, Viet Nam's Fisheries Association and the Viet Nam Association of Seafood Exporters and Producers (FAO, 2016).

6.4.3 Non-Government Stakeholders

There are also a number of other stakeholders that influence or are affected by these policies and laws. These include the private sector (formal and informal), research and development organizations, society as a whole and the various individuals and groups within it (e.g. farmers, fishermen), NGOs, CBOs and cooperatives. In Vietnam, many of the stakeholders in this group are relatively recent and are emerging post-doi moi[18]. As such, civil society is becoming an increasingly important voice but is still relatively weak. As this changes the effects will be felt in the RRR sector.

6.4.3.1 Civil Society, CBOs and NGOs

There are five important decrees or laws currently in existence, which govern different elements of civil society organisations (CSOs) in Vietnam. The **Grassroots Democracy Decree 79 (2003)**[19] institutionalises the participation of local communities and CBOs in development activities at the level of the commune. The **Law on Cooperatives No. 25/2012/L-CTN, 2003**, recognises cooperatives as voluntary organisations functioning as independent economic entities. **Decree 177/1999/ND-CP** promulgating the regulation on organization and operation of the social funds and charity funds. The **Law on Science and Technology, No. 21/2000/QH10 of June 9, 2000**, recognises professional

[18] The economic reforms initiated in Vietnam in 1986 intended to create a socialist-oriented market economy.
[19] 'Decree on the issuance of regulation on implementing democracy in communes', but popularly known as the 'grassroots democracy decree' (UNDP, 2006).

associations as independent service organisations and is the law under which most development NGOs are registered. This requires them to justify and link their existence and operation to science and technology (Sabharwal and Huong, 2005). The **Law on Associations, 2003** (Decree 88) defined associations but it was limited and was felt to restrict and facilitate associational activity in equal measure, with an emphasis on control (Sidel, 2008; Sidel, nd). It was perceived by the voluntary sector as 'preventing a range of organizations from registering and expanding … through … a highly detailed and restrictive system of approval'. In 2009 the Ministry of Home Affairs revised the 2003 **Decree on the Organization, Activities and Management of Associations, Decree No. 45/2010/ND-CP (2010)**, which continues to govern the registration, operations, activities, and management of a wide range of associational groups (Sidel, nd). It has been widely criticised and 22 independent CSOs issued a press release in 2015, stating that 'the draft law serves to further bolster the communist party's stranglehold on civic spaces in the country'. They contend that the primary function of the draft law is to enhance the government's mandate to regulate, control, monitor, and manage civil society (DVOV, 2015).

Despite this, a comprehensive study undertaken by The Asia Foundation (Taylor et al., 2012) on civil society in Hanoi and HCMC highlights the growth in CBOs as a result of the relatively more hospitable environment provided by the state for civic engagement. They recognize that the complex nature of the development process requires contributions from many stakeholders, and CSOs can play a constructive role in providing feedback to improve the effectiveness of government policies. However, this relationship between the state and civil society in Vietnam is still evolving. The ongoing lack of a clear legal framework for CSOs creates an uncertain operating environment and reinforces the importance of personal networks (Taylor et al., 2012). Sidel (nd) suggests that the voluntary sector is filling social needs that the state is retreating from.

One organization that is particularly relevant is the **Coalition for Clean Water (CCW)**, also known as the 'Coalition to Advocacy for Water Pollution Control and Clean Water Act'. It is an open network of organizations and individuals concerned with protection and control of water pollution in Vietnam. The **Center for Environmental and Community Research (CECR)** is the coordinating agency. It includes non-government, research and communication organizations, management agencies, the public, businesses, professionals, scientists and lawyers working together to monitor the construction and implementation of policies to protect clean water and prevent pollution, contributing to development of the **Clean Water Act (CCW, 2014)**. They are engaged in discussions with the MONRE, MOIT and MARD for a law on water pollution control (CCW, 2015). They also work with **media agencies**, which they believe have, over the years, 'brought to light many culprits of water pollution and helped raise public awareness of protecting the environment' (CCW, 2014).

6.4.3.2 Mass Organizations, Professional Associations, NGOs and CBOs

Mass organizations have been part of society in Vietnam and the focus of the government since the first National Congress of the Communist Party of Vietnam in 1935. They maintain large memberships of several million and continue to play a dominant role in civic life in Vietnam. They operate through extensive bureaucratic structures at all government levels. The mass organizations include the **Vietnam Women's Union, Farmers' association, Vietnam Fatherland Front, General Federation of Trade Union, Labor Confederation, Ho Chi Minh Communist Youth League, Vietnam Peasants Association, Vietnam War Veterans Association** (Taylor et al., 2012; Sidel, nd).

Professional associations have also operated at both national and local levels since independence. By 2006 there were 364 associations registered at the national level and by 2010 there were some 15,000 operating at all levels across the country. Examples are the **Vietnam Union of Science and Technology Associations (VUSTA), the Vietnam Union of Art and Literature, the Vietnam Union of Friendship Organizations (VUFO),** as well as a wide variety of other associations related to sports, economic activities, charitable activities and businesses. At the local level, these associations are registered under local governments but whether operating at national or local level, most of them rely on state subsidies (Taylor et al., 2012).

6.4.3.3 International Non-Governmental Organizations

There are numerous international non-governmental organisations (INGOs) working in Vietnam, often filling the space that would usually be occupied by NGOs in other countries. Many of these INGOs are linked through the **VUFO-NGO Resource Centre**, which facilitates the work of INGOs and contributes to the sharing of information, resources and experiences between the INGOs, their partners and local organisations. It also aims to strengthen relationships and enhance dialogue between INGOs and other development actors in Vietnam, including government agencies and donor organisations. It was established in 1993 and now has 111 INGO members (VUFO-NGO Resource Centre, 2015).

The VUFO-NGO Resource Centre has several working groups including the '**Sustainable Agriculture and Natural Resources Management Working Group**' and the 'W**ater Supply, Sanitation and**

Hygiene Working Group'. Both groups include, in addition to INGOs, bilateral donors, the United Nations network, and the Vietnamese Government (VUFO-NGO Resource Centre, 2015).

6.4.3.4 The Private Sector

The adoption of Doi Moi in 1986 and other crucial legal reforms embodied in such laws as **the Enterprise Law, the Land Law, and the Investment Law** have spurred economic development, encouraging the emergence and growth of market activities, the private sector, and foreign investment in a country long governed by central planning. The private sector in particular is playing an increasingly significant role in the economy (Ninh, 2010) and, since its accession to the World Trade Organization in 2006, Vietnam has continued to improve its regulatory environment for business (Stallard, 2007).

There is still much to do however to strengthen the private sector and to open up areas that have traditionally been managed by the public sector to these emerging companies. Examples include the energy sector, with its roadmap for full access by 2022 and waste management which is still dominated by government businesses despite policy and legislation advocating private sector participation and PPPs. Examples have emerged over the past few years of PPPs in the WWT sector, such as BOT contracts for WWTPs (ADB, 2010; Odis, nd; Nhandan, 2013).

6.4.3.5 Donors

Key funding agencies for sanitation and wastewater projects include: ADB, Belgian Technical Cooperation Agency (BTC), Danish International Development Agency (DANIDA), Research Institute for France (IRD), JBI), German Reconstruction Credit Institute (KfW), Swiss Agency for Development and Cooperation (SDC), and the World Bank (USAID et al., 2010). Recently the Japanese government has awarded a USD 130 million contract to a private company to improve an existing WWTP in HCMC (Water World, 2015). The World Bank is also funding sewerage and WWT in HCMC under the second phase of the HCMC Environmental Sanitation Project, which began in 2001 and is due to be completed in 2019 (TN News, 2013). They have pledged a further USD 450 million to continue the project. This will fund infrastructure as well as capacity building and awareness raising (World Bank, 2015). In Hanoi, JICA is funding sewerage and WWT based on a PPP approach (Vietnam Environment, 2011).

The major wastewater infrastructure projects being funded in Vietnam include sewerage and WWT but there is little mention of reuse components. The World Bank has also funded pollution management projects including reviewing the legal and regulatory aspects of pollution management and industrial WWT (Water-Technology.net, 2012).

1.1.1.1 Waste Producers and Users

Urban households are the waste generators but also benefit from improved wastewater management and RRR. They are required to be connected to septic tanks, which drain into sewers where they exist. They are also required to pay drainage fees set by the PCs. In the peri-urban area households may take on a different significance if they are also making use of the waste, in agriculture and aquaculture for example. Many farmers and aquaculturalists pump or channel wastewater from polluted rivers to irrigate land and fill aquaculture ponds. Estimates suggest that some 658,000 farmers make use of wastewater in Hanoi and the surrounding area (Raschid-Sally and Jayakody, 2008).

6.4.4 Summary of Stakeholders

The stakeholders discussed in this section are listed in Table 6-1 with a brief description of their role to enable comparison of their remits, and overlap or gaps in roles.

Table 6-1. List of key government stakeholders in WSS

Stakeholders	Role and related legislation
PM	The Prime Minister approves the WSS strategy and orientation and laws
MOC	Ministry of Construction is the line ministry of urban WSS and drainage under Decree 62/2013/ND-CP. Specifically tasked with encouraging reuse
MONRE	Ministry of Natural Resources and Environment manages water resources, water use, pollution and hydrology. Responsible for ensuring compliance with the LOEP, 2005 and the LOWR, 2012 and for the national water resources master plan.
MARD	Ministry of Agriculture and Rural Development is the line ministry of rural water supply, sanitation and drainage. State management of agriculture, forestry and irrigation. Includes managing river basins, and construction, use and protection of irrigation works and rural water supplies.
MOH	Ministry of Health controls drinking water quality. Monitors and regulates pollution and environmental health. Food safety, disease control and prevention. Environmental and occupational health.
MPI	Ministry of Planning and Investment’s remit includes investment planning; socio-economic development; advice on FDI; proposals to attract ODA. Set criteria for allocation of investment capital and evaluating effectiveness. Certify PPP investment projects.
AED	Agency for enterprise Development provides support to small and medium scale enterprises (SMEs) through their portal and Technical Assistance Centres.
MOF	Ministry of Finance distributes state funds, sets annual goals and regulates accounting. Collects taxes and fees, and manages state enterprises.

Stakeholders	Role and related legislation
MOST	Ministry of Science and Technology manages standardization and technology in water and sanitation.
MOET	Ministry of Education and Training manages integration of health, water and environmental issues into standard curricula and lesson plans.
VFF and VWU	Vietnam Fatherland Front (VFF) collects opinions, petitions, and grievances and reports at the opening of the National Assembly. Vietnam Women's Union (VWU) undertakes community mobilization, health education and microfinance.
PCs	People's Committees have multiple roles throughout various areas of waste management including environmental protection of water bodies, and urban planning and infrastructure development, including WWT. Several roles are outlined in the LOEP, 2014.
DOC and DTPW	Department of Construction and Department of Transport and Public Works supervise operations of the water supply companies (WSCs).
WSCs	There are 64 state-owned Water Supply Companies in 61 provinces and cities
URENCOs/ SADCOs	Urban Environmental Companies (URENCOs) and Sewerage and Drainage Companies (SADCOs) are responsible for drainage and WWT in cities
DONRE	Department of Natural Resources and Environment monitors and controls wastewater discharge and collects the Environmental Protection Fee
DOF	Department of Finance advises PCs on budget allocation
DPI	Department of Planning and Investment advises the city PC on new investments and the extension of existing drainage or sewerage systems
CCS	Coalition for Clean Water is a network concerned with protection and control of water pollution and development of legislation
Urban residents	Generate wastewater. Required to connect to sewage network and pay drainage and environmental fees.
Farmers	Thousands of farms and aquaculture ponds are estimated to make use of wastewater in and around Hanoi.
Donors	Several international donors fund sanitation and wastewater management

6.5 Policies, Legislation and Implementation

This chapter gives an introduction to the legislation covering wastewater and environmental pollution, as well as reuse elements, principally in agriculture and aquaculture. Several laws and related pieces of legislation were reviewed of which the most salient are presented here. Two laws in particular stand out as being relevant to waste management and RRR, those being the Law on Environmental Protection (LOEP), 2005 and 2014 and the Law on Water Resources (LOWR), 2012. Following from these, and other laws, are multiple pieces of legislation giving guidance on implementation or amending elements of the Laws. Due to this complexity, the chapter starts with an explanation of the system of law making in Vietnam and the various layers of legal documents that exist. This is followed by descriptions of the relevant legislation.

6.5.1 Legislation and the Promulgation of Legal Documents

The legal documents system of Vietnam, according to the Constitution, 1992 (amended 2001) and the Law on Promulgation of Legal Documents (2008) (LPLD, 2008), has a hierarchy from high to low legal force. They are divided into laws and ordinances and 'secondary regulations'. **Laws and ordinances** are passed by the National Assembly (Article 83 Constitution 1992). **Secondary regulations** are issued by state organizations (administrative and judicial organizations) as legal documents of a lower rank (Loan, 2010). The title of each legal instrument normally sets out the other legal instrument(s) to which it is subordinate. If a legal instrument is intended to replace an earlier one, this will usually be mentioned.

The legal documentation system has changed over the years due to the considerable confusion it caused and the plethora of legislation that had been past. Consequently, the number and type of legal documents that certain agencies can create has been rationalized under LPLD, 2008. The current legal system consists of the following (see also Annex 12):

- **The Constitution** is passed by the ***National Assembly***;
- **Laws and Codes** are passed by the ***National Assembly*** and are Vietnam's highest form of legal direction;
- **Ordinances and Resolutions** are also passed by the ***National Assembly***. Resolutions aim to interpret the constitution, laws and ordinances;
- **Orders** are issued by the ***State President*** on the promulgation of Laws and Ordinances;
- **Decrees** are passed by the ***government*** and generally implement Laws and Ordinances. Decrees are often supplemented by more detailed Regulation;
- **Government Decisions** are issued by the ***Prime Minister*** on the implementation of regulations (see below);
- **Circulars, Directives and Ordinances** are issued by ***individual ministries*** and usually provide guidance as to how a particular ministry will administer a law or decree;
- **Guidelines** are policy outlines (not legal instruments) issued by the ***Prime Minister*** indicating that governmental committees should be set up to deal with the issue;
- **Ministerial decisions** promote regulations on certain Ministry-related issues. The LPLD, 2008 has done away with Ministerial Decisions but those created prior to 2008 may still be valid;
- **Regulations** are passed by local/provincial governments.

The revised LPLD, 2015, which will come into effect in July 2016, abolishes a further five types of legal document, including:

- Joint resolutions of the Standing Committee of the National Assembly or the Government;
- Joint circulars of ministers and heads of ministerial-level agencies;
- Directives of provincial PCs;
- Directives of district PCs; and
- Directives of commune PCs.

In addition, there are a number of **standards** which define technical requirements and characteristics, for example in relation to pollution or products. Decree No. 179/2004/ND-CP clarified the system of product and goods quality standards applied in Vietnam. The current system is based on **The Law on Standards and Technical Regulations No. 68/2006/QH11**; and Decree No. 127/2007/NĐ-CP Detailing the implementation of a number of articles on the Law on Standards and Technical Regulation issued by the Government on 1 August 2007. The terminology used is:

- **Vietnamese standard (TCVN)** applicable throughout the country;
- **Branch standard (TCN)** applicable throughout the country for goods without a TCVN; and
- **Base standards** (supersede Local Standards (TCV) and Manufacturer/Base Standards (TC)).

6.5.2 Water and Wastewater Related Laws and Regulations

The laws covering wastewater management from domestic properties, commercial properties and industries can be found in the **Law on Environmental Protection No. 52/2005/QH11** (LOEP, 2005, 2014); the **Law on Water Resources Order No. 15/2012/L-CTN** (LOWR), 2012; and the **Ministry of Construction (MOC) Building Code, 2008** (also referred to as plumbing code). The government's strategies on urban sanitation and industrial wastewater are formulated in **Decree No. 80/2014/ND-CP on The Drainage and Treatment of Wastewater** (under MOC's guidance), recently accompanied by **Decision 930/QD-TTg**, which provides future targets (ADB, 2010). A plethora of other decrees and directives are also relevant, covering WWT, compliance with water quality standards and conditions for licenses to discharge wastewater.

6.5.2.1 Law on Water Resources

The LOWR (2012) is the highest legal document on all aspects of water resources protection and lays down the '***principles of management, protection, exploitation and use of water resources***…' and makes it the '*responsibility of all agencies, organizations and persons to protect water resources … water quality and aquatic ecosystems, and remedy and mitigation of pollution, deterioration and* *depletion of water sources*' (Article 3). It also specifies the responsibility of the state and investors. '*State policies must include investment in and adoption of measures to encourage organizations and individuals to invest in research and application of technologies to treat wastewater up to the standards and technical regulations for reuse*' (Article 4). Details of relevance to WSS, WWTU and water pollution are provided in Annex 13, salient features are that:

- **A number of actions are prohibited under the LOWR (2012)** with the intention of protecting receiving waters including dumping wastes, discharging hazardous substances into water sources or other acts that cause water pollution of surface or groundwater. Damage must be remedied and compensation paid. Commercial and industrial premises must adopt measures to: treat, control and supervise the quality of wastewater; and to respond to pollution incidents (LOWR, 2012, Article 26 and 27).
- It also stipulates terms for **water resources master plans** (Section 2, Articles 14-24).
- **Section 3 of the LOWR, 2012, deals with 'Protection of Water Resources'.** The responsibility for protection of water resources, pollution prevention and ceasing or reporting violations is given to all organizations and individuals, including local authorities (Article 25).
- The Provincial PCs must take '*measures to prevent and restrict the expansion of polluted areas, handle and mitigate pollution in areas under their management…*' Where a perpetrator cannot be found the costs of remedying the situation will come from the State budget (Article 27).
- **Water resources used for certain purposes are protected under the LOWR (2012),** these include those used for domestic water supply and irrigation, as well as urban water bodies (Article 31).
- **Article 37 deals with discharge of wastewater** and requires master plans for urban areas and industrial zones to contain details of wastewater collection and treatment systems, as well as water sources capable of receiving these volumes.
- Organizations and individuals are expected to '*increase the use of recycled water and water reuse'* (Article 39).
- It encourages research into water conservation including '*Researching into and applying and developing technologies for using recycled water or reusing water so as to improve water efficiency in industry, construction and agriculture*' (Article 42).
- **The LOWR (2012) also covers water for agriculture and aquaculture.** It makes the State responsible for investing in water supply for agriculture and requires users to undertake conservation and prevent pollution (Article 47).

- **Aquifer recharge** is permitted but must be based on assessment of the aquifer to be supplemented (Article 56).
- **Water resources financing revenue** comes in many forms and includes: water resource royalties and other taxes; charges and fees; money from the grant of exploitation rights; and fines for violations (Article 64).

Organizations with defined responsibilities under LOWR (2012) include MONRE (Article 70); Provincial PCs (Article 71); District and commune PCs (Article 71); River basin organizations (Article 72); the national water resource council (Article 74); and MONRE Inspectorate and DONRE inspectorates and agencies (Article 75). For an outline of their roles see Annex 13.

6.5.2.2 Law on Environmental Protection

The Law on Environmental Protection No. 55/2014/QH13 (LOEP, 2014) is effective from 1 January 2015. Prior to this was the **Law on Environmental Protection No. 52/2005/QH11** (LOEP, 2005). Relevant details of both LOEP (2005) and LOEP (2014) are provided in

Annex 14.

The LOEP (2014) lays down the responsibilities for all citizens and organizations in the protection of natural resources. It is wide ranging and covers land, water and air pollution. It makes **environmental protection the responsibility and obligation of '*every agency, organization, family household and individual*'** (Article 4) prioritizes solutions for water contamination (Article 5). By comparison, the LOEP (2005) concentrates on establishments that seriously pollute the environment; remedying polluted and degraded areas; and environmental protection of urban centres and residential areas (Article 5).

Wastewater management is covered in the LOEP (2012), Section 4, which requires all wastewater to be collected and treated in accordance with environmental standards, as established under the LOEP (2005) and related legislation. All urban areas and residential areas must have systems for rainwater and wastewater; and business and manufacturing establishments must collect and treat wastewater (Article 100). Every sewage treatment system must: have a suitable technological process; have sufficient capacity; treat the wastewater according to environmental standards; and be operated regularly. The systems must be monitored and records kept (Article 101).

It is the responsibility of households to '*minimize, process, and discharge domestic sewages at proper places*' (Article 82) but unlike the LOEP (2005) there is no requirement for environmental protection planning of urban centres and residential areas to include central wastewater collection and treatment facilities (LOEP, 2005, Article 50).

Acts prohibited in the LOEP (2014, Article 7) include getting '*rid of untreated wastes or sewage to meet the rigorous standards stipulated in technical regulations on environment… '*. Other sections deal with the quality and protection of river water (Chapter VI, Section 1, Article 52) and lake, pond, canal and ditch water (Article 56).

An important funding mechanism outlined in the LOEP (2014) and LOEP, 2005), is that of the **Environmental Protection Funds (EPFs),** which includes funds from central environment, ministries and provinces but the state also encourages enterprises, organizations and individuals to establish their own EPFs (Article 149). This has the potential to support reuse activities.

The LOEP (2005) contains a number of elements of relevance to RRR. For example, **it espouses the establishment of environmental service enterprises**, including waste collection, recycling and treatment, through competitive bidding for contracts (LOEP, Article 115). In addition there are statements about investment in research, preferential policies for technology transfer to address urgent environmental problems, contracts for organizations and individuals that possess environmental technologies for waste reduction and treatment services, and priority access to loans (LoEP, 2005, Article 108 and 117).

Responsibilities defined by the LOEP (2014) include: MONRE (Article 55); Provincial PCs; District and commune PCs; and the Environment Protection Agency (for details see

Annex 14).

6.5.2.3 Decrees and Decisions Relating to Water and Wastewater Laws

A number of decrees, decisions and circulars have been developed pursuant to the LOWR (2012) and the LOEP (2005), as well as the Law on Urban Planning, 2009, the Law on Construction, 2003, and others.

Decision No. 04/2008/QD-BXD Vietnam Building Code on Regional and Urban Planning and Rural Residential Planning covers 'Planning on wastewater drainage and management of solid wastes' (Chapter 7), which requires: collection and treatment of all urban wastewater to satisfy environmental standards; domestic wastewater from toilets in houses, public buildings, and hospitals to be treated in septic tanks before entering the municipal sewerage system; industrial wastewater being discharged to water bodies to meet prescribed environmental standards; discharge points and WWTPs to be located where there is sufficient land.

Chapter 4 on 'Water Supply Planning' sets radii of protection around water sources. For surface water sources prohibited activities within 100-200 m include construction, discharge of waste and irrigation water, animal breeding, bathing and washing. Groundwater sources must have a >25 m protection radius from construction, cess pools, animal breeding and garbage disposal. It also details which water sources are acceptable for which purposes, such as firefighting and plant watering, including sea water and geothermal water but does not mention recycled water.

In 2007, the Government issued **Decree No. 88/2007/ND-CP on Drainage and Sewerage for Urban Areas and Industrial Zones** creating the legal and institutional framework for efficient and sustainable wastewater management. This was replaced in January 2015 by **Decree No. 80/2014/ND-CP, 2014, on water drainage and wastewater treatment**, which '*provides for water drainage and wastewater treatment activities in urban areas, industrial parks, economic zones, export-processing zones and hi-tech parks … and concentrated rural residential areas; and rights and obligations of organizations, individuals and households engaged in water drainage and wastewater treatment in the Vietnamese territory*' (Article 1). It applies to domestic organizations, individuals and households; and foreign organizations and individuals engaged in water drainage and WWT (Article 2). The general principles adopted in the **Decree No. 80/2014/ND-CP** are that the polluter pays for drainage services which the state regards as public utility services, prioritizing and encouraging investment to ensure sustainable development (Article 3). It also encourages community participation, eco-friendly WWT, and both decentralized and centralized WWTPs (previously the emphasis was on centralized systems) (Article 3). The **Decree places provincial PCs in charge of drainage and wastewater systems**, with the authorization to delegate to district or commune PCs (Article 10).

The importance of **Decree No. 80/2014/ND-CP** for reuse cannot be understated because it overtly advocates wastewater use, stating in Article 16 that **WWT technologies should be chosen to, among other things, enable the 're-use of treated wastewater and sludge'. Article 24 is dedicated to the 'Management and use of treated wastewater' (Box 6-1).**

Box 6-1. Article 24: Management and use of treated wastewater

1. The use of treated wastewater must meet the following requirements:

a) The quality must conform with standards and technical regulations on use of water for different purposes, not harm people's health and ensure environmental sanitation and safety;

b) Upon use, treated wastewater is distributed to points of consumption in a separate system without infiltrating and affecting the clean water supply system in the same locality or area.

2. The MONRE shall assume the prime responsibility for, and coordinate with related ministries and sectors in, promulgating standards and technical regulations on use of treated.

Source: Decree No. 80/2014/ND-CP, 2014, on water drainage and wastewater treatment

The Decree sets out the basis for determining water drainage charge rates, based actual cost for the drainage and treatment of $1m^3$ of wastewater (Article 36). It states modes of water drainage charge collection and payment, within water supply charges or as a separate fee (Article 43). MOC **Circular No. 02 /2015/TT-BXD Guiding the Methodology for Pricing Wastewater Services** (pursuant to the Decree No. 80/2014/ND-CP) gives full details for determining the cost of wastewater services. The Government updated Decree No. 88/2007/ND-CP, issuing **Decision No 1930/QD-TTg dated November 20, 2009, which described development of urban drainage and wastewater up to 2025 and a vision to 2050** (WHO et al., 2011). A summary of these objectives is given in (Table 6-2). Note that by 2025 20-30 percent of treated wastewater is to be reused.

Table 6-2. Objectives for development of urban drainage and wastewater treatment

	2015	2020	2025
Floods	Will be solved in category II or higher urban areas	Will be solved in category IV or higher urban areas	Will be solved in all urban areas
Service coverage	70-80 %	>80 %	90-95 % and 100 % in category IV or higher areas

Service coverage of drainage water collection and treatment system	40-50 % in category III or higher urban areas	• 60 % in category III or higher urban areas • 40 % in category IV, V urban areas and craft villages	• 70-80 % in category IV or higher urban areas • 50 % in category V urban areas and craft villages • WWTPs in craft villages
Industrial and hospital wastewater	• All wastewater is treated • All industrial parks have their own discharge system		
Other items	Public toilets are installed in category IV or higher urban areas	Pipes, sewers, channels will be upgraded to prevent pollution at concentrated residential areas	20-30 % of treated wastewater will be reused

Source: WHO et al (2011) based on Decision No 1930/QD-TTg

Other decrees of relevance include:

- **Decree No. 04/2007/NĐ-CP, 2007 on revision and supplementation of some articles of Decree No. 67/2003/NĐ-CP on Environmental Protection Charges** requires all households and organizations discharging wastewater directly into the environment to pay an environmental protection fee (which is different to the wastewater fee and not paid by those paying a drainage/wastewater fee as per Decree No. 80/2014/ND-CP). It lists environmental protection activities and products eligible for incentives and support, including energy from waste businesses.
- **Decree No. 149/2004/ND-CP on the Issuance of permits for water resource exploration, exploitation and use, or for discharge of wastewater into water source** requires all individuals and organizations, discharging anything other than small volumes of non-hazardous waste to have a license to do so.

6.5.2.4 National and Technical Standards for Water and Wastewater

There are hundreds of standards set in Vietnam for various activities. Those of relevance relate to water disposal and ambient water quality, as well as the quality of water for activities such as irrigation. Some of these deemed to be important for RRR are listed in Table 6-3.

Table 6-3. National and technical standards relevant to wastewater use

National Standards: Discharge of daily life wastewater into • sources for irrigation must comply with TCVN 6773-2000 • freshwater sources for protection of aquatic life must comply with TCVN 6774-2000 • surface water sources must comply with TCVN 5942-2000
National Technical Regulations: • QCVN 14:2008/BTNMT on Domestic Wastewater • QCVN 24: 2009/BTNMT on Industrial Wastewater

- QCVN 39: 2011/BTNMT on Quality of Water for Irrigation
- QCVN 39: 2011/BTNMT on Surface Water Quality

6.5.2.5 Technologies and Technology Development

Specifications for WWT are that the technologies must be appropriate for the wastewater category, have sufficient capacity, comply with environmental standards, have outlets connecting to drainage systems and operate on a routine basis (LOEP, 2005, Article 82). There is no statement on WWT for reuse.

The State encourages research and application of technologies for WWT and pollution remediation, and is responsible for improving awareness of these issues. Under the LOEP (2005, Article 6) the State encourages "*carrying out the scientific research, transfer and deployment of waste treatment, recycling and environmentally friendly technologies*" and the State is required to invest in R&D as well as disseminate information on environmental issues and recycling (see LOEP, 2005, Article 5; 6). The LOWR (2012, Article 42) covers development of water conservation and prioritizes research into wastewater treatment, recycling and reuse in all sectors including agriculture. The relevant ministries and PPCs are required to allocate funds to this.

6.5.2.6 Funding and Charges

Central government is responsible for funding capital expenditure on sanitation infrastructure in cities, while drainage and sanitation companies are to cover their operation and maintenance costs (GHK International, 2005). According to the LOEP (2005, Article 110; 112; 113) financial resources for environmental protection are derived from: the state budget; organizations and individuals, for the prevention of adverse impacts from their businesses; revenues from compensation; domestic and foreign support and financial assistance; and environmental taxes and fees.

All households and organizations discharging wastewater into water drainage systems are obliged to pay **water drainage charges,** also known as a sewage tariff, under the Government's **Decree No. 88/2007/ND-CP**. If they discharge directly to the environment, they must pay an additional environmental protection fee as per **Decree No. 67/2003/NĐ-CP, Decree No. 04/2007/NĐ-CP and Decree No. 25/2013/ND-CP on Environmental Protection Charges**. It should be noted that there is some confusion between wastewater fees and environmental fees. The former should be collected from everyone who is connected to the sewage system by the sewerage company. The latter was established as an environmental change by MONRE, to be collected in addition to wastewater fees and is calculated on: volumes of waste and the extent of their adverse impacts on the environment; toxicity; and the carrying capacity of receiving waters.

Decree No. 88/ND-CP requires the Urban Environmental Companies (URENCOs) to equitize and to operate on a cost recovery basis with subsidies from the central government for capital investment. **Decision No. 1930/QD-TTg** (November 2009) which describes the development orientations for drainage and wastewater in urban areas and industrial parks, emphasizes the application of the polluter-pays principle, especially for industry, moving towards cost recovery for drainage overall (WHO et al., 2011).

Although the government has created the potential for a significant increase in user charges, by introducing legislation for tariff increases, these have not been implemented to the extent required for sustainable operation. At present each household in Hanoi pays approximately USD 0.15 per m^3 of water of which 10 percent goes to sanitation and drainage, but the fee bears no relation to actual costs, with only 25 percent of the SADCO's expenses being covered (GHK International, 2005; WHO et al., 2011). As a result, the waste management companies rely heavily on the PCs' contributions and, because of financial constraints at the central government level, little capital expansion has taken place (GHK International, 2005).

6.5.3 Wastewater Management in Hanoi

Decision No. 725/QD-TTg Approving the Master Plan on Hanoi Capital's Drainage Through 2030 With a Vision Toward 2050, approved in May 2013, sets an ambitious plan for wastewater management, treatment and reuse. It includes upgrading existing drainage systems, building separate systems for storm water drainage and sewers to transport sewage to STPs. It provides estimates of the total sewage volume to be collected and treated (Table 6-4) (Socialist Republic of Vietnam, 2013) and plans for STP (Table 6-5). The fund for implementation of Hanoi Capital's drainage master plan by 2030 is estimated at VND 116,500 billion (USD 5.5 million)[20].

Table 6-4. Sewage drainage requirements by 2030 and 2050

Drainage area	Basins	Sewage volume (m^3/day)		Drainage levels (litres/person/day)	
		by 2030	by 2050	by 2030	by 2050
Central urban areas	29	1,439,300	1,883,300	254-321	312-379
Satellite urban areas	10	369,000	599,000	239-274	312-350

[20] http://www.xe.com converted on 19 March 2014.

Total	39	1,808,300	2,482,300		

Source: Decision No. 725/QD-TTg

Wastewater treatment planning is also contained in **Decision No. 1081/QD-TTg Approving the Master Plan on Socio-Economic Development of Hanoi City through 2020, with Orientations toward 2030**. This Decision aims to: treat over 80 percent of wastewater by 2020; build a wastewater collection system and treat 100 percent of wastewater discharged from industrial areas; increase water areas for aquaculture; and make use of all kinds of surface water. Unlike Decision No. 725/QD-TTg it does not specifically plan for WWTU. How these two plans integrate is not clear.

Table 6-5. The main STPs expected to be constructed for urban areas of Hanoi

No.	**Urban area**	**Type of drainage system**	**Number of STPS**	**Combined capacity of the STPs (m^3/day)**	
				By 2030	By 2050
I	Central urban areas				
1	At the south of Red River (in To Lich river basin and part of Nhue river left-bank basin)	Mixed	5	588,300	588,300
2	At the south of Red River (in area from Nhue River right-bank area to Day river and part of Nhue left-bank basin)	Separate	11	406,000	675,000
3	At the north of Red River	Separate	13	445,000	620,000
II	Satellite urban areas				
1	Son Tay	Separate	1	50,000	75,000
2	Hoa Lac	Separate	2	149,000	238,000
3	Xuan Mai	Separate	1	58,000	100,000
4	Phu Xuyen	Separate	1	33,000	52,000
5	Soc Son	Separate	3	66,000	116,000
6	Quoc Oai (eco-urban area)	Separate	2	13,000	18,000
	Total		39	1,808,300	2,482,300

Source: Decision No. 725/QD-TTg

6.5.4 Agriculture and Aquaculture

6.5.4.1 General Agricultural Provisions in Law

The background to the agriculture sector should be set in the context of the economic reform and reduction in government control over agricultural production decisions and management. The goal was to modernize agriculture and introduce greater productivity and efficiency in land use, water resources, labour and capital, as espoused in **Decision No.124/QD-TTg issued by the Prime Minister on 2 May 2012, approving the master plan to develop agricultural production by 2020 and vision**

to 2030. Various decisions have been issued for each agricultural sub-sector to increase productivity and efficiency, some of which relates to water and fertilizer. These decisions include:

- Decision No. 1445/QD-TTg approving the master plan for **aquaculture development** by 2020, vision to 2030, to develop sustainable aquaculture, enhance value addition, adapt to climate change, and **ensure environmental and ecological protection of aquatic resources.**
- Decision No.18/2007/QĐ-TTg approving the **forestry development** strategy in Vietnam during 2008-2020.
- Decision No. 10/2008/QD-TTg approving the **livestock development** strategy by 2020.
- **Cultivation** - in 2012 MARD initiated a project to develop the cultivation industry including **high quality irrigation systems, and enhancing quality, hygiene and food safety.**
- Decision No. 1397/QD-TTg approving **irrigation planning** in the Mekong river delta from; and Decision No.1554/QD-TTg approving **irrigation planning** in the Red river delta. **To build efficient and sustainable irrigation systems, serving agricultural production.**

Criticisms were levelled at these plans, for example that: they lacked powerful policies and solutions to develop and implement them, and measures to assess and determine their effectiveness; dissemination was poor; there was a lack of coherence between the sub-sector policies; and there was no local mechanism for implementation. Consequently, in 2013, the Prime Minister issued the **Decision No. 899/QD-TTg approving the plan of restructuring the agricultural sector towards improving value-added and sustainable development (Agricultural Restructuring Plan, ARP).**

6.5.4.2 Waste Use in Agriculture and Aquaculture

The use of wastewater use in agriculture or aquaculture is advocated in Decree No. 59/2007/ND-CP, Article 9 in rural areas where quantities are lower, the content is less likely to contain toxic chemicals and waste can be dealt with nearer the point of generation. Furthermore, there is **no regulation that prohibits the use of wastewater for irrigation and aquaculture as long as the water quality meets the standards stipulated in the Irrigation Regulations and the Surface Water Quality Regulations**:

- QCVN 39: 2011/BTNMT – National Technical Regulation on Quality of Water for Irrigation (Annex 15).
- QCVN 38: 2011/BTNMT: The National Technical Regulation on Surface Water Quality for the Protection of Aquatic Life - specifies maximum limits for various parameters of surface water quality (Annex 16).

More recently, **Decree No. 80/2014/ND-CP on Water Drainage and Wastewater Treatment**, states that **MARD 'shall promulgate technical regulations on wastewater discharged into irrigation systems'** (Article 5). Giving legitimacy to wastewater recycling but still within water sector rather than agriculture sector legislation, at this stage.

Environmental protection of reservoirs for irrigation is covered in the LOEP, 2014 (Article 64), which requires water quality to be routinely monitored in order to predict changes, regulate water resources and protect the environment.

The only mention of the use of waste in agriculture or aquaculture is in relation to domestic solid waste (not faecal sludge) which can be used after compositing. For example Decree No. 59/2007/ND-CP, Articles 9 and 29, allow for organic fertilizer production as a legitimate means of dealing with waste*".* The potential impact of the use of wastewater or compost on soils is not covered in the LOEP (2005) but the National System of Environmental Standards (Article 10) does include ambient environment quality standards for soil for *agricultural, forestry and fishery production and other purposes*, as well as a set *of surface and ground water quality standards established for the purposes of ... aquaculture and agricultural irrigation.*

6.5.5 Summary of Legislation

The key pieces of legislation discussed in the previous section are presented in Table 6-6.

Table 6-6. List of legislation relating to water and wastewater management

	WSS	Reuse
National Laws		
Law on Water Resource No. 15/2012/L-CTN (LOWR, 2012)	√	Y
Law on Environmental Protection No. 52/2005/QH11 (LOEP, 2005)	√	S
Law on Environmental Protection No. 55/2014/QH13 (LOEP, 2014)	√	S
Decrees, Decisions, Circulars and Technical Regulations		
Decision No. 04/2008/QD-BXD Vietnam Building Code on Regional and Urban Planning and Rural Residential Planning**.**	√	N
Decree No. 80/2014/ND-CP, 2014, on water drainage and wastewater treatment	√	Y
Decree No. 88/2007/ND-CP on Drainage and Sewerage for Urban Areas and Industrial Zones	√	Y
Circular No. 02 /2015/TT-BXD Guiding the Methodology for Pricing Wastewater Services	√	N
Decision No 1930/QD-TTg dated November 20, 2009, which described development of urban drainage and wastewater up to 2025 and a vision to 2050	√	Y
Decree No. 04/2007/NĐ-CP, 2007 on revision and supplementation of some articles of Decree No. 67/2003/NĐ-CP on Environmental Protection Charges	√	N
Decree No. 149/2004/ND-CP on the Issuance of permits for water resource exploration,	√	N

exploitation and use, or for discharge of wastewater into water source		
Technical Regulations		
QCVN 39: 2011/BTNMT – National Technical Regulation on Quality of Water for Irrigation	√	N
QCVN 38: 2011/BTNMT: The National Technical Regulation on Surface Water Quality for the Protection of Aquatic Life	√	N

WSS: Water supply and sanitation. √ = contains elements related to water supply or sanitation.
Y = currently mentions reuse. S = has elements that are potentially supportive of reuse but may not mention it directly. N = does not currently mention reuse but has the potential to do so (i.e. it is relevant to the sector).
SW = is supportive of nutrient recovery from solid waste but does not include faecal sludge.

6.6 Chapter Summary

This chapter has described the relevant policy and legislative areas that affect RRR in Hanoi, referring to national, provincial and local legislation. It can be seen that some are highly supportive of reuse, predominantly in the water and environment sector, while others either ignore the issue, principally those on the potential reuse side. It is also clear that Vietnam is forging a path for improved WWT with reuse beginning to form a legitimate part of wastewater management. Furthermore, it can be seen that PPPs and cost recovery are becoming more prominent.

The chapter has also introduced the stakeholders that work in or are influenced by the various sectors that intersect in the RRR arena, ranging from national policy makers, to local government implementers and regulators, farmers and fishermen. All have a role to play in RRR with come having greater involvement and influence than others. In Hanoi the PCs and SADCOs are among the most important stakeholders in wastewater management and treatment, although the VEA and CCW are also emerging as strong agencies especially in advocating for pollution prevention.

The detailed analysis of the stakeholders, legislation, current practices and the institutional arrangements that these form is presented in the discussion.

7 Discussion - Institutional Arrangements for Reuse

This chapter finalizes the institutional analysis for each case study city. A more detailed assessment is presented for Bangalore to reflect the level of field work and to take account of the interviews conducted in the city. The analysis utilizes a power and interest matrix to elucidate the existing and potential roles of stakeholders.

Triangle analysis is conducted for both Bangalore and Hanoi considering three components of institutional arrangements:

- **Content**- written laws, policies and budgets;
- **Structure** - mechanisms for implementation; and
- **Culture** - values and behaviour that shape how people deal with and understand an issue.

The discussion then moves into a comparison of the findings for each city and identification of elements of the institutional environment that support or impede reuse.

7.1 Bangalore

This section builds develops the stakeholder and institutional analysis, incorporating the interviews with numerous stakeholders in Bangalore. It considers their interest in the wastewater reuse sector and their potential or power to affect the reuse landscape. The chapter focuses on key stakeholders and ends with a table summarizing stakeholder support for wastewater reuse.

7.1.1 Stakeholder Roles, Interest, Strengths and Shortcomings

Stakeholders were placed on an 'interest and influence' matrix (Figure 7-1) to provide a visual impression of which stakeholders are most interested in the sector and which have the power or means to influence it. The matrix should be read in a way that considers the relative position of stakeholders and as a point of departure for discussion. It is not a precise or 'correct' picture of the stakeholder landscape with which all stakeholders will agree but is based on the opinions of the author and interviewees who are familiar with the local situation. Critically it is a way of identifying who should be engaged with, because they are directly affected, because they are highly influential or because they are disinterested at present but could stimulate reuse if persuaded of its merits. Discussion of the interest and influence of certain stakeholders is provided below Figure 7-1.

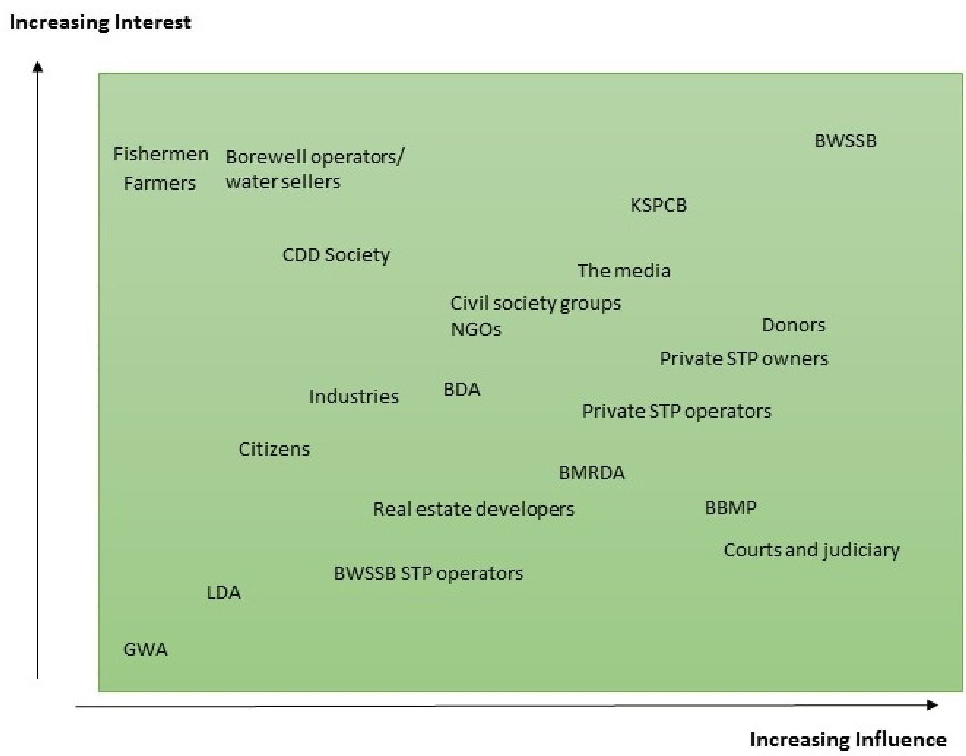


Figure 7-1. Interest and influence matrix for stakeholders of water reuse in Bangalore
Source: Author (2015)

7.1.1.1 Government Departments and Bodies

The **BWSSB** has a significant interest in RRR because of its mandate. It is critical in influencing policy and action, and appears to be highly pro-reuse (Box 7-1). It has recently established the New Initiatives Division, whose aim is to understand and replicate best international practice in water conservation, loss reduction and reclamation (e.g., in Israel, Jordan and South Africa). The Division recognises that a major constraint is public perception and has established a section on 'New Initiatives and Public Outreach'. There is considerable scope for reuse since the BWSSB has installed capacity to treat and sell 75 MLD but only 20-50 MLD is actually sold. This generates an annual revenue of around INR 4 million (USD 60,399), and is a path that BWSSB would

Box 7-1. Examples of BWSSB's commitment to WWTU

- When in 1994, the Janata Dal government identified Devenahalli, in Bangalore Rural District, as the location for the Bangalore airport, the BWSSB promised to provide recycled water.
- Also in the 1990s, the BWSSB agreed to provide recycled water to the Bidadi power plant from the Vishabhavathi valley project where there was an STP with a capacity of 60 MLD.
- In mid-2013 the BWSSB established the "New Initiatives Division" to investigate and implement water reclamation projects.

Source: Former BWSSB Chief Engineer in charge of corporate planning and wastewater planning, pers. comm. (2013)

like to follow (BWSSB official, pers. comm., 2013). They have also recently announced a proposal for augmentation of the water supply in TG Halli reservoir (Bangalore 5, 2015).

So why is RRR not more widespread? The principal issues appear to be public perception, funding and internal incentives:

- **Funding:** The cost of constructing drains, sewers and STPs is high and the BWSSB are dependent on central government or donor funds for capital investment. All the existing reclamation plants were built with donor funding in association with mostly European WWT companies. The most recent initiative is being funded by the Government of Singapore. The BWSSB is therefore unlikely to initiate expansion projects without committed funds (Connors, 2005). Funding for operations is derived from water tariffs, based on metered supplies. The cost for BWSSB to supply water is 30-40 INR/kL (0.49-0.66 USD/kL) but tariffs are politically determined by the state and until 2014 had not risen since 2005.
- **Coordination:** The process of laying sewers and pipes can be difficult because of the need for permission from land owners and authorities. In some cases there can be significant coordination issues. For example, it can, according to a BWSSB Executive Engineer, be lengthy and complex to obtain permission from BBMP to dig up roads. This lack of coordination is regularly published in the media, as exemplified in the report in the Deccan Chronical 26th May 2015, concerning BWSSB digging up a road to replace pipelines (Deccan Chronical Correspondent, 2015).
- **User attitudes and costs**: Industries that have accesses to sufficient, low cost, fresh water may not be interested in utilizing reclaimed water, especially if they have to fund the pipeline to their premises, even though the unit price is less than BWSSB piped fresh water. Domestic users are wary of water reuse projects, especially those that may be designed for potable use. To address this the BWSSB have a project with three Singaporean agencies to raise awareness and understanding among the general population (Lalitha, 2015). Despite this, public opinion, voiced through local media, is that a 'huge challenge still lies in accepting such treated water for potable purposes by the public' (Bangalore 5, 2015).
- **BWSSB preferences:** One opinion of other stakeholders is that BWSSB prefers large centralized treatment, constructed and managed by them or large companies; rather than small decentralized STPs being established by a large number of players (former BWSSB Chief Engineer, pers. comm., 10 June, 2013). However, there is evidence that ward-level STPs will be seen in the future (McKinsey and CII, 2014).

- **Internal incentives**: Incentives are lacking within BWSSB for its staff to support RRR (former BWSSB Chief Engineer, pers. comm., 10 June, 2013). The Temasek Foundation project suggests that capacity is also lacking; something that the project plans to address.
- **Size and influence:** The New Initiatives Division is only a small part of the BWSSB and its strength is limited. For example, wastewater is regularly disposed of to open water bodies and the problem is now so severe that the KSPCB has initiated a criminal case against the BWSSB Chairman and Chief Engineer (and other civic bodies) under the Water (Prevention and Control of Pollution) Act, 1974, 1988 and has requested that the BWSSB Chairman is removed from the Board of the KSPCB (Chetan, 2015; Express News Service 2015).

Like BWSSB, **KSPCB** has a high interest in WWTU but is considered by some stakeholders to have **limited powers because of its nature and mandate** (Professor, Indian Institute of Science (IISc), pers. comm., 27 July, 2013). Their only recourse is to issue a notice to stop activities and to take violators to court, which can be time consuming and expensive. Thus violation of rules is evident all over the city according to an STP expert who identified several private STPs that were not built according to the specifications agreed in the CFE, were incorrectly sized or had bypass pipes (pers. comm., 17 July, 2013).

Despite this, KSPCB is promoting reuse and is committed to water recycling. The former Chairman of the KSPCB, A.S. Sadashivaiah believes that an inescapable imperative of towns and cities in India is to conserve water, treat wastewater, renovate, recycle and reuse (Kodavasal, 2011a). The current Chairman is also supportive of water reuse and has helped to protect lakes from sewage flows. KSPCB has been proactive in requiring apartments to treat and recycle their wastewater onsite in accordance with national and State legislation. The KSPCB have taken care to issue stringent rules for reuse of urban sewage, especially where there is human contact (Environment Officer, KSPCB, pers. comm., 18 July, 2013) and have provided guidelines for onsite STP design and management (Kodavasal, 2011a).

However, there is some confusion amongst residents over what the rules are and what compliance is required. Members of RWAs frequently meet the KSPCB to discuss these issues, and plans are underway for the KSPCB to work with the Confederation of Real Estate Developers' Associations of India (CREDAI) to make the rules clearer (BBMP expert committee member, pers. comm., 28 January, 2014). A major concern was the “zero disposal” requirement, which many considered would work against reuse because most of the water cannot physically be made use of in the apartments. This frustrates residents and prevents beneficial recharge of lakes and groundwater (Kodavasal, 2011b). The stringency of KSPCBs reuse norms is also a concern of the President of the CDD Society (Susmita Sinha, pers. comm., 12 August, 2013) who feels that reuse standards should be more practical, taking account of the WHO's guidelines on the quality of wastewater for reuse. Some of these concerns have been heard because in 2015 KSPCB issued revised standards and required secondary treated wastewater to be used or sold for non-potable purposes (KSPCB, 2015). The KSPCB has also intimated that there could be sharing between farmers and private STP owners (Natesh and Varman, 2014). As a further supportive measure, KSPCB reduced the cess on apartments with STPs.

The, KSPCB has recently filed a number of cases against several civic bodies that it accuses of allowing sewage and effluent to enter urban water bodies. One of these is the BWSSB which it claims has failed to address sewage discharge even after several notifications from KSPCB officers (Chetan, 2015). This is potentially a pivotal moment for wastewater management in Bangalore, as well as having a major bearing on the relationship between two prominent players in the sector.

In terms of WSS, **BBMP** does not work directly in this sector but it is responsible for the BMA's infrastructure and for approving building construction plans and giving completion and occupancy certificates. BBMP has a whole range of departments and functions under its remit but wastewater reuse does not feature highly. The **BDA** is not active in implementing wastewater reuse either but could ensure that it is part of development plans and land allocation. The BDA allocates land for STPs for residential layouts and neighbourhoods (Official at the BDA, pers. comm., 5 February, 2014).

The **KSDA** is not active in the RRR sector but they could be a critical link in wastewater reuse options, through extension services to maximize benefits and minimize risk.

7.1.1.2 Private STP users, suppliers and managers

Private STP users could substantially contribute to overall reuse in the city. Positive experiences could drive demand stimulating the market for STP suppliers and managers. Water scarcity, the absence of BWSSB water supplies in many areas, reliance on groundwater or water tankers, the lack of a sewerage network and the requirement to obtain KSPCB certification, are all incentives for citizens to install and use STPs appropriately (CDD Society, pers. comm., 12 August, 2013). The cost of water, especially from tankers, is resulting in the realisation that there are real savings to be made from on-site WWTU (Environment Officer, KSPCB, pers. comm., 18 July, 2013).

Unfortunately, at present, many private STPs are installed by builders who lack technical knowledge or by STP designers who have no involvement STP management. Poor management leads to bad odours, inadequate treatment, STP failure and dissatisfied residents. However, STP design and management companies, are picking up more contracts to build, rehabilitate and manage STPs on behalf of RWAs (STP expert, pers. comm., 17 July, 2013). This is good news because functioning, effective STPs will persuade those who are currently unconvinced.

According to an STP expert interviewed for this study (17 July 2013), the main difficulty the STP managers/operators face is in hiring and retaining staff. The cost of training, STPs being left unmanaged and the time taken to find new staff are all problems. The KSPCB could provide training and certification for STP managers to alleviate some of the difficulties and provide a status to the job. This would also benefit KSPCB and the residents.

As part of this study, three RWAs were interviewed. They appeared to have little knowledge of the rules that they needed to obey viz a viz reuse, however, they were generally positive towards RRR, feeling that it would benefit the city. They were much more aware of solid waste management rules, which have featured highly in the media. The research also identified examples of communities implementing effective institutional arrangements to address their WSS problems. A case in point is Rainbow Drive where residents are working to reduce water losses and manage infrastructure more efficiently to conserve water, improve facilities and reduce costs (

Annex 17).

7.1.1.3 Farmers, Fishermen and Groundwater Suppliers

Farmers, fishermen, groundwater sellers and other informal users are critical for wastewater use and would be significantly affected by any changes to reuse practices in Bangalore. In general, they do not drive reuse but capitalise on its economic potential. At present, these stakeholder groups are in need of good quality water but have very little voice in the city because they tend not to be in organized groups, they are disparate and their use is informal. They are also concerned about the formalization of wastewater use and related regulations, which may put them out of business.

- Farmers are often considered to be a strong lobby but small-scale urban and peri-urban farmers are often not well represented by farmers' organizations or the KSDA.
- The opinion of the authorities is that farmers actually impede attempts at WWT because they are worried that nearby STPs will affect the land value (Officials at the DMA, pers. comm., 3 December, 2013).
- The fishermen who fish in Jakkur Lake, and have been interviewed as part of this project, are migrants from Andhra Pradesh and are not willing to voice their opinions.
- Groundwater suppliers risk being regulated and the quality of their water tested if they publicize their activities.

Occupational health risks associated with using water in agriculture do not appear to be a priority for government departments such as KSPCB. As a Research and Training Assistant at the Centre for Public Health and Equity explains, "In the case of the health of agriculture labourers, even the safe use of pesticides has not been addressed as a priority, so it is unlikely that water is on the radar" (pers. comm., 26 November, 2013).

The opinion of the Director of the Biome Environmental Trust, is that farmers, fishermen (and other informal users or suppliers of resources from waste) potentially stand to lose from formalized channels of reuse (pers. comm., 31 May, 2013).

7.1.1.4 Industries

The industries are a vital component in the reuse sector and are currently not playing as strong a role as the BWSSB and other stakeholders would like. Although they could receive a regular supply of high quality treated wastewater, at a price below other sources, many are still not taking advantage of this. The reasons cited are that, where groundwater is available it is less costly than the treated wastewater; and there are challenges in transporting treated wastewater to the factories (see BWSSB section) (Jamwal, 2014). The BWSSB acknowledges that a supply 'backbone' is required and point out that some industries are willing to receive treated wastewater but only if it is available immediately, if they have to wait they prefer to put in alternative systems (official New Initiatives Division, BWSSB, pers. comm., 19 July, 2013).

7.1.1.5 Civil Society Groups, NGOs and Courts

Although many users of wastewater (farmers, fishermen and groundwater suppliers) have very limited agency, they are in some cases supported by civil society, NGOs or the media. For instance, ESG, has helped groups file PIL cases and petitions in the Karnataka High Court such as the PIL against the move to have lakes managed by private companies. ESG claimed that this would amount to private ownership, and argued that Bangalore's lakes were used by communities for fishing, grazing and recreation and that their rights needed to be protected (CSE, 2006).

The courts have played a significant part in the development of environmental legislation, however, the process is renowned for being slow and the courts are viewed as being "too patient". Although the courts give orders it is hard for them to monitor compliance (SWMRT member, pers. comm., 19 September, 2013). The Lok Adalat, an alternative dispute resolution system that allows citizens to engage with government departments on issues of public interest, has also played a key role in mediating between NGOs and citizens groups, and institutions such as the BBMP.

7.1.1.6 Donors

Donors have been central to developments in the sector up to now, with JICA and the French government in particular driving WWTU. More recently the Singaporean government, DFID and DGIS are engaging with BWSSB and supporting extensive WWTU, as well as working to achieve a cultural shift within the organization and the community. A number of other agencies, both local and international, have supported information generation, technology development and awareness raising. There is no doubt that the donor community is important in the sector and has, at least historically, appeared to drive WWTU initiatives in the city. This could be changing with greater interest emanating from within the city, and donors supporting rather than driving. However, they remain an important voice and source of funding for an otherwise underfunded sector. Recently, finance for small-scale STPs within residential areas and campuses has emerged.

7.1.1.7 Summary of Stakeholder Support for RRR

The descriptive analysis can be used to identify some key elements that either support or hinder the establishment or extension of RRR from wastewater in Bangalore. This is summarized in Figure 7-2, where '+' indicates a supportive attribute and '-' indicates an element that could impede reuse. As can be seen many organizations provide some level of support, or the potential to do so, but may be restricted by, for instance, funding, mandates or influence.

7.1.2 Institutional Analysis

The sections leading up to this one have gradually unpicked the stakeholders, their roles in relation to wastewater reuse, their relationships and the institutional arrangements that govern or influence them. This section attempts to condense that learning into a framework that provides an interpretation of the institutional set-up across the reuse landscape by using triangle analysis for several interlinked 'action arenas': water management; effluent discharge, sewerage and sanitation; central WWTU systems; decentralized WWTU systems; and agriculture (Annex 18). These elements are drawn on to identify key institutional arrangements across the whole WWTU sector (Figure 7-3).

Figure 7-2. Summary of stakeholder roles, attitudes and actions to water reuse

BWSSB
+Established New Initiatives Division for water recycling
+Implemented WWTU projects
+Pro-water reclamation
+Hired agency to improve public perception/knowledge of RRR
+Project with Singapore on WWTU, capacity building, public outreach
-Must obtain external capital funding
-Perception – prefer centralised WWT and to exclude small players
-Insufficient incentives for staff to promote RRR
-Does not set tariffs - politically determined

KSPCB
+Interacts with BWSSB, BBMP, BDA (in Masterplan) and Health Dept.
+RRR culture in KSPCB and support for RRR from the Chairman
-New leadership may change opinion to RRR
+Enacted reuse norms and reduced cess on apartments with STPs
+Advocate training and certification for STP operators
-Over stretched – cannot effectively monitor all STPs
-Limited legal recourse (Water Act) if waste producers do not comply but recently took BWSSB to court
-Reuse norms too stringent, lead to flouting (but recently revised)
+Competent technical committee but only reviews CFE. Does not monitor

BBMP
+Significant number of lakes under BBMP
-Currently does not deal directly with WSS
-Contracting arrangements may hamper development of large scale infrastructure
-No significant approach to public health

BDA
+Allocates land for development including STPs
+Manages some lakes - currently limited to desilting

LDA
+Could manage lakes for recharge, fishing, irrigation
--Limited actual power - no statutory backing; no punitive provisions
+recently subsumed into new KLCDA with statutory authority

GWA
+Overall mandate around GW regulation and conservation
-More needs to be known about Bangalore's aquifers to support recharge
-Limited remit and resources - emphasis on registering wells and protecting aquifers; no remit on GW quality

Real Estate Developers
+Build local water supplies and STPs
+/-Need clearance from KSPCB
+See payback from satisfied residents therefore more willing to invest
-Not always part of their skill set therefore STPs may not function as desired

Private STP installers and operators
+Some companies are improving the running of STPs and promoting reuse
+Others increasingly seeing the benefits
-Many builders install STPs incorrectly
-Staff training and retention – frequent loss of staff affects STP operation
-No specialised local environmental engineers – designs could be more appropriate

Private STP owners
+Legal obligation to run STPs
+Many adhere to rules and employ qualified STP managers
+Many campuses run STPs effectively and use the treated water
+Increasingly aware of the scarcity, cost of water and value of treatment/use
+Some see value of STPs - payback (3-8y); water availability
-Space to store and ability to utilize all treated wastewater. Require dual plumbing.
-Lack of technical knowledge
-STPs sometimes viewed as a burden - not enough RWAs see the benefits; requires time for consensus building and education

Industries
+Many treat and reuse water onsite because it is cost effective
+/-Some buy treated WW from BWSSB but less interested if other sources of water available at similar cost
-Expected to pay for infrastructure i.e. tertiary pipes to receive treated WW
-Obtaining permission to lay pipes - requires approval from several authorities

Farmers, fishermen and groundwater sellers
+Informally tap into treated or untreated WW – see economic value of wastewater
+WW use can stimulate a market that could drive treatment
+Have developed techniques to improve health and safety
+/-Water quality must meet requirements for use (irrigation, fisheries etc.)
-Not a powerful group, unable to lobby for treatment and use
-May not want STPs nearby because reduce land value

Communities
+Communities and KSPCB form watchdog committees to monitor WWT
+Complaints and PIL have driven positive developments in reuse
+Increasing support for on-site treatment and use
-Concerns over health and amenity e.g. smell

-Limited support for BWSSB wastewater recycling due to concerns that this will be used to supplement drinking water

Civil society groups and NGOs
+Support environmental protection, NRM, public health protection, livelihoods, informal sector rights and consumer protection
+Engage through activism, policy consultation, research and implementation
-Have different perspectives - so may not always work together
-May work against RRR e.g. those concerned about health impacts
-Typically donor dependent to sustain their work – may influence areas of work

The Media
+Coverage of WWTU issues raises awareness
-May not be supportive of some reuse options and may emphasise health problems

Courts and judiciary
+Can prosecute those breaking environmental laws
+Have directed the establishment of committees on issues e.g. lake management
-Slow process
-Very little means of monitoring compliance with their directives

Donors
+Evidence of financial and directional support – e.g. BWSSB funding for STPs and reuse
+Local donors engaging in novel wastewater management/use options
-May be limited to donors' areas of interest

Academia
+Undertaking research into nutrient recover from waste
-Funds are limited

Source: Author (2015)

Status

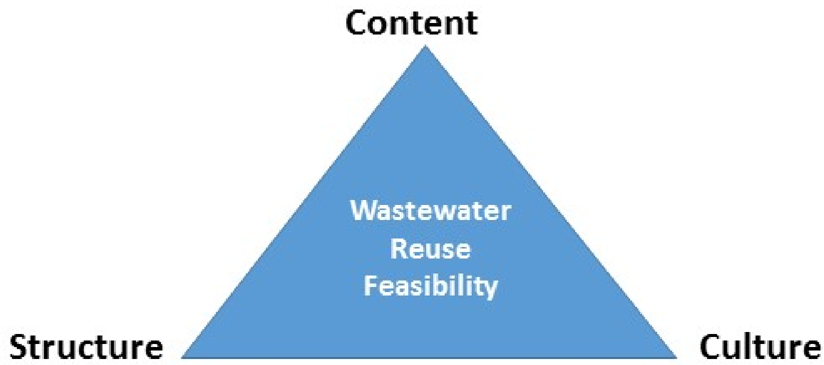
- Inter-state sharing agreements and groundwater restrictions (Groundwater Act) limit water supply
- The Bangalore Water Supply (Amendment) Regulations, 2012 supports reuse for non-potable purposes.
- NWP, 2002; 2012 encourages recycling and reuse (household; groundwater recharge)
- Environment (Protection) Act and Rules, 1986 sets effluent discharge standards
- KSPCB regulations require recycling within apartments, commercial businesses etc.
- NEP, 2006 calls for recycling and reuse of all wastewater by public agencies and PPPs
- PC's 11th Five Year Plan expects treatment and reuse for non-potable purposes. Incentives e.g. tax holidays and concessions on tax duties on equipment
- Sewage cess reduced for properties with STPs

= PLENTY OF HIGH LEVEL SUPPORT FOR THE CONCEPT OF REUSE

Limitations

- The Bangalore Sewerage (Amendment) Regulations, 2012 – prohibits irrigation with effluent
- National Policy for Famers, 2007and National Livestock Policy, 2013 do not comment on wastewater use but product safety is important.
- NWP, 2012 no mention of wastewater use in agriculture.
- No obligation to reuse wastewater from municipal STPs (e.g. by industry)
- Pricing inadequate to stimulate wide uptake
- Incentives lacking

- **= WOEFULLY INADEQUATE MEASURES TO TRANSLATE POLICY INTO PRACTICE** (i.e. no real incentives or deterrents)



Status

- BWSSB provide piped water and sewerage in BMA. Unserved areas rely on groundwater or tankers; septic tanks or onsite STPs. Established New Initiatives Division for unconventional water supply including recycling. Introduced 14 STPs some with reuse.
- Residents responsible for their own STPs.
- KSPCB – monitor and enforce discharge and compliance
- Funding for STPs/infrastructure available through central and state government and donors.
- FD leases out fishing rights
- MID have schemes to augment tank water with wastewater
- KSDA no involvement in reuse
- Private STP operators gaining ground but developers usually install STPs with limited experience (and cut costs)

Limitations

- KSPCB's and BWSSB - insufficient funds and staff
- LDA weak, new KLDCA but remit on WWT not clear
- Coordination between sectors negligible.
- BWSSB not accountable to ULB (BBMP) or public because unelected.
- No accreditation for private STP operators

Status

- Widespread acceptance of recycling for industrial use but actual use limited due to infrastructure, no incentive (if GW available), water quality (perception).
- Some public support for agricultural reuse (after treatment)
- Low but increasing support for onsite recycling but technical capabilities lacking
- Little or no support amongst the public for recycling for potable supply
- Media regularly report on reuse. Seem supportive of certain projects. Critical of some aspects e.g. fees, disruption during construction
- Active civil society many in favour of reuse but tend to support small-scale, decentralized systems

Limitations

- Acceptance does not translate into use

Figure 7-3. Triangle analysis of institutional aspects of wastewater use in Bangalore
Source: Author (2015)

7.1.2.1 Content

In India, the **water and environment policies espouse the importance of using domestic and industrial wastewater after appropriate treatment** for certain purposes. India's NWP (2002; 2012) promotes recycling and reuse for such functions as groundwater recharge, and encourages household reuse after primary treatment. The NEP (2006) calls for recycling and reuse of domestic and industrial wastewater by public agencies and PPPs operating ETPs and STPs. Both policies **recommend the introduction of appropriate incentives, taxes and deterrents**, although no guidance is given on the form these should take. Their support for PPPs may be an essential factor, as new business models will be required for the expansion of WWTU. The NEP (2006) sets out to enhance the capacities of municipalities for **recovery of user charges** and **promotes R&D of low cost WWT at different scales**, in particular bio-processing models, to yield multiple benefits.

Across Karnataka the KSPCB has issued reuse standards and, in line with national policy, requires commercial and residential properties to implement WWTU, **to treat and use or sell their wastewater**, and to fit dual plumbing systems **(KSPCB, 2015)**. Enforcement in however difficult.

The Bangalore Water Supply (Amendment) Regulations, 2012, support reuse of wastewater for non-potable purposes and BWSSB has set lower fees for treated wastewater (10-25 INR/kL depending on the treatment level and delivery mechanism) than potable water (domestic 6-36 INR/kL; and commercial and industrial 36-60 INR/KL, depending on the quantity used).

However, "Direct disposal of sewage or industrial effluents for irrigation of crops to be used for human consumption or for washing of cattle is prohibited." **Opposition to the use of untreated wastewater for agriculture**, has implications for farmers who are already utilizing wastewater, making it difficult to introduce options that could protect farmers and consumers as an interim measure while treatment is still not possible. A more pragmatic approach in line with the WHO (2006b) Guidelines could be effective in protecting health and the environment, and contributing to the city's wastewater management aims.

Financial mechanisms are weak in Bangalore but donor funding and PPPs have emerged to support both centralized WWTU systems and decentralized public systems. In addition there are a number of funding mechanisms for social enterprises that could be appropriate for RRR models, for example for companies establishing themselves to manage STPs for reuse. The BWSSB receives financing from central government and donors; it does not make sufficient income to cover capital costs. This not only limits what can be implemented but also reduces their incentive and ability to invest in projects. More recently PPP models have provided part of the finances to implement WWTU but overall it would seem that finance is not easily obtained.

7.1.2.2 Structure

In Bangalore there is an organization dedicated to water supply and wastewater management - BWSSB. Water supply tends to be the priority but the need to provide water to a growing population has stimulated reuse projects. As an unelected, parastatal, BWSSB has greater autonomy and flexibility, allowing them to implement more unusual projects, but also means that they are less accountable. Furthermore their **jurisdiction does not match with that of other government bodies,** which can cause difficulties and leave areas unserved and may further reduce their accountability. There is considerable pressure put on them by the media, civil society and more recently the KSPCB.

Within the BWSSB there is a distinct department with clearly defined projects and plans for reuse – the New Initiatives Division. It is limited in size and it is not clear whether their reuse agenda is widely supported across BWSSB, although there are undoubtedly some dedicated individuals. It is however an important development and one which may generate interest from national and international funders.

The KSPCB is responsible for monitoring and enforcing environmental legislation including effluent discharge standards. However this is a huge task requiring far more manpower and funding than the KSPCB has. New, more workable models are required that provide incentives for self-regulation or which involve the private sector. For example, accreditation of STP managers would provide the KSPCB with a tranche of competent and reliable third parties to help implement private STPs. Any organization found to be failing would have their license revoked.

Accreditation and training have been called for by private STP designers and operators. In their opinion Bangalore has potential, with a number of individuals and academic institutes with expertise, and a growing number of private companies, but there is currently no accreditation system or technical training for staff. Consequently they find it difficult to hire and retain staff, and clients can be sceptical about their skills. Furthermore, the private sector requires greater links with BWSSB and KSPCB so that they can achieve mutual benefits in terms of pollution control and RRR.

Public private partnerships are in place for WWTU in central BWSSB STPs. How effective these are has been difficult to ascertain but they provide avenues to fund STPs and alternative working arrangements that can promote reuse. An example is that of the BIAL; a PPP in which the airport uses sewage treated by BWSSB and recycles its own wastewater internally. The treated wastewater is used for landscaping, cooling and toilet flushing.

There is no institutional structure in place for users such as agriculture, fisheries or industry to make use of wastewater. In fact, wastewater use is prohibited in agriculture. Despite this the MID has initiated reuse projects and the FD is issuing licenses for fishing on lakes receiving treated wastewater. Having departments or organizations that collaborate with wastewater managers (e.g., BWSSB and KSPCB) and are knowledgeable about the risks and benefits of wastewater use would increase the potential for out-scaling reuse

Residents and owners of commercial properties are required to have STPs and make use of treated wastewater on-site but incentives and expertise are lacking. Market forces and environmental conditions are beginning to create incentives and residents are seeing the benefits of an assured supply of water for non-potable purposes. This is stimulating interest and investment in STPs. Water selling, sharing or disposal will stimulate treatment because benefits will accrue either in the form of monetary payments or improved environmental conditions around the property, which will add value. The KSPCB has also published a manual on STP operation which should help to ensure STPs function effectively and thereby gain support.

7.1.2.3 Culture

There is widespread acceptance by industry of the notion of recycling but this has not translated into significant actual reuse. This is due to the absence of infrastructure to connect industries with STPs, the relative ease and lower cost of obtaining groundwater and issues over trust, in terms of an adequate, reliable supply of the required quality. These factors could be addressed by changing the pricing structure, constructing the required infrastructure, prohibiting the use of groundwater in certain areas or for defined purposes, and engaging trusted third parties to reassure industries.

Similar issues exist for the general public. They are broadly accepting of reuse but only for certain purposes, such as industrial use, some agricultural practices and lake rehabilitation. There is very little support for augmentation of potable supplies. The BWSSB is addressing this through a major project in collaboration with Singapore. **Use of small, decentralized STPs established to irrigate**

parks within the city has been consistently good over many years and the practice is accepted by most stakeholders. Technically the systems are effective.

The media and activists regularly report on reuse. Their position often depends on the specific scheme or action of the authorities but they seem supportive of the general notion of reuse. They are however critical of some aspects such as the disruption during construction, the expectations placed on residents to treat and use their own wastewater, and the costs and fees associated with treatment and use. They, like the highly active civil society in Bangalore, would like to see more support from BWSSB for decentralized systems, rather than relying on users. Most accept the inevitability of finding reuse solutions to meet growing water demand.

7.2 Hanoi

7.2.1 Institutional Analysis

An institutional analysis was performed in the same way for Hanoi, utilizing the triangle analysis methodology as depicted in Figure 7-4.

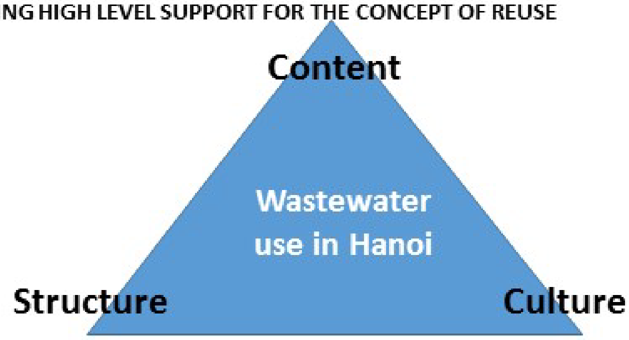
7.2.1.1 Content

The LOWR (2012) requires the collection and treatment of wastewater from urban, commercial and industrial areas, **considers recycling and reuse to be priorities and offers financial incentives for treatment and recycling.** The emphasis is on protecting receiving waters and water sources. For example, licences are required for any sort of wastewater disposal and penalties are set for violation (LOWR, 2012; Decree No. 149/2004/ND-CP).

Similarly, the LEOP (2014) focuses on preventing pollution and requires all urban areas to have WWT facilities, stipulating that treatment must meet national technical regulations for disposal or use. The previous environmental law, LOEP (2005), placed greater emphasis on waste collection, treatment and recycling. This remains valid today since the decisions and decrees made to implement the LOEP (2005) are still in place, such as **Decision No. 1930/QD-TTg, 2009, which envisages 20-30 percent reuse of wastewater by 2025.** In addition, MONRE has issued the Action Plan Implementing Decision No. 403/QD-TTg, which promotes recycling and reuse of wastes in water (VEA, 2014b) and Hanoi's socio-economic development master plan (Decision No. 1081/QD-TTg) aims for 100 percent wastewater collection and treatment of 80 percent.

- Decree No. 80/2014/ND-CP on water drainage and wastewater treatment sets out requirements for using treated wastewater.
- The Law on Water Resource (LOWR), 2012 requires urban wastewater to be collected and treated, and has wastewater treatment (WWT), recycling and reuse as priorities.
- Financial incentives are also offered for WWT and recycling.
- The Law on Environmental Protection (LOEP), 2014, requires all urban areas to have WWT and to treat it to stipulated national technical regulations appropriate for the waste and disposal or use i.e. domestic or industrial waste; used for irrigation or disposed of to open water.
- Licenses are required for any sort of WW disposal and penalties are set for violation (LOWR, 2012; Decree 149/2004/ND-CP).
- Hanoi's socio-economic development master plan (Decision No. 1081/QD-TTg) aims for 100 % wastewater collection and treatment of 80 %.
- Decision No 1930/QD-TTg, 2009, updating Decree No 88/2007/ND-CP envisages 20-30 % reuse of wastewater by 2025.
- MONRE has issued the Action Plan implementing Decision No. 403/QD-TTg, which includes promotion of recycling and reuse of wastes in water (VEA, 2014b).

= **LIMITED BUT INCREASING HIGH LEVEL SUPPORT FOR THE CONCEPT OF REUSE**



- WSS responsibility of MOC in urban areas and MARD in rural areas. MPI for investment decisions. MONRE, with VEA, oversees water quality and pollution. Collaboration required but is limited. Too much overlap of roles.
- Decree No. 80/2014/ND-CP puts MOC in charge of drainage and reuse, along with Provincial PCs.
- VEA is coordinating with CCW to bring together many of the players e.g. MONRE, MARD, MOIT and MOC to discuss wastewater management and use (VEA, 2014c).
- SADCO responsible for sewers and drains. Tertiary level infrastructure devolved to local authorities. SADCO Hanoi is stretched and only around 60 % of the city is sewered.
- Overlap between LOEP, 2014 and the draft 'Decree on waste and scraps management', urban wastewater management component (VEA (2014c).
- Fees for wastewater discharge are collected as part of the water supply tariff (Decree No. 67/2003/ND-CP). Most too low to cover O&M.
- Capital funding comes from the government but investment has been limited.
- Insufficient funding to manage facilities effectively. PCs make up shortfall. Unsustainable.
- Wastewater management in Hanoi is strictly separated from agricultural water management, and farmers are not integrated in the chain (Evers et al., 2010).

= **HIGHLY STRUCTURED SECTOR BUT MUCH OVERLAP. MOC RESPONSIBLE FOR REUSE WITH OTHERS**

- Several communities using wastewater via polluted rivers e.g. Hoang Liet commune, Thanh Tri district uses water from the To Lich River for aquatic plant and fish production.
- Lots of other examples of reuse exist see (Marcussen et al., 2007; Khai et al., 2007; Dao et al., 2010) suggesting that it is tolerated or accepted.
- However health concerns are arising because of the greater quantities of industrial waste (Vuong et al., 2007).
- Farmers in Thanh Tri District strong willingness to obtain wastewater. Long term use resulted in an effective system that has become part of the district development plans (Vo Quy Hoan, 2001).
- Strengthening the collection and reuse of WW advocated by the VEA and collaborators (CCW, Government Office, MONRE, MARD, Ministry of Justice, MOH, Ministry of Transport, MOIT and MOC) (VEA, 2014c). However, as yet there appears to be little taking place on the ground.
- The culture within the government appears to be changing with the promulgation of new legislation such as Decree No. 80/2014/ND-CP.

= **CURRENTLY INDIRECT REUSE. SUPPORT FOR FORMAL REUSE HARD TO ASCERTAIN BUT SEEMS TO BE INCREASING IN GOVERNMENT**

Figure 7-4. Triangle analysis of institutional aspects of wastewater use in Hanoi
Source: Author (2016)

Recently **Decree No. 80/2014/ND-CP on water drainage and wastewater treatment has been passed, with much greater emphasis on wastewater (and sludge) reuse after treatment.** It includes options for decentralized treatment, which could stimulate local reuse. It is too early to comment on the outcome of this piece of legislation but it is undoubtedly a turning point for Vietnam.

In summary, there is ample evidence that strong legislation is in place to regulate wastewater discharges and to require treatment. However, the mechanisms for monitoring and enforcement appear insufficient and there is criticism that the LOEP (2005) lacks clarity and specifics, leading to poor enforcement (CCW, 2014). There is little evidence to suggest that these specifics have been introduced through the LOEP (2014). There are also various pieces of environmental legislation that support reuse, including instruments for funding, research support and institutional support for investment and interventions (LOWR, 2012) and more recently the explicit reuse element in Decree No. 80/2014/ND-CP. However, the means of implementation need greater clarity.

7.2.1.2 Structure

The government sector in Vietnam is highly structured but the **complexity of the system may be hampering WWTU.** Sanitation and water supply are the responsibility of MOC in urban areas and MARD in rural areas. Furthermore MARD is responsible for all aspects of agriculture and aquaculture and therefore would have responsibility for the reuse end of the sanitation chain, if permitted by law. MPI is responsible for investment decisions. MONRE, with VEA, oversees water quality and pollution issues. In theory many organizations are expected to work together with designated lead agencies but **in practice coordination is limited and there is overlap of roles and activities**. Further overlap is predicted by the VEA (2014c) between the LOEP, 2014 and the draft 'Decree on waste and scraps management', urban wastewater management component, being written by the VEA with the CCW. They are working to overcome these coordination problems, bringing together many of the players e.g. MONRE, MARD, MOIT and MOC for discussions (VEA, 2014c).

At local level responsibility for water and wastewater is vested in the PCs, which have departments that mirror the ministries. **Decree No. 80/2014/ND-CP shores up the role of the PCs as the owners of the drainage network, who have the right to pass responsibility to lower level PCs**.

In cities such as Hanoi, state owned enterprises, known as SADCOs or URENCOs have been established under PCs with responsibility for sanitation infrastructure. Their remit has been limited to primary and secondary sewers and drains, because of the enormity of the task, while responsibility for tertiary level infrastructure has been devolved to local government (e.g., at commune level). In Hanoi, SADCO sewers only cover around 60 percent of the city. Hanoi SADCO suffers from lack of infrastructure, funds and staff.

Wastewater management is funded in two main ways. Capital funding comes from the state but investment has been limited. Operation and maintenance is covered by fees for wastewater discharge, which are collected as part of the water supply tariff (Decree No. 67/2003/ND-CP). Recent changes mean that these can be set locally although most remain around 10 percent of the fresh water fee. The amount is higher in Hanoi but is still insufficient to cover costs. At present only 25 percent of SADCO's operating expenses are covered (GHK International, 2005; WHO et al., 2011). **Lack of financing means that PCs must make up the shortfall and there is insufficient funding to manage facilities effectively**. The outcome is that facilities are old and poorly maintained and most of the wastewater from Hanoi is discharged untreated. However, once again, Decree No. 80/2014/ND-CP and Circular No. 02 /2015/TT-BXD, may change this, due to their explicit description of what can be covered under the drainage charge, method of calculation and modes of collection.

MARD and DARDs are responsible for agriculture and aquaculture. There is very little if any collaboration between DARD and agencies involved in wastewater. Their focus is on modernizing agriculture and aquaculture and improving irrigation. There appears to be no mandate on recycling.

Vietnam's NGO sector is nascent, although many mass organizations exist. They can be very active in areas of social development and have been taking over tasks that the state is unable to fulfil. The CCW appears to be an energetic and effective network advocating for wastewater management and bringing together state and non-governmental entities to develop policy. Similarly, the private sector is gradually being brought into the WSS sector. ADB (2010) noted that Vietnam is attempting to transform '*the water sector from a social to a business focus. They aim to strengthen sector institutions in order to promote efficiency and conservation, expand access to reliable water supply, provide safe drinking water, and promote wastewater management'.*

In summary, the structures for implementing WSS and WWTU are, in almost equal measure, complex, overlapping and full of gaps. Crucially the links between wastewater management and reuse sectors do not appear to exist. Despite the various pieces of legislation that support RRR, the structures and means of implementation are not in place. This lack of implementation level procedures and guidelines is highlighted by the fact that the German Government has funded a six year project to provide financial and technical support for capacity building in wastewater management. Under the 'Wastewater and Solid Waste Management in Provincial Centers' (WMP) project, the German Technical Cooperation Agency (GTZ), the German Development Service (DED), and MOC have developed a template for local regulation on wastewater management. They believe that this serves the urgent need to assist local governments and wastewater operators in the implementation of national laws and regulations, such as Decree No. 88/2007/ND-CP and Circular 09/2009/TT-BXD (MOC and GIZ, 2012).

There is significant mention of fees, fines and methods of funding wastewater management and treatment in legislation but details about the means of collection and allocating these fees are not adequate and in practice, political motivations result in low fee rates, while deficiencies in collection processes exacerbate the problem. The result is that waste management companies cannot cover O&M costs and the funding for development of infrastructure and services is not forthcoming.

7.2.1.3 Culture

Several communities are making use of wastewater via pumping from rivers containing wastewater e.g. Hoang Liet commune in Thanh Tri district pump water from the To Lich River, via a brick channel, for use on fields and in ponds to cultivate aquatic plant and fish. However health concerns are arising because of the greater quantities of industrial waste entering the To Lich (Vuong et al., 2007). Lots of other examples of reuse exist (see Marcussen et al., 2007; Khai et al., 2007; Dao et al., 2010) suggesting that it is tolerated or even accepted. Hoan (2001) found that all the farmers interviewed in Thanh Tri District displayed a strong willingness to obtain wastewater, and that its long term use resulted in an effective system that had become part of district development plans.

Within the government sector, strengthening the **collection and use of wastewater in accordance with laws is advocated by the VEA and their collaborators** including CCW and several ministries (VEA, 2014c). Work done under the WMP project may also be changing opinion and stimulating interest in reuse. However, there appears to be **little reuse taking place on the ground**. It is difficult to determine whether this is due to cultural reasons, financial constraints or physical factors, however it is likely to be a combination of these. Brief discussions with government officials in the environment and agriculture sector, as well as university staff, did not highlight a culture in which wastewater reuse was a high profile issue.

7.3 Comparison of Institutional Arrangements in Bangalore and Hanoi

This section draws together the findings from the two case studies and considers the four sub-questions that were posed at the outset of the research:

- What wastewater use systems exist in the case study cities?
- What policy and legislative components are in place relating to wastewater use in the case study cities?
- What stakeholder structures are in place relating to wastewater use in the case study cities?
- What institutional arrangements contribute to the success or failure of wastewater reuse systems in the case study cities?

7.3.1 Water and Wastewater Context

The situations in Bangalore and Hanoi are similar in that a large portion of the cities are sewered but a considerable number of households and businesses are not connected, the sewers are not well maintained, they rarely reach low income communities, and the majority of the wastewater is usually disposed without treatment. The sewers therefore move the problem but do not satisfactorily protect public or environmental health. In both cities there are some large centralized STPs. In Hanoi these have been introduced in the past few years, whereas Bangalore has had some capacity for decades. Both cities are planning to increase the level of treatment through central STPs. In addition Bangalore has hundreds of small STPs in private buildings, although many do not function. Industrial ETPs also exist in both countries but many do not operate for various reasons.

In Bangalore there are clear WWTU models including:

- treatment of municipal wastewater in central WWTPs and use in industry and for lake recharge (with incidental benefits to fishermen, livestock owners and groundwater users);
- on-site treatment and use of domestic wastewater in apartments and commercial buildings;
- decentralized treatment of municipal sewage for irrigation of parks;
- reuse of ‘untreated’ effluent in agriculture, in planned and unplanned systems, the former being implemented by the irrigation department and utilizing natural attenuation processes.

In Hanoi reuse is predominantly in the form of indirect use of untreated wastewater (from rivers) in agriculture and aquaculture. This practice is long established and has in some places been recognized in official local plans. In both cities further reuse is planned by the city/state water authorities in the form of centralized treatment and use for non-potable purposes, principally industry. Bangalore is also proposing to augment drinking water supplies in the future and is considering decentralized WWTPs to rehabilitate lakes and wetland ecosystems.

In both cities RRR plans all involve treatment, with the exception of planned agricultural use in Bangalore, which relies on natural treatment over a 7 km stretch of river.

7.3.2 Policy and Legislation

Both cities have strong reuse elements in water and environmental legislation. For example: the NWP 2002 and 2012, the NEP, 2006, the Water (Prevention and Control of Pollution) Act, 1974 in India; the LOWR, 2012, the LOEP 2005 and 2014 in Hanoi all support reuse and recycling in various forms, mainly for non-potable purposes and after appropriate treatment. India's NWP, (2002; 2012) advocates the reuse of industrial and domestic wastewater after appropriate treatment for purposes including groundwater recharge, urban needs and non-potable household uses. State environmental legislation is very specific and requires certain premises (based on size and location) to have STPs and utilize reclaimed water for non-potable domestic applications such as toilet flushing and gardening. The most recent iteration of the law allows the sale of treated wastewater from private STPs (KSPCB, 2015). In Vietnam the LOWR (2012) considers reuse and recycling to be priorities and environmental legislation requires it (Decree 80/2014/ND-CP). This legislation also allows decentralized options, which could stimulate greater reuse.

The use of untreated wastewater is not supported by law in Bangalore, with the LOWR (2012) stating that the use of untreated wastewater in agriculture is not permitted. The Environmental Protection Rules (1993) provide standards for discharge of environmental pollutants to water, sewers, irrigated land and coastal waters; while the Bureau of Indian Standards provides standards for water quality for best designated use including propagation of fisheries, irrigation and industrial cooling (Annex 5; Annex 6; Annex 7). In both cases reasonably strict standards are given but it is interesting to note that neither include pathogens. This may provide some leeway for the use of domestic wastewater after certain barriers as proposed by the WHO Guidelines (2006). In Hanoi irrigation standards do specify *E.coli* levels.

The national laws and policies have been incorporated and in some cases enhanced in local level legislation. The Bangalore Sewerage (Amendment) Regulations, 2012 are a good example of this. So too is KSPCB's legislation on recycling in apartments and commercial buildings in Bangalore, although this has faced criticism for being two prescriptive. These concerns have partly been addressed in changes published in 2015. In Hanoi the multiplicity of legislation is a major complicating factor. This is being addressed through the LPLD (2015) but more needs to be done to rationalize overlapping or contradictory legislation. In both cities, despite local level legislation, specific guidance on how to implement WWTU and meet legal obligations is lacking.

The pro-reuse water and environmental legislation is not reciprocated in reuse legislation at the end of the sanitation chain (i.e. in industry, agriculture or irrigation), although water policy does provide a full circle of use for urban purposes and domestic non-potable uses. Completing this chain so that policy and legislation require reuse in certain sectors and provide guidance, support and even incentives for reuse, would greatly enhance the ability of stakeholders to push a reuse agenda or engage in reuse.

As an example, the fact that it is illegal to use untreated wastewater for agriculture in India rules out a major reuse market. Legislation that gave detailed guidance on how wastewater could be used in agriculture, taking account of natural attenuation and other barriers to risk, to ensure human, crop and environmental safety, would have several benefits – the city could reduce its treatment budget; the agriculture sector would receive a regular, reliable water supply, containing nutrients; the authorities would need to find less water for irrigation; and farmers would be at less risk of losing their water supply to other users, because the quality would not be suitable.

Introducing 'end of chain' reuse legislation would also protect users, such as farmers and consumers of agricultural produce, and would facilitate appropriate barriers to be put in place, in line with the WHO (2006) guidelines on wastewater use in agriculture and aquaculture.

Financial mechanisms have been shown to be instrumental to the success or failure of wastewater management in both cities and of reuse projects in Bangalore. Wastewater management is generally funded by a fee within a water supply fee, although additional fees apply in Hanoi. These fees are too low to cover O&M and come nowhere close to allowing capital investment. This has limited progress and has stifled private sector investment. Alternative funding mechanisms will be required and in Bangalore, reuse is providing a solution because wastewater costs less to treat and supply than fresh water.

7.3.3 Implementation – Stakeholder Structures

The implementation level is where Bangalore and Hanoi can be said to differ significantly. Bangalore has a department dedicated to WSS, the BWSSB, and within that a section that focuses on non-conventional water resources, including wastewater reuse, which has identified lack of knowledge and awareness to be major obstacles. There is also a strong environment agency (KSPCB) pushing onsite reuse and the BBMP which officially undertakes certain aspects of wastewater management. In Hanoi, although SADCO exists to implement wastewater management, they are effectively a service provider and not a dynamic, autonomous agency that will develop new ideas or implement novel projects. For this, the lead must be taken by PCs and their departments, but they have multiple areas of responsibility and interest. At the national level responsibility for wastewater management spans numerous ministries and departments, hampering decision-making, implementation and accountability.

A complication that appears to be specific to Bangalore, is the role of the KSPCB because, although its mandate is to enforce compliance with environmental legislation it is also driving on-site reuse. This means that they may need to take on a dual role of supporting and prosecuting users. In addition they monitor BWSSB and are currently in dispute with them about their failure to adequately treat wastewater. It would appear beneficial for these bodies to be working closely on the reuse agenda but at the same time a regulatory authority is essential. Greater clarity on roles and the establishment of sections or organizations to collaborate on reuse and to support users is necessary.

Official organizational structures to implement reuse in agriculture, aquaculture or industry could not be found in either city. In Bangalore the MID has introduced reuse but this is not part of formal policy, nor is there a formal structure within MID. It is notable that the success and subsequent public support has resulted in them proposing more reuse, which may lead to the development of institutional arrangements. Similarly, there is no structure in place to support industrial use, which could potentially facilitate such things as joint development of distribution infrastructure or sharing arrangements, as seen in South Africa in the landscape analysis. In Hanoi there are strong informal institutional arrangements for sharing wastewater across ponds and fields, similar to those in Faisalabad (see landscape analysis). Arrangements are in place to operate sluice gates, to fill ponds by rotation and to drain ponds to irrigate fields and supply nutrients.

In both cities the private sector are beginning to engage and have been involved in BOT projects for WWT. In Bangalore they are also increasing their presence in the market for small-scale STP construction and operation. However, they are not attempting novel business models or reuse but are instead remaining in the tested treatment sector. Stimulating the RRR sector and finding ways for private companies (and state organizations) to finance their operations is vital. For companies supporting private STPs, this is emerging as the price of water rises and availability declines. For centralized systems the sale of wastewater offers some scope but is insufficient. Systems that provide multiple revenue streams (e.g., fuel, energy and fertilizer) should also be considered.

In both cities it is notable that there is neither joined up policy nor collaboration. A proposed structure, taking Bangalore as an example, is provided in Figure 7-5.

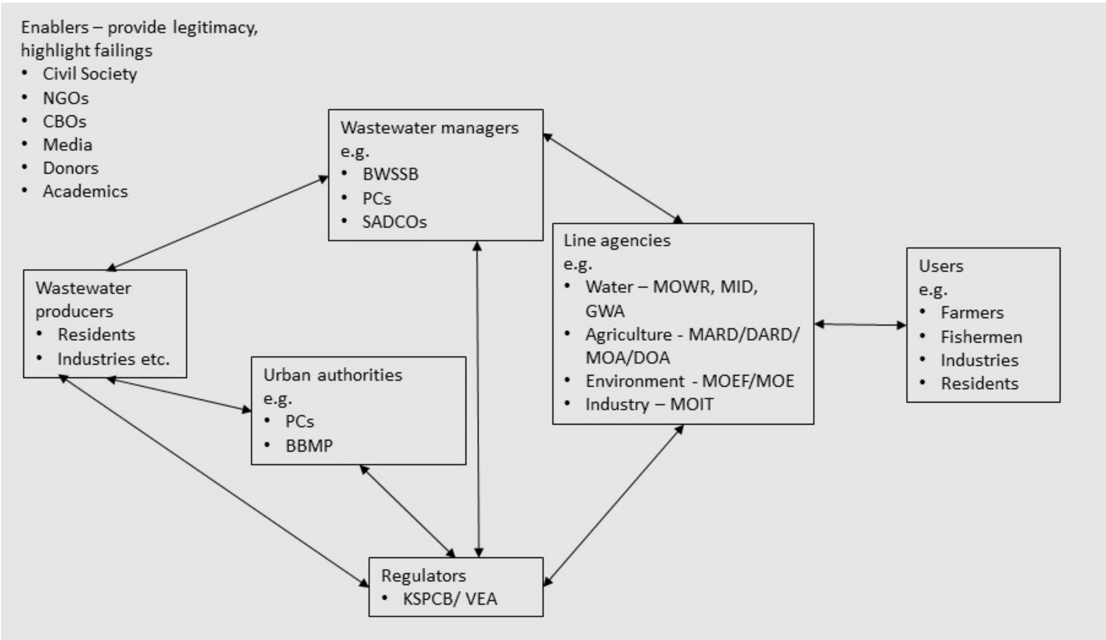


Figure 7-5. Example of stakeholder relationships required for wastewater reuse
Source: Author (2016)

7.3.4 Practice and Attitudes

There is no reciprocal support for reuse in agricultural legislation but that does not mean there is no support from the sector. In Bangalore the irrigation authorities have introduced municipal wastewater to waterbodies that are utilized for irrigation further downstream. Natural attenuation means that the water is of adequate quality at the point of use and the practice has resulted in multiple livelihoods benefits including groundwater recharge, which is now utilized for drinking water supplies. Consequently the authorities propose to extend such schemes.

Likewise there is theoretical support from industry but physical and institutional barriers exist. The authorities expect the industries to pay for tertiary pipes but the distribution system is absent. Not only is construction costly but it requires the consent of several departments and landowners which has hampered development. The BWSSB is now proposing to develop the distribution network to facilitate reuse.

In Hanoi it was difficult to gain an impression of opinions because there were only a two examples of wastewater use identified and neither utilized treated wastewater. The use of untreated wastewater in agriculture and aquaculture has existed for many years and some local authorities in Hanoi have incorporated these reuse practices into their water management plans, suggesting that there is potential for further official support. There are also plans for largescale treatment and use in the city, although to what extent officials and citizens back these proposals is not easy to ascertain.

Public attitudes vary in Bangalore, depending on the use and their involvement.

- Residents of apartments with reuse systems are generally supportive but find it practically difficult. They lack the skills to manage STPs and suffer when they fail. Those who successfully operate their STPs and utilize the treated water are experiencing the benefits, especially where other sources of water are not available or are costly.
- Most residents fear the prospect of wastewater use in the potable supply.
- Most residents are supportive of industrial use and of lake regeneration and augmentation with treated wastewater.
- Reuse in parks has been practiced for many years with little complaint.
- Farmers appear satisfied with the use of wastewater and would welcome more due to water shortages in many locations.

It is interesting to note the number of mass media articles written about WWT, reuse and environmental matters, in Bangalore and Hanoi. The media in Bangalore are very well informed and often criticise government agencies and public figures. This is in part due to the strong civil society and NGO culture in Bangalore, with organizations and individuals who regularly publish informed articles. This may be instrumental in driving good practice. Hanoi has a less well developed media and NGO sector but CCW is actively collaborating with VEA on pollution prevention. Donors also play an important part but at present emphasise WWT over RRR in both countries. The value of ‘influencers’ should not be underestimated.

7.4 Key Institutional Factors for RRR Feasibility

The research was designed to identify a set of factors that could be used to aid in determining whether a location was suitable, in terms of the institutional context, for wastewater reuse. The set of factors developed draws together all elements of the study – literature review, landscape mapping and case studies. The factors are presented in Table 7-1. They can be considered in relation to specific reuse options or broadly for a city or location. The factors are not exhaustive but represent those considered most important based on the research. They are structured according to the elements of triangle analysis and can be used in conjunction with that methodology. It should be noted that some sections overlap, for example the budget element of the content component and the financial mechanisms in the structure component. For this reason the factors cannot be used to 'calculate' the feasibility of a project (based on how many boxes are ticket). Rather the factors are a guide to aid with interpretation of the institutional arrangements in a given setting, and like the triangle analysis help to organize information and give guidance that must be interpreted by the analyst.

The factors are considered for Bangalore and Hanoi in Table 7-2. An assessment is provided of how well each country is doing in relation to the indicators and a judgement made on whether, based on these factors alone, wastewater reuse is has high, moderate, low or no feasibility. In some cases a range is given, for example high-low, because there may be high feasibility for some aspects, such as reuse in industry, but low feasibility for others, such as reuse in agriculture.

A judgement is provided in Figure 7-6 on the ability to obtain information for each factor using literature only and therefore the usefulness in of a desk based study to assess institutional feasibility. This could offer potential for investors to make a preliminary appraisal to identify institutional barriers or advantages prior to a more detailed assessment. The applicability of the system was considered under three categories: easy to obtain information and ascertain feasibility; moderately easy to obtain information and ascertain feasibility but some gaps in knowledge; and difficult or impossible to obtain information and ascertain feasibility. Broadly it was found that much of the information could be obtained from literature review and internet searches but the details of operation of organizations and attitudes could not be assessed.

Table 7-1. Factors to determine feasibility of RRR from wastewater

Component	Factors
Content (written laws, policies and budgets)/ norms and rules of the game	
Reuse policy and legislation	• National policies endorse RRR and are consistent across sectors. • National legislation supporting RRR exists and is consistent across sectors. • National legislation has been interpreted into local legislation. • Certain users are mandated to recycle or to accept recycled water. • Legislation includes specific incentives and deterrents for users.
Budget for reuse	• A national budget exists for RRR. • Means of funding capital expenditure and O&M for RRR are clearly stated. • Funding has been allocated to RRR activities.
Policy support for private sector involvement	• Private sector involvement is specified in relevant policies and provisions are made for contractual arrangements. • There are no significant legal impediments to private companies entering the sector.
Structure (mechanisms for implementing a law or policy; informal institutional arrangements)	
Implementation (government)	• Government agencies exist that are dedicated to RRR or that have dedicated RRR departments. • Well understood mechanism are in place to implement RRR. • Government agencies function well and have sufficient (technical) capacity and resources.
Private sector	• A private sector already exists that can implement RRR projects. • RRR businesses can easily establish themselves (legal requirements slight; competition low). • They have clear RRR strategies and have successfully implemented RRR projects. • They have sufficient technical capability and other resources. • Accreditation schemes exist and are well implemented.
Ease of establishing RRR systems	• Technical skills and knowledge exist. • Technical support exists (e.g., Chamber of Commerce, department of agriculture etc.). • Financial support exists from government organizations, banks etc.
Collaboration and coordination	• All parties (government, private sector, civil society and communities) collaborate on RRR. • A clear benefits structure is established along the chain of stakeholders.
Accountability	• All parties, are accountable to relevant stakeholders. • Clear mechanisms exist to share plans and report on progress and results.
Financial arrangements	• Adequate mechanism for capital and O&M funding are in place. • There is donor interest in and financial support for RRR.
Culture (the values and behaviour that shape how people deal with and understand an issue).	
Local acceptance	• Residents are willing to engage in recycling or make use of the products (e.g. water, crops, fish). • They are aware of the rules regarding WWMU and are satisfied that products are safe. • They trust the authorities or private sector who are engaged in RRR.
Awareness of laws	• People are well aware of the rules regarding waste management and reuse. • People regularly follow the rules and see the benefits of doing this.
Knowledge development and sharing	• Technically knowledgeable third parties exist (e.g. university departments) and provide information to wastewater managers and users. • R&D takes place in respected institutes and is widely disseminated. • There is trust in these organizations to be impartial and informative.
Civil society, donor and media support	• There is a strong civil society advocating for relevant issues and supportive of reuse. • The media often reports on relevant issues, publicises policies and are supportive of reuse. • There is donor interest and they provide technical support.

Table 7-2. Institutional feasibility of reuse in Bangalore and Hanoi and review of indicator effectiveness

	Bangalore - Feasibility and description of the situation	Hanoi - Feasibility and description of the situation
Content		
Reuse policy and legislation	*High-Medium* - national and state water and environmental policy and legislation require WWT and wastewater RRR. Reuse is possible in agriculture provided water quality meets discharge and irrigation standards. No explicit reciprocal reuse legislation in the agriculture, fisheries or industrial sector. The water policy recommends bio-treatment i.e. Kolkata wetlands.	*Moderate* - national water and environmental policy and legislation endorse RRR. No reciprocal support in the agriculture sector. Reuse is supported in general but specifics hardly given. The emphasis seems to be for municipal wastewater to be treated and used for urban activities such as street cleaning. No specific incentives could be found although some tax breaks are mentioned and support is given for R&D.
Budget for reuse	*Moderate* - A budget is provided for treatment but no specific budget was identified for RRR except BWSSB project funding. There is funding for lake development (which can be linked to RRR as per Jakkur Lake).	*Low* - because no national budget could be identified or specific mechanisms for funding RRR. In general sanitation is underfunded both for capital investment and O&M leaving little for 'additional' components such as reuse.
Policy support for private sector involvement	*Moderate* - National Water Policy is supportive of private sector involvement.	*Moderate* - private sector involvement in WWM is anticipated in relevant policies but this relates to a general opening up of sectors to private companies. At present wastewater management is still controlled by state operated companies and People's Committees.
Structure		
Implementation (government)	*High-Medium* - BWSSB for WWT and a dedicated department for WWTU. KSPCB active in on-site WWTU. Involvement of MID and DOA would be required for agricultural use. All lack capacity in terms of numbers of staff and technical expertise for reuse. Certain organizations that have related remits e.g. BDA and BBMP but do little in relation to WWTU.	*Low* - no evidence of dedicated agencies or departments for reuse activities in water, wastewater or reuse sectors. Several government departments undertake water/wastewater management, however, many are stretched and under-funded. In cities dedicated agencies exist for WWM (SADCOs and URENCOs) but they too are underfunded and severely stretched. The VEA is interested in wastewater reuse and could take on some of this role.
Private sector	*Moderate-Low* - Businesses that make use of the wetland products can be relatively easily established (e.g. fishing rights; use of groundwater). Central WWT remains the domain of BWSSB although PPPs exist. No accreditation or training schemes.	*Low* - private sector involved in WWT through BOT arrangements but no formal reuse identified. Strong informal, institutional arrangements for use in agriculture and aquaculture, which have been formalized in one commune.
Ease of establishing RRR systems	*Low* - Institutional barriers low provided the businesses met the environmental standards but technical capabilities are limited both in the private sector and for domestic users (e.g. RWAs that are required to have WWTU in	*Low* – PPPs being introduced trough donor funded projects for centralized WWTPs but the climate is not conducive for private investment in WWM. Funding mechanisms have deterred the private sector. There are many individuals and groups willing to engage in

	Bangalore - Feasibility and description of the situation	Hanoi - Feasibility and description of the situation
	apartments); technical support is limited; and although financial mechanisms have been identified they are not currently mainstreamed.	WWU but this is unlikely to drive investment because farmers/fishermen are utilizing contaminated river water for free. There is little evidence of technical skills in WWTU, although there are small-scale examples such as BORDA and private companies constructing WWTPs for industries. Under the EPFs industries can access funds for WWT, although there are complaints that funds difficult to obtain.
Collaboration and coordination	*Low* – BWSSB is on the board of KSPCB but KSPCB also monitors BWSSB. KSPCB is currently taking BWSSB to court. There is little or no collaboration between BWSSB, KSPCB and farmers, DOA, MID, FD, LDA etc. BWSSB is attempting to improve their relationship with RWAs. Industry and BWSSB have a relationship to some extent but could be improved.	*Low* - cooperation between government organizations is inadequate and there are overlapping roles. Likewise coordination between government agencies and NGOs or networks is limited but some examples do exist, such as the collaboration between CCW, VEA and various ministries. There appears to be no collaboration between agencies responsible for water and wastewater management and those in the reuse sectors, such as agriculture, aquaculture and industry users.
Accountability	Low – BWSSB is a parastatal with low accountability. Increasingly state organizations publish information and are open to scrutiny from the media and other CSOs.	Not ascertained
Financial mechanisms	*Low* – There is some donor support for WWM, WWT, institutional strengthening and community engagement. Mechanisms for fee collection are inadequate but changes have recently been made. Central funding is inadequate.	*Low* – there is good donor support for sanitation and wastewater management, including wastewater treatment, however none of the project documentation includes recycling of wastewater. Mechanisms for fee collection are inadequate but changes have recently been made. Funding relies on central government and PC budgets which are stretched.
Culture		
Local acceptance	*High-medium* - Industries and farmers already use treated wastewater. Generally communities are supportive of reuse of water in lakes and wetlands. Media support reuse, especially in industry. People are concerned about direct potable use. Industry users are concerned about infrastructure, price, quality and reliability but accept reuse in theory.	*Moderate* - studies have revealed many farmers and fish pond owners utilizing river water in the full knowledge that it contains wastewater. They perceive the benefit of its use due to its reliability and nutrient value. In certain areas it has become part of the water management plan. How users would react to a supply of treated wastewater is not well documented.
Awareness of laws	*Low* – RWAs were unclear about expectations; farmers had little awareness of water quality except that which affected them.	*Low* - There is evidence from the new LOEP and the emphasis on awareness raising that the general public are probably not well aware of waste management rules.

	Bangalore - Feasibility and description of the situation	Hanoi - Feasibility and description of the situation
Knowledge development and sharing	*Moderate* – several universities with activities relating to the sector. Well respected and trusted. Information shared via newspapers, online chats, NGO groups To what extent they reach the public is less evident.	*Moderate* – several universities with activities relating to the sector, some extremely active and prominent in the sector. To what extent they reach the public is less evident.
Civil society, media and donor support	*High* - Extensive media coverage of water scarcity problems, WWT and water quality, strong civil society and NGOs, supportive courts, although slow.	*Low* - civil society and NGOs are nascent but emerging and taking on roles in the WSS sector. Mass organizations are active and taking on some roles that local government cannot manage. However, they are heavily controlled by the state. The media reports on projects but rarely criticises the government.
Summary	There is overall High-Moderate feasibility for WWU in Bangalore – there is supportive legislation and local interpretation; no concomitant end-use legislation but this is not preventing reuse; appropriate but over stretched and under resourced government agencies; more collaboration is required along the chain to reach high feasibility; insufficient funding and incomes; donor, media and public support for some reuse systems.	There is overall LOW FEASIBILITY because some legislation endorses reuse (water and environment) but potential reuse sectors do not (agriculture, aquaculture). Budgets and private sector involvement are not apparent. Structures are not in place to implement reuse, nor is there a strong NGO, civil society or donor community advocating or funding reuse. There is however good knowledge and interest at universities.

Figure 7-6. Assessment of the suitability of indicators for desk based analysis of RRR feasibility

8 Conclusions

8.1 Introduction

This chapter returns to the guiding research question: '***What institutional arrangements support or hinder wastewater reuse in developing countries*?'** and aim of the research: **'*to identify a set of key institutional factors that are necessary for wastewater reuse and that can be used by stakeholders to: determine whether the institutional context is conducive to wastewater reuse and identify barriers that need to be removed to facilitate reuse*'** and summarises pertinent findings.

A summary of the institutional factors that are considered to support or hinder reuse are presented, based on the findings in Chapter 7 and the set of institutional factors to be considered when assessing the feasibility of wastewater RRR systems (Table 7-1). The utility and effectiveness of these factors as a means of assessing the institutional feasibility of wastewater reuse in other cities is evaluated in conjunction with the triangle analysis methodology, with particular reference to their use in *ex situ* assessments. The chapter also reflects on the study's contribution to knowledge, making reference to how it might play a part in governments' efforts to attain some of the SDGs. The chapter concludes with a review of the limitations of the study and suggestions for further research.

8.2 Institutional Arrangements Support or Hinder Reuse in Study Cities?

Based on the discussion in Chapter 7, the following institutional arrangements can be highlighted as having a considerable positive of negative impact on reuse systems in the case studies (Table 8-1).

Table 8-1. Institutional arrangements that support or hinder RRR in Bangalore and Hanoi

Support	Hinder
• National policies on water and environment. • Local level interpretation and development of reuse policies. • Dedicated departments in the water, sanitation, environment sector. • Income from sale of wastewater • Support for private sector involvement • Private sector in STP management growing • Local support for non-potable reuse • Media and civil society support (depending on the reuse) • Donor support	• Lack of national policies on agricultural, industrial reuse etc. • Inadequate guidance on how to implement laws. • No dedicated departments at the reuse end of the chain (i.e. agriculture, industry). • Funding constraints – low revenue, require central funding • Private sector not well engaged, lack expertise, accreditation and income generation opportunities • Collaboration along the sanitation chain insufficient • Media and civil society criticism (depending on the reuse) • Small research/academic/technical sector to inspire trust and facilitate development of technologies/processes

8.2.1 Overcoming institutional barriers

Reframing the Discussion

In both cities much of the legislation arises from an environmental protection perspective in which the emphasis is on solutions to pollution; or from within the water supply discourse as a means to augment supply. Reframing the discussion around the greater benefits that can accrue from RRR, particularly at an individual level, could stimulate acceptance. These include the regularity of water supply and reduced costs. Changing the emphasis from compliance and monitoring, to support for WWTU (e.g. for apartments in Bangalore) could garner support and potentially reduce the burden on the environmental authorities. Success could lead to self-regulation and would draw in the private sector (i.e. STP experts) thereby improving standards and further reducing the monitoring burden felt by the authorities.

Clear Benefits

A clear chain of benefits for all those engaged in the WWTU process, not just end users, would greatly improve the success of RRR projects. Benefits need not be financial but must contribute to the remit or defined activities of each group. For example, in Bangalore, wetlands improve water quality, which supports lake health and fisheries, benefitting the LDA and BBMP who are better able to fulfil their remit and potentially engage in cost sharing with the BWSSB. Local residents benefit from an improved environment and may be encouraged to maintain the ecosystem either through voluntary contributions or through payment for certain non-essential (non-polluting) recreational uses. They may also benefit from groundwater recharge, which would assist BWSSB and GWCB. Benefits along the chain are essential to prevent distortions that occur when certain parties do not receive adequate reparations and thus do not fulfil their element of the system. For apartments in Bangalore, allowing them to sell their treated wastewater could stimulate reuse.

Unconventional Partnerships

Linked to the framework in Figure 7-5, unconventional partnerships may be required, for example between farmers and water supply agencies, either directly or through agriculture departments. These could stimulate exciting reuse models or improve those that are currently operating sub-optimally. Whatever the form, there needs to be greater collaboration between all parties along the sanitation chain.

Training and Accreditation

Establishing some sort of official training linked to accreditation for developers or a code of conduct with relevant associations, such as CREDAI in Bangalore, would strengthen the position of the private sector. This could be done for both developers and STP companies, who find it hard to find and retain skilled staff. Their belief is that raising the status of the industry would address this.

Perceptions, Attitudes and Influencers

Perhaps the most significant institutional barrier is that of perception and attitude. Until stakeholders, at all levels and in all sectors, are convinced of the need for reuse and the benefits that it can accrue it will only be a small part of the water supply system. Fortunately good practice is gaining the attention of the media and citizens, which, combined with growing expertise in the city, could drive reuse.

8.3 Summary of Institutional Arrangements for Reuse

The two studies have highlighted important factors that need to be in place if reuse is to be feasible (see Table 7-1). These can be summarized as:

- Legislation approving reuse in all its forms for all relevant sectors along the sanitation chain.
  - Specific legislation, implementation mechanisms and guidance needs to be formulated across sectors so that the entire wastewater generation and use chain is encompassed. Legislation and implementation mechanisms must be unambiguous and not contradictory.
- A structure to support development and implementation of legislation.
  - The structure must include agencies to implement; provide advice and support; and monitoring and enforcement. It should span government and private sector as well as end users.
- Support from the wider community.
  - Civil society, private sector, residents, NGOs, CBOs, the media, academia and donors are all important stakeholders with roles ranging from implementation to promotion of reuse.
- Incentives and financial mechanisms must be put in place.
  - Incentives are needed for stakeholders along the reuse chain.
  - Engage private sector stakeholders and financing mechanisms to maintain the system will be imperative for scaling up.
  - Financing (capital and O&M) must be appropriate and sustainable.

8.4 Utility of the Assessment Framework

In addition to identification of factors that support or limit reuse, the aim of the study was to develop a useful framework to assess the feasibility of potential reuse interventions. This section assesses the effectiveness of the factors identified as well as the methodology used in the study.

Triangle analysis was an extremely useful analytical approach to disentangle the multiple element of the WW reuse sector. The three components – content, structure and culture – enabled the data to be efficiently sorted and easily presented. The table of institutional factors that was developed from the analysis is also deemed to be a suitable framework that would facilitate assessment of institutional feasibility of WWTU, with the additional advantage that it focuses more specifically and immediately on the reuse sector. This allows the feasibility of a reuse model to be assessed quickly. However, the narrow focus may result in key components being missed or nuances being overlooked.

The feasibility framework should therefore be used with some caution but is an effective checklist to ensure that the most relevant components have been considered. Used in conjunction with triangle analysis a robust descriptive assessment can be made of the feasibility of wastewater use in any given setting.

The Hanoi case study was an opportunity to test the methods *ex situ* using secondary literature and analysis of legal documents. Triangle analysis and the table of institutional factors developed for this study proved to be suitable for an effective institutional assessment even when no interviews were possible. The elements that were not adequately assessed from literature were the cultural context and the relationships between stakeholders. Where more literature exists, such as ADB country studies, this can be satisfactorily filled. The conclusion is that the method is as effective as the available literature. In a situation where interviews or field work are not possible it is a valuable substitute but the researcher must make cautious assessment based on their opinion of the quality and bias of any information used. Ideally it would be used as a first stage prior to interviews or workshops.

8.5 Contribution to Knowledge

The analysis has provided insight into the institutional arrangements that are present where wastewater is successfully being used in various systems. It has identified some of the most important enabling factors and institutional elements that restrict the introduction or expansion of reuse. The study has also identified elements that could make RRR models more viable and thereby encourage investment and stakeholder engagement, which will contribute to treatment and pollution reduction.

In addition, a methodology for the rapid assessment of the institutional arrangements within a given setting (e.g. a city) and how they influence reuse has been developed and evaluated. This has the potential to be useful to investors such as governments, donors and the private sector. The ability to highlight key constraining or supportive factors would allow an investment plan to be more targeted. By expediting the feasibility process and identifying options for removal of barriers, investors will be better placed to implement RRR.

The expansion of wastewater reuse is a global imperative in the light of growing populations, increasing demand for water, changing living standards and inadequate sanitation in many parts of the world. The SDGs commit nations to 'ensure the availability and sustainable management of water and sanitation for all' (SDG 6, UN, 2015). This includes improving water quality through reduced pollution, halving the quantity of untreated wastewater, increasing recycling and safe use, improving access to sanitation, increasing water availability in cities, reducing the number of people suffering from water scarcity, and protecting and restoring water-related ecosystems. Wastewater reuse can contribute to all these aspects and the knowledge gained in this study can improve the likelihood of investment in reuse systems as well as their long term viability and sustainability. Depending on the reuse system itself, there can also be contributions to SDG 2 on ending hunger and improving food security (though reuse in agriculture and aquaculture); and SDG 3 on healthy lives and reducing water-related diseases (UN, 2015).

8.6 Limitations of the Research

Although institutional analysis of wastewater reuse may seem to be a relatively contained topic it is actually wide ranging, spanning water, wastewater, environment, agriculture, aquaculture, industry and construction. This means that the documentation and legislation around these topics is considerable and the range of stakeholders within those sectors, as well as the courts, the media, civil society, NGOs and residents is manifold. In addition wastewater use includes both formal and informal, treated and untreated wastewater use. As such it may not have been possible to do justice to all elements and some may require further research.

The major limitation, which had a considerable impact on the work for Hanoi, and in fact led to a change in the research plan, was the ability to obtain interviews. The case study methodology required several interviews with a range of organizations but gaining access to these organizations, particularly to senior members of staff who would have the required knowledge, was often not possible. Influential contacts or those with an existing relationship are required to facilitate access.

Obtaining information on peoples' opinions, beliefs and relationships requires trust and would have benefitted from a research framework that allowed more time with stakeholders. An ethnographic approach may be been appropriate, but as stated above, the wide ranging nature of the case study phenomenon under consideration precluded such an approach. Gaining more feedback, beyond a single FGD and discussions of findings with key informants could have strengthened this aspect.

The nature of institutional arrangements is that they are always changing. During the course of the research major new legislation was introduced in both cities. This was incorporated into the study but it is not possible to determine the outcome for reuse systems in the time frame.

8.7 Suggestions for Further Research

Further research could contribute to an even greater understanding of instructional arrangements that support or hinder wastewater reuse. Some of these are suggested here.

Adding value to reuse models through linkages with other sectors will stimulate investment and expansion. Examples are: the energy sector through models that generate energy in the treatment process or solid fuel as a product of treatment; and fertilizer suppliers or the agriculture sector which could make use of sludge from the treatment process. Analysing institutional arrangements across these sectors and how stakeholders interact would provide useful knowledge.

The research focused principally on city level institutional arrangements but there is potentially more to learn about how reuse systems were established and the current institutions that operate within them. A good example of this is industry users of treated wastewater. A detailed case study within these organizations would provide operational details to investors, users and donors. In particular a deeper understanding of what is preventing industries from using treated wastewater could aid those supplying wastewater.

A key component of the study was to present a set of factors that can be used in a feasibility assessment for wastewater reuse. The factors are based on literature review, landscape analysis of wastewater use and two case studies. The set of suggested institutional arrangements that support or hinder reuse could be strengthened if assessed in more cities. Paired with the triangle analysis methodology a useful tool could be developed for rapid assessment of the institutional conduciveness of a proposed RRR site.

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10 Annexes

Annex 1. Types of Health Risk Study and Examples for Wastewater Irrigation

Type of study	Examples of health related studies in literature
Microbial analysis	
Contributions: • Determines concentrations of excreted organisms in water or on produce • Data on pathogen die-off rates • Identify sources of pathogens • Link pathogens and infection/disease **Limitations:** • Expensive, unless indicators used • Time consuming (sample collection; results) • Needs trained staff and lab facilities • Lack of standardized procedures	• Amoah et al., 2005: Microbiological water and crop contamination monitored on urban vegetable farms in Kumasi and Accra, Ghana. Faecal coliform and helminth egg contamination levels of drains, streams and shallow wells exceeded WHO recommendations for unrestricted irrigation and faecal coliform levels on lettuce exceeded common guidelines. • Amoah et al. 2007: the farm was the main point of lettuce contamination in Ghana and despite unsanitary conditions in markets contamination levels did not increase on crops. • Feenstra et al., 2000: wastewater used around Haroonabad, Pakistan contained far more faecal coliform bacteria and helminth eggs than advised by the WHO (1989). • van der Hoek et al., 2002: an assessment of water quality in Haroonabad, found that wastewater had levels of E. coli and worm eggs, including hookworm, roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*), dwarf tapeworm (*Hymenolepsis nana*), and beef tapeworm (*Taenia saginata*), exceeding international standards for irrigation and could pose a risk to human health. No worm eggs were detected in the wash water from vegetables grown on the wastewater-irrigated fields suggesting that the risk was primarily to the farm workers and not produce consumers.
Epidemiological studies*	
Contributions: • Measures actual disease in an exposed population • Can test exposure hypotheses • Can be used for chemical risk assessments **Limitations:** • Expensive • Bias can affect results • Needs large sample • Needs ethical clearance	• Reviews by Shuval et al., 1986; and Blumenthal and Peasey, 2002: considered four exposure groups: farm workers, families, nearby communities, consumers. • Feenstra et al., 2000: in the farmer community exposed to wastewater near Haroonabad, the prevalence of diarrheal diseases and hookworm infections was very high, especially among male farm workers. • Peasey et al., 2000: Farm workers and their children in contact with raw wastewater have a significantly higher prevalence of Ascaris infection than rain-fed farming families. Excess infection is greater in children than adults. Retention in reservoirs reduces the excess infection. Risk associated with eating onion and green tomato (but no other product) grown with wastewater. • Srinivasan and Reddy, 2009: morbidity surveys in villages around Hyderabad, India, found that there was significantly higher morbidity rates in wastewater than control villages, and higher morbidity rates

	for males than females, and high rates for agricultural labourers, which may relate to time spent weeding and in contact with wastewater. • Ensink et al., 2008: increased risks of hookworm infections in farmers in Hyderabad engaging in farming with irrigation water with high levels of helminth eggs (Asacris lumbricoides: 70 ova/l; hookworms: 76 ova/l; and Trichuris trichura: 4 ova/l).
QMRA	
Contributions: • Can estimate very low levels of risk of infection/disease • Low-cost method of predicting risk • Comparisons of different exposure routes • Principles can be applied to chemical risk **Limitations:** • Exposure scenarios can vary and are difficult to model • Validated data inputs are not available for every exposure scenario • Predicts risks from exposure to one type of pathogen at a time.	• QMRA has been applied to risks associated with viruses, bacteria and protozoa but there are few studies on helminths (WHO, 2006). • Hamilton et al., 2006 – a stochastic QMRA for spray irrigation of vegetable crops with non-disinfected secondary treated wastewater, demonstrated that a withholding period (using freshwater), could be an effective means of mitigating the risk of enteric virus infection to consumers. • QMRA studies have indicated a significant threat to farmers and consumers (Seidu et al. 2008) with an annual loss of about 12,000 Disability-Adjusted Life Years (DALY) in Ghana's five major cities due to wastewater contaminated vegetables (Seidu and Drechsel 2010).

*Literature cited includes epidemiological and other health studies e.g. livelihoods assessments.
Source: WHO, 2006; Bos et al., 2010

Annex 2. Examples of studies of heavy metals in wastewater agriculture

- Sharma et al. (2007) found that concentrations of Cd, Cu, Zn, Pb, Cr, Mn, and Ni in irrigation water were below the internationally recommended (WHO) maximum permissible limits set for agricultural use and that the mean heavy metal concentrations in soil were below the Indian standards for all heavy metals but that at certain times of the year concentrations of Cd, Pb and Ni exceeded permissible Indian standards in the edible parts of the leafy vegetable studied.
- The concentrations of heavy metals in crops sampled by Yadav et al. (2002) in an area irrigated with wastewater found all samples to be within permissible limits.
- Heavy metals (Fe, Cu, Zn, Mn, Ni, Pb and As) have been found in concentrations of concern in vegetables irrigated with water from the Akaki river in Addis Ababa (Itanna and Olsson, 2004; cited in Bahri, 2009).
- In Haroonabad, India the heavy metal concentration levels found in the soils of the wastewater-irrigated fields were within the range of normal soil concentrations (van der Hoek et al., 2002).
- In Hubli–Dharwad there are no heavy industries so concentrations were below the permissible limits in the sewage streams (Bradford et al., 2009).
- Studies on flax, cotton and rice have shown that uptake of metals from contaminated soils is low, although health risks were not ruled out (Angelova et al., 2004; in Toze, 2006a; Fazeli et al., 1998).
- Ofosu-Asiedu et al. (1999) found that crops irrigated with domestic wastewater had similar levels of metals to background environmental levels and posed no additional risk to health.
- Results for soils used to grow wheat in Faisalabad, Pakistan indicate that in both canal water and wastewater irrigated plots, soil Cd, Pb and Zn concentrations are below the EU Maximum Permissible levels in sludge amended soils. Furthermore, wheat straw (dry weight), Cd and Pb concentrations were orders of magnitude below the EC Maximum permissible levels (Directive 2002/32/EC) for Pb and Cd in feed materials and therefore pose no threat to the fodder-livestock food chain, even after 25-30 years of irrigation (Simmons et al., 2010).
- Hussain and Al-Saati (1999) concluded that the short- and long-term uses of different types of wastewaters for irrigation did not show any significant increase in the bioaccumulation of heavy metals in crops and soils.

- By contrast, studies conducted in Mexico (Assadian et al., 1998, 1999), where wastewater has been used for crop irrigation for decades, show that it may account for up to 31 percent of soil surface metal accumulation (Cd, Pb, Ni, Zn, Cr, and Co). Even so, the heavy metal concentrations in alfalfa posed no risk to animals or human health.
- These findings are partially supported by Chary et al. (2008) who found a substantial increase in metal concentrations along the Musi River in Hyderabad, which has been irrigated with contaminated river water for many years. However, they also tested crops and milk and found high levels of Zn, Cr and Pb in cow and buffalo milk, and Zn, Cr, Cu, and Pb in vegetables, and concluded that contaminated vegetables are likely to induce health hazard, particularly Zn, Pb and Cr, based on a risk assessment using recommended dietary intake.

Annex 3. Institutional Analysis Interviews

Stakeholder	Remarks/Purpose – To understand ….
BWSSB / Ex BWSSB	The role BWSSB plays in WWT and use. History of reuse. Reuse plans. Policies/regulations around reuse that influence/mandate BWSSB.
Operator of BWSSB owned STP – Jakkur lake	Motivations for operation e.g. costs, cost savings, financial flows, water quality. Contractual relationships with BWSSB (and others e.g. KSPCB, local communities). Awareness of rules governing STPs. Knowledge of reuse. Incentives are for private sector to get into WWT/reclamation.
KSPCB / Ex KSPCB	What KSPCB plays in reuse e.g. regulating and enforcement (does this stimulate or hinder reuse?). Policies or legislation that give them a specific role in reuse. How they execute these roles. Relationships.
KSPCB Regional Office	Specifics relating to implementing legislation around water recycling in the home; industrial wastewater management; pollution of water bodies etc. Is implementation working? How easy/difficult is it?
Fisheries Department	The role FD plays in reuse. Awareness and perception of reuse. Rules governing reuse. Relationships. Opinion of impact on/potential for fisheries.
LDA	The role of LDA in reuse. Awareness and perception of reuse. Rules governing reuse. Relationships. Opinion of impact on/benefits for lakes.
Minor irrigation Department	Management of lakes. Use of reclaimed water. Agricultural water demand. The role of MID in reuse. Awareness and perception of reuse. Rules governing reuse. Relationships. Opinion on impact of reuse on agriculture and irrigation.
BBMP	The role of BBMP in reuse. Relationships. Awareness and perception of reuse. Asked to manage more lakes but apparently can't afford it.
BDA / BMRDA	The role BDA plays in reuse and lake rehabilitation and management (WB project). Awareness and perception of reuse. Relationship with other departments e.g. BWSSB. Master Plan.
DoA	Fertilizer subsidy and availability. Perception of wastewater use and FS use.
Courts	How court rulings change the way government departments operate i.e. environmental rulings.
Health/PHI	How they interact with other departments and their opinion on water reclamation for non-potable and potable uses.
IISc	Lake management and their potential role in water reclamation.
University of Agriculture	Perceptions of waste reuse from the point of view of the ag. Dept. and fertilizer department. Policies etc. Roles of agriculture officers.
Ecotech	The company's role in private STP construction/upgrading/management. Relationships with stakeholders. Establishment and growth of the business. Drivers for STP upgrading/building and operation. Reuse in apartments.
Honeysucker owner	How the business operates. How they make money. How much they can transport etc.
Resident's associations	Motivations for WWT and reuse. Costs and management regimes. Opinions on reuse. Any issues with management. Understanding of the law.
ESG	The process of PIL and how the courts influence management of resources.
CDD	On site sanitation management – how extensive is it, what is the opinion locally, is there funding, what is the future?

Annex 4. Jakkur Lake, Bangalore – Wastewater Treatment and Use Case Study (Draft)

Location

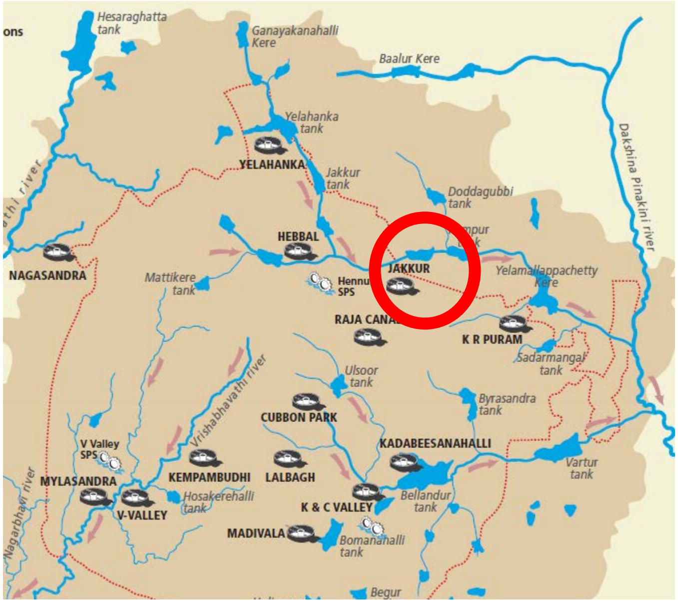


Figure 2: Location of Jakkur Lake case study (circled in red).
Source: Centre for Science and Environment, 2011.

Process

Process details	Stakeholders
Wastewater generated in Bangalore flows through the sewers to the Bangalore Water Supply and Sewerage Board (BWSSB) sewage treatment plant (STP). The STP has a capacity of 10 MLD but currently treats just 5 MLD (more connections are anticipated). The BWSSB receives some payment in the form of the sewage cess that they charge to people.	• Sewage generators • BWSSB • STP operator
The treated wastewater flows to a constructed treatment wetland (CTW) and into Jakkur Lake. The lake is owned by the Bangalore Development Authority but leased to and managed by the Lake Development Authority. BBMP may also have a role.	• BDA • LDA
Rights to fish in the lake are leased by the Fisheries Department (FD) to a fishing contractor. He in turn allows a number of people to fish the lake. The fish are sold locally.	• FD • Fishing contractor • Fishermen • Fish consumers
The lake water recharges the groundwater and is tapped by local people, some of whom sell the rights to pump from their wells to private water tanker operators. Alternatively tanker operators own their own wells. The water is taken to the city and sold to domestic consumers.	• Well owners • private water tanker owners

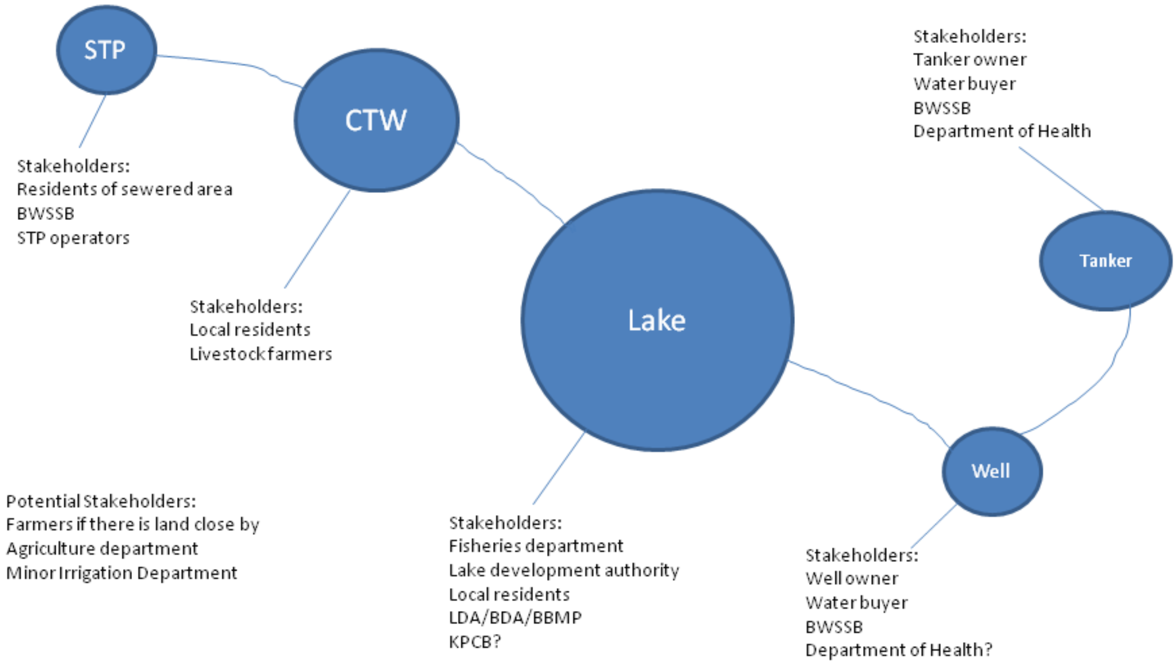


Figure 1: Schematic of waste flow and stakeholders involved

Process Summary

Resource(s) Recovered

- Nutrients for fish production
- Water through aquifer recharge
- It could be said that energy is saved because the BWSSB do not have to treat a certain quantity of water that is supplied from the wells but this is speculative.
- Other resource recover streams could be: use of sludge from the STP although farmers are wary of metals and other pollutants: use of CTW products e.g. reeds for animals or energy.

Waste Stream(s) (source)

- Raw sewage through sewer networks from Yelahanka new town and urban areas.

Business models

- Payment for sewage treatment by residents.
- Income from fisheries (sale of fishing rights)
- Private income from sale of groundwater via water tankers

Agencies involved (Supporting institutions)

- BWSSB operates the plant
- The lake is either managed by the LDA/BDA or BBMP
- Fisheries department could be involved in some way
- KSPCB as environmental regulator
- BWSSB's regulatory role as Groundwater authority

Sources of information

- Field visit organized by Biome, Bangalore.

Annex 5. Use based classification of surface waters in India

Designated Best Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1.Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 2mg/l or less
Outdoor bathing (Organised)	B	1.Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3mg/l or less
Propagation of Wild life and Fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 4. Biochemical Oxygen Demand 5 days 20 °C, 2mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25 °C micro mhos/cm, maximum 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
	Below-E	Not meeting any of the A, B, C, D & E criteria

Source: CPCB (2008); MOUD and JICA (2013b)

Annex 6. Indian Bureau of Statistics Water Quality Standards (Source IS 2296:1992)

Designated Best Use	Class
Drinking Water Source without conventional treatment but after disinfection	A
Outdoor bathing (Organised)	B
Drinking water source after conventional treatment and disinfection	C
Propagation of Wild life and Fisheries	D
Irrigation, Industrial Cooling, Controlled Waste disposal	E

Characteristics	Standards for designated best use				
	A	B	C	D	E
Dissolved Oxygen (DO)mg/l, min	6	5	4	4	-
Biochemical Oxygen Demand (BOD)mg/l, max	2	3	3	-	-
Total coliform organisms MPN/100ml, max	50	500	5,000	-	-
pH value	6.5-8.5	6.5-8.5	6.0-9.0	6.5-8.5	6.0-8.5
Colour, Hazen units, max.	10	300	300	-	-
Odour	Un-objectionable		-	-	-
Taste	Tasteless	-	-	-	-
Total dissolved solids, mg/l, max.	500	-	1,500	-	2,100
Total hardness (as $CaCO_3$), mg/l, max.	200	-	-	-	-
Calcium hardness (as $CaCO_3$), mg/l, max.	200	-	-	-	-
Magnesium hardness (as $CaCO_3$), mg/l, max.	200	-	-	-	-
Copper (as Cu), mg/l, max.	1.5	-	1.5	-	-
Iron (as Fe), mg/l, max.	0.3	-	0.5	-	-
Manganese (as Mn), mg/l, max.	0.5	-	-	-	-
Chlorides (as Cl), mg/l, max.	250	-	600	-	600
Sulphates (as SO_4), mg/l, max.	400	-	400	-	1,000
Nitrates (as NO_3), mg/l, max.	20	-	50	-	-
Fluorides (as F), mg/l, max.	1.5	1.5	1.5	-	-
Phenolic compounds (as C_2H_5OH), mg/l, max.	0.002	0.005	0.005	-	-
Mercury (as Hg), mg/l, max.	0.001	-	-	-	-
Cadmium (as Cd), mg/l, max.	0.01	-	0.01	-	-
Selenium (as Se), mg/l, max.	0.01	-	0.05	-	-
Arsenic (as As), mg/l, max.	0.05	0.2	0.2	-	-
Cyanide (as Pb), mg/l, max.	0.05	0.05	0.05	-	-
Lead (as Pb), mg/l, max.	0.1	-	0.1	-	-
Zinc (as Zn), mg/l, max.	15	-	15	-	-
Chromium (as Cr^{6+}), mg/l, max.	0.05	-	0.05	-	-
Anionic detergents (as MBAS), mg/l, max.	0.2	1	1	-	-
Barium (as Ba), mg/l, max.	1	-	-	-	-
Free Ammonia (as N), mg/l, max	-	-	-	1.2	-
Electrical conductivity, mho/cm, max	-	-	-	-	2,250
Sodium Adsorption Ratio, SAR, max	-	-	-	-	26
Boron, mg/l, max	-	-	-	-	2

Annex 7. Guidelines for Evaluation of Irrigation Water Quality in India

Water class	Sodium (Na) %	Electrical conductivity (mS/cm)	SAR	RSC [21] meq/l
Excellent	< 20	< 250	< 10	< 1.25
Good	20 - 40	250 – 750	10 – 18	1.25 – 2.0
Medium	40 - 60	750 – 2,250	18 – 26	2.0 – 2.5
Bad	60 – 80	2,250 – 4,000	> 26	2.5 – 3.0
Very bad	> 80	> 4,000	> 26	> 3.0

Source: NIH (nd)

[21] Residual Sodium Carbonate (RSC) is a good indicator of the sodicity hazard of irrigation water or the proportion of sodium ions in the water. It is defined by the formula RSC = (CO_3^- + HCO_3^-) - (Ca^{++} + Mg^{++}). The anions HCO_3^- and CO_3^- in the irrigation water tend to precipitate calcium and magnesium ions in the soil resulting in an increase in the proportion of the sodium ions (Abrol et al., 1988).

Annex 8. Role and key activities of state and city level stakeholders

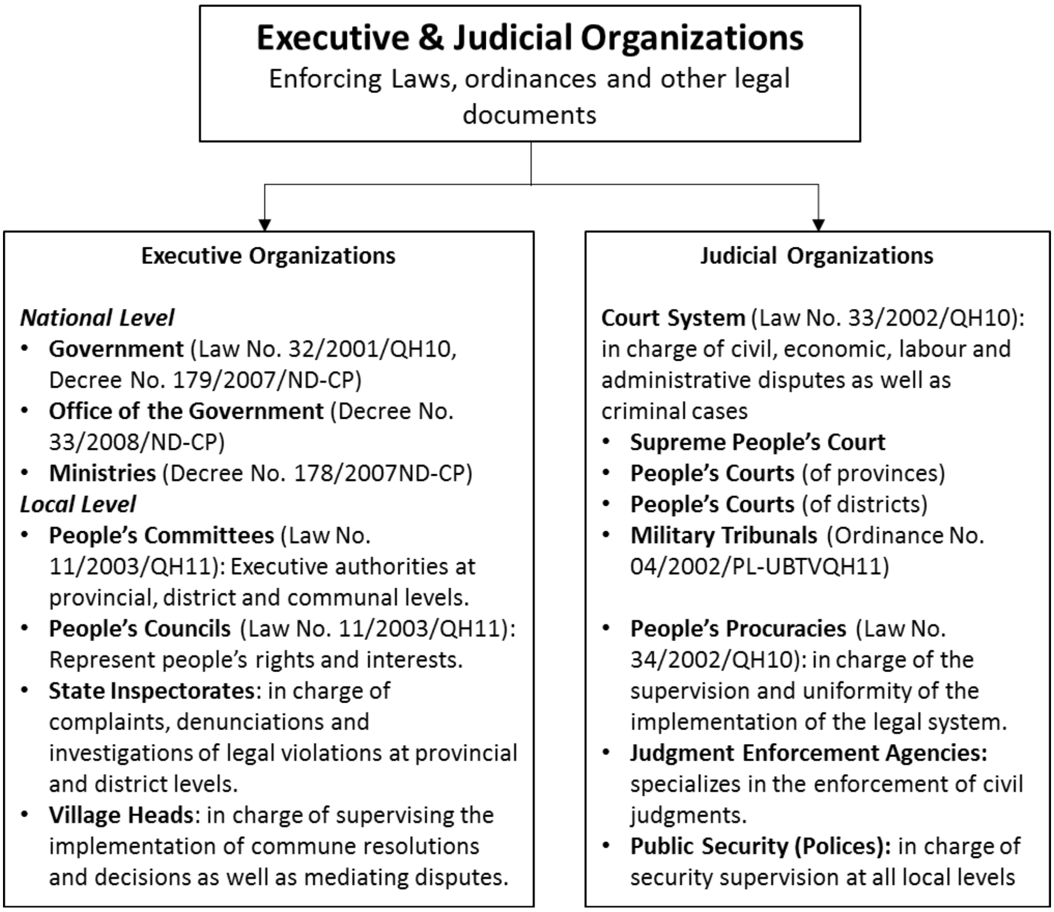
Stakeholder	Role and norms of behaviour
Water supply and sanitation	The **BWSSB** is the main agency responsible for WSS in the BMA, including transport and disposal of waste. The New Initiatives Division is actively working on reuse. The **BBMP** is responsible for civic infrastructure including drains and sanitation in public places, which overlaps with BWSSB's role. They must approve building construction plans and give completion certificates (important for wastewater provision). The KSPCB is the regulating agency for water and wastewater, and monitors and enforces water pollution and effluent standards, as well as consent to discharge. Groundwater is regulated and protected by the GWA, which is composed of several organizations including BWSSB and KSPCB.
Land use planning	BMRDA and BDA in their respective areas. Responsible for masterplans including urban drainage. BDA operates reuse plants in two urban parks, as well as undertaking lake management with LDA (now amalgamated into the new KLDCA).
Finance	KUIDFCL is the local government body to organize finance for infrastructure projects and liaise with donors.
Agriculture	KSDA provide agricultural extension and input services, including on-farm water efficiency but little is done on reuse. DAHF, KMF and KCPF have roles in dairy and poultry but none relates to wastewater use. Agricultural water management is the responsibility of WRD and MID but both are national agencies with no local equivalent. MID has been involved in some wastewater reuse projects in Karnataka.
Domestic/ commercial properties	Sewage producers with responsibility to connect to BWSSB sewers or collect and treat, depending on the size and location.
STP operators	Includes BWSSB staff, private companies in PPPs with BWSSB and private companies installing and operating private STPs.
Water users	Includes those supplied by BWSSB, private wells and tankers. All require supplies, pay different amounts depending on the source and receive varying quality and reliability of water supply.
Private water suppliers	Tanker operators sell to consumers at high prices but meet a demand in locations where authorities are unable (or unwilling) to supply.
Farmers, fishermen, industries	Current or potential users of wastewater in various forms. Farmers may accept lower quality, whereas industries require high quality water and are willing, at least in certain locations to pay for a reliable supply.
Citizens and groups	Advocate for change and have brought issues to the courts.
Research organizations	Few are working on RRR but many are involved in related aspects.
The media	Highly proactive in raising the profile of environmental issues and government failings.
Courts and judiciary	Offer a means through which to seek judgments on Public Interest Litigation (PIL). Many dealings with environmental issues.
Funding agencies	Fund research, advocacy work, feasibility studies, demonstration, pilots, and interventions. Indian Corporations funding action research and pilots for innovation.

Annex 9. Revised BWSSB sewerage charges (selected categories)

	BWSSB water consumption (KL)	Only sanitary connections (INR/month)	Water and sanitary connections (INR/month)	Water Charge (INR/KL/ month)
Individual households	No connection	30	-	
	<8		14	INR 7 (min INR 56)
	8-25		15	11
	25-50		25% of water charges	26
	>50		25% of water charges	45
Each flat in an apartment	No connection	50	-	
	>0		25% of water charges	22
Commercial premises	No connection	300	-	
	>0		25% of water charges	50-87 depending on consumption
Premises with private borewells	No connection	300/horse power (HP) of pump		
	Supplemental supply		300 per HP of pump	

The exchange rate at the time of writing was USD 1 to INR 65.9.
Source: BWSSB (2014)

Annex 10. State organizations in Vietnam



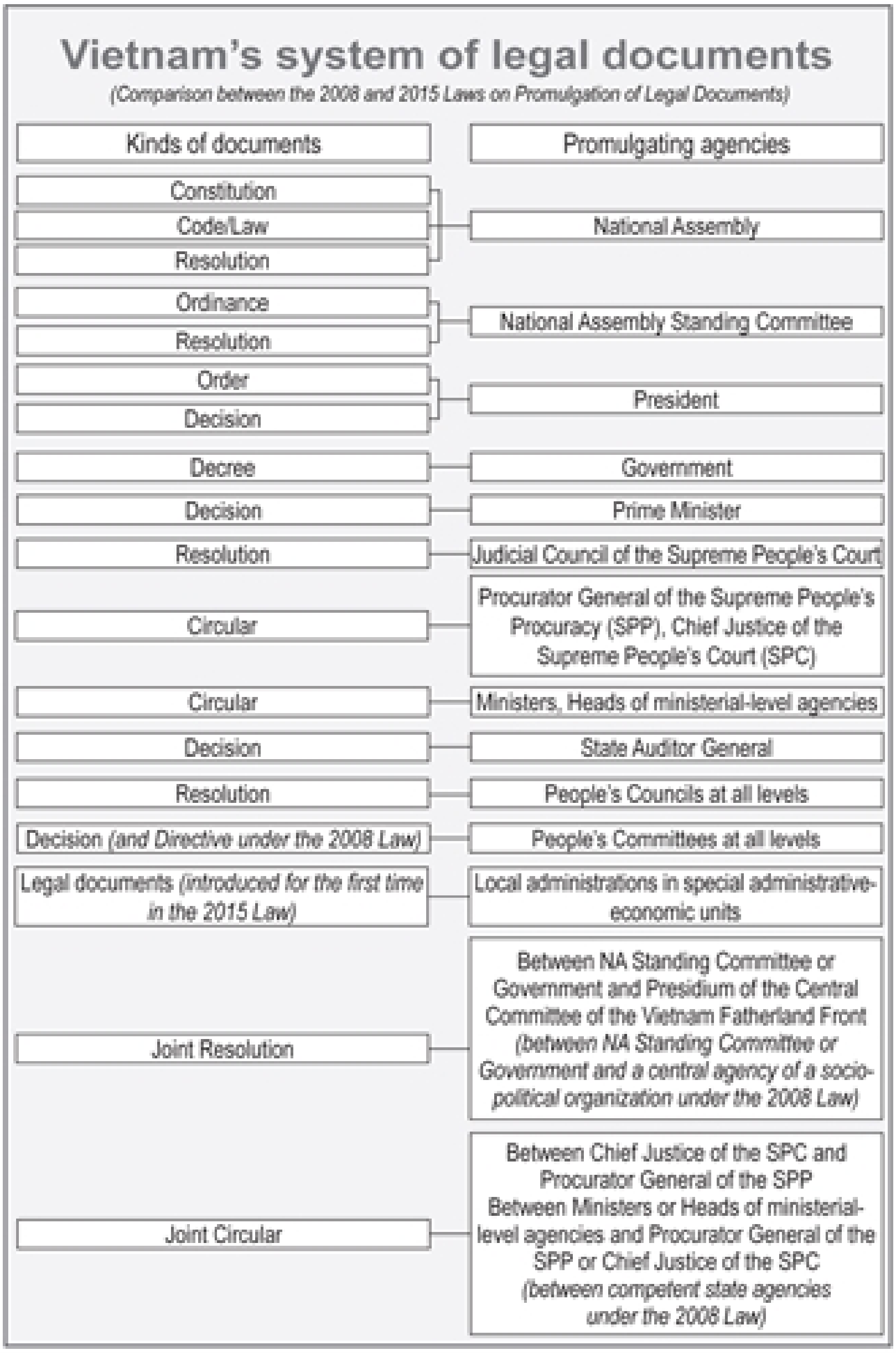
Source: adapted from Loan (2010)

Annex 11. Classification of Cities and Urban Areas, and Administrative Control

Class	Type	Definition	Number		Administrative set up
			2009*	2012**	
I	National centres	Very large cities. Important role in national development. Special City population >1.5 million. Class I City population >500,000. Density >120-150 persons/ha	2 7	2 7	Under Central Government administration. Includes Hanoi and Ho Chi Minh City (HCMC).
II	Regional centres	Large cities. Important role in development of a territory. Population >250,000. Density >100 persons/ha	14	59	Under Provincial administration
III	Provincial cities or towns	Large-medium. Important role in development of a province. Population >150,000. Density >80 persons/ha.	45		
IV	Provincial towns	Small-medium size towns. Play an important role in development of a province. Population >50,000. Density >80 persons/ha.	40	45	Some under District, others under Provincial administration
	District towns	Small towns. Play an important role in development of a district. Population >4,000. Density >20 persons/ha.	646	620	Under District administration
	TOTAL		754	733	

Source: *Decree 42/2009/ND-CP Urban Classification and Level of Urban Management in ADB, 2010; ** GSOV, 2014; WHO et al., 2011

Annex 12. Vietnam's system of legal documents



Source: Vietnam Law and Legal Forum (2015)

Annex 13. Details of the *Law on Water Resources*

The LOWR (2012) is the highest legal document on all aspects of water resources protection and lays down the '***principles of management, protection, exploitation and use of water resources**…*' and makes it the '*responsibility of all agencies, organizations and persons to protect water resources … water quality and aquatic ecosystems, and remedy and mitigation of pollution, deterioration and depletion of water sources*' (Article 3). It also specifies the responsibility of the state and investors. '*State policies must include investment in and adoption of measures to encourage organizations and individuals to invest in research and application of technologies to treat wastewater up to the standards and technical regulations for reuse*' (Article 4). Investors are required to coordinate with relevant authorities on public consultation for projects (Article 6). Furthermore, the PCs and VFF are responsible for communication and education about water resources and their protection (Article 5).

A number of actions are prohibited under the LOWR (2012) with the intention of protecting receiving waters. This includes, '*Dumping wastes and garbage, discharging or leaking hazardous substances into water sources or committing other acts which cause water source pollution, deterioration or depletion*' and '*Discharging wastewater or bringing wastes into hygiene protection zones of domestic water-supplying areas; discharging into water sources untreated wastewater or wastewater treated not up to standards or technical regulations*' (Article 9). Discharging wastewater into groundwater resources through drilled or dug wells is also prohibited under Article 9.

Anyone involved in activities that result in a decline in water quality must remedy the damage and if necessary pay compensation, those that fail to do so will be suspended from operation or relocated. Commercial and industrial premises must adopt measures to: treat, control and supervise the quality of wastewater; and to respond to pollution incidents (LOWR, 2012, Article 26 and 27).

It also stipulates the terms for the establishment of water resources master plans, including other plans and sectors that it must conform with; responsibilities of ministries and local authorities; and the need to consult with and involve local communities (Section 2, Articles 14-24).

Section 3 of the LOWR, 2012, deals with 'Protection of Water Resources'. The responsibility for protection of water resources, pollution prevention and ceasing or reporting violations is given to all organizations and individuals, including local authorities (Article 25). Establishments must '*adopt measures to treat, control and strictly supervise the quality of their wastewater and wastes before discharging them into the soil or water sources*.' If any pollution occurs, establishments must take measures to control, treat and supervise wastes (Article 26), to rehabilitate the water body and pay compensation to those affected (Article 27). Those that fail to do so will be suspended from operation or relocated (Article 26). They and construction projects, including water supply and drainage works and wastewater storage, '*which are likely to cause water source pollution, deterioration or depletion must have a plan*' to prevent this (Article 26). If pollution does occur, not only is it the responsibility of the establishment to remedy the situation but the local authority must identify the cause and responsible parties, and coordinate with them to mitigate the harmful effects and supervise the situation. The Provincial PCs must take '*measures to prevent and restrict the expansion of polluted areas, handle and mitigate pollution in areas under their management, coordinate with related provinces and centrally run cities in preventing and handling incidents'* and report to MONRE. Where a perpetrator cannot be found the costs of remedying the situation will come from the State budget (Article 27).

Water resources used for certain purposes are protected under the LOWR (2012), these include those used for domestic water supply and irrigation, as well as urban water bodies (Article 31). Organizations and individuals exploiting water for domestic purposes must monitor water quality and have plans for alternative sources in case pollution occurs. Provincial PCs must determine and publicize hygiene protection zones for domestic water supplies and water quality. District and commune PCs must take measures to protect the quality of domestic water sources in their localities (Article 32). Likewise, organizations that exploit groundwater or undertake activities that might affect groundwater must take measures to prevent pollution. Where groundwater is over exploited, local authorities will place these areas in restricted zones (Article 35). Furthermore, organizations and individuals supplied with domestic water must contribute funds for water source protection, exploitation and water treatment (Article 45).

Article 37 deals with discharge of wastewater and requires master plans for urban areas and industrial zones to contain details of wastewater collection and treatment systems, as well as water sources capable of receiving these volumes. Furthermore, plans for business establishments (new or upgrading) must contain rainwater harvesting and wastewater management, including treatment and drainage up to required standards. Those discharging wastewater into water sources require a licence from the relevant state agencies.

As would be expected, **water conservation is a prominent theme in the LOWR (2012).** Organizations and individuals are expected to '*increase the use of recycled water and water reuse'* (Article 39). It tasks MONRE and Provincial PCs with water conservation measures, formulating water consumption norms and popularizing water conservation technologies, but does not include reuse. This is addressed to some extent in the next article which encourages research into science and technologies around water conservation including '*Researching into and applying and developing technologies for using recycled water or reusing water so as to improve water efficiency in industry, construction and agriculture*' (Article 42).

The LOWR (2012) also covers water for agriculture and aquaculture. It makes the State responsible for investing in water supply for agriculture and requires users to undertake conservation and prevent pollution. Also, '*organizations and individuals may only exploit and use water that ensures standards and technical regulations for agricultural production'* (Article 46). The same statement is made in relation to aquaculture, and in addition '*the exploitation and use of water resources for aquaculture must conform to water resource master plans and neither cause water source pollution, deterioration or depletion* …' (Article 48). **Aquifer recharge** is permitted but must be based on assessment of the aquifer to be supplemented. MONRE will identify aquifers and zones requiring supplementation and guide and monitor the application of recharge measures (Article 56).

Water resources financing revenue comes in many forms and includes: water resource royalties and other taxes; charges and fees; money from the grant of exploitation rights; and fines for violations (Article 64).

Responsibilities defined by the LOWR (2012) for government agencies are as follows:

- **MONRE** - promulgate legal documents, technical regulations, norms and unit prices on water resource planning and protection; develop master plans on such aspects as rehabilitation of polluted or depleted water resources; announce areas where groundwater exploitation is banned; disseminate and educate people about the LOWR; grant/revoke exploitation licences; survey water resources and disseminate information; and settle disputes (Article 70).
- **Provincial PCs** – promulgate and organize the implementation of legal documents on water resources; elaborate, publicize and implement master plans; announce areas where groundwater exploitation is prohibited; organize the response to water pollution incidents; establish and manage water source protection zones; assure domestic water supply; grant/revoke water resource licences; survey water resources and report to MONRE (Article 71).

- **District and commune PCs** – take measures to protect water resources; coordinate with other organizations to protect water related facilities; organize the response to water pollution incidents; disseminate knowledge about the LOWR (2012); handle violations and settle disputes; report to higher level PCs on the water resource situation; and organize the registration of water resource exploitation and use, and discharge of wastewater (Article 71).
- **River basin organizations** - propose the regulation and distribution of water sources and supervise the exploitation, use and protection of water resources in inter-provincial river basins (Article 72).
- The **national water resource council** – advises the Government and the Prime Minister on water resources decisions (Article 74).
- **MONRE Inspectorate and DONRE inspectorates and agencies** - water resource inspection (Article 75).

Annex 14. Law on Environmental Protection

The **Law on Environmental Protection No. 52/2005/QH11** (LOEP, 2005) has recently been superseded by the **Law on Environmental Protection No. 55/2014/QH13** (LOEP, 2014) which was effective from 1 January 2015. The new law lays down the responsibilities for all citizens and organizations in the protection of natural resources. It is wide ranging and covers land, water and air pollution. It makes **environmental protection the responsibility and obligation of '*every agency, organization, family household and individual*'** and also requires '*any organization, family or individual who uses environment components and profits from the environment … to make their financial contribution to the environmental protection task*,' as well as being responsible for remedial action and paying damages, when necessary (Article 4). As part of the general statement on regulatory policy (Article 5) it prioritizes solutions for water contamination. By comparison, the LOEP (2005) concentrates on establishments that seriously pollute the environment; remedying polluted and degraded areas; and environmental protection of urban centres and residential areas (Article 5).

Wastewater management is covered in the LOEP (2012), Section 4, which requires all wastewater to be collected and treated in accordance with environmental standards, as established under the LOEP (2005) and related legislation. All urban areas and concentrated residential areas are to have separate systems for rainwater and wastewater; and business and manufacturing establishments must collect and treat wastewater (Article 100). Sewage treatment systems must be in place for manufacturing and business zones, trade village complexes, and establishments that are not connected to the sewage network. Every sewage treatment system must: have a suitable technological process for the wastewater type; have sufficient capacity; treat the wastewater according to environmental standards; have discharge outlets at locations convenient for inspection; and be operated regularly. The systems must be regularly monitored and records kept (Article 101).

It is the responsibility of households to '*minimize, process, and discharge domestic sewages at proper places.*' (Article 82) but unlike the LOEP (2005) there is no requirement for environmental protection planning of urban centres and residential areas to include central wastewater collection and treatment facilities (LOEP, 2005, Article 50). The focus for wastewater treatment appears to be industrial, manufacturing and business establishments, rather than domestic wastewater. The closest the LOEP (2014) comes is in the requirement to: '*Ensure urban landscape, environmental hygiene; public sanitation works are installed'* (Article 80).

Sanctions for businesses that pollute the environment are stipulated in LOEP, 2005 and 2014, Article 49 and comprise of: fines and measures to reduce and treat waste; temporary suspension of operation; and compensation payments if appropriate. If pollution is severe further sanctions will be applied including enforced cessation of activities, relocation or environmental remediation. Such sanctions may stimulate reuse.

Acts prohibited in the LOEP (2014, Article 7) include getting '*rid of untreated wastes or sewage to meet the rigorous standards stipulated in technical regulations on environment… ; discharge [of] hazardous wastewater, waste substances and microorganisms and other poisonous agents which can impose risks to human beings and creatures into water sources'*. Other sections deal with the quality and protection of river water (Chapter VI, Section 1, Article 52) and lake, pond, canal and ditch water (Article 56). In the case of rivers, waste discharged to river basins must be within accepted standards of the river's maximal load; and the quality of the river must be regularly assessed (Article 52). The stipulations for urban water bodies include renovation and preventing encroachment (Article 56).

An important funding mechanism outlined in the LOEP (2014) (and LOEP, 2005), is that of the **Environmental Protection Funds (EPFs),** which includes funds from central environment, ministries and provinces but the state also encourages enterprises, organizations and individuals to establish their own EPFs (Article 149). This has the potential to support reuse activities.

The LOEP (2005) contains a number of elements of relevance to RRR. For example, **it espouses the establishment of environmental service enterprises**, including waste collection, recycling and treatment, through competitive bidding for contracts (LOEP, Article 115). In addition there are statements about investment in research, preferential policies for technology transfer to address urgent environmental problems, contracts for organizations and individuals that possess environmental technologies for waste reduction and treatment services, and priority access to loans (LoEP, 2005, Article 108 and 117).

Responsibilities defined by the LOEP (2014) for government agencies are as follows:

- **MONRE –** national-level planning for environmental protection; directs and instruct environmental monitoring, and manage this information and data; establish criteria for classifying polluted areas; provide instructions on environmental remediation and improvement; inspect and verify completion of pollution reduction and environmental remediation; report on environmental status; inspect compliance (with MOIT and other agencies); submit lists of non-compliant entities. For river water environmental protection they must assess river quality and determine maximal loads and waste discharge limits for inter-basin and transnational rivers, and communicate this to the public (Article 55).

- **Provincial PCs** – lead in local planning for environmental protection, in consultation with departments, regulatory agencies and district PCs; inspect and approve the report on the provincial-level planning for environmental protection; verify environmental reports for investment projects; decide on the establishment and operation of their own EPFs. For river water environmental protection: disclose information about wastes discharged into rivers; direct activities to control these; assess the river's maximal load and determine waste discharge limits; publicise limits; and assess losses incurred by pollution. In relation to urban water resources: assess water quality and formulate plans for renovation.
- **District and commune PCs –** certify the environmental protection plan of projects for production, trading and service provision, and authorize the commune, ward or town PCs to do the same; inspect environmental protection in industrial complexes; concentrated business zones; and trade villages; submit reports to competent authorities and provincial PCs. Decisions to take action against polluting entities must be reported to district PCs who communicate this to the public.
- **Environment Protection Agency** - affiliated to provincial PCs: certify the environmental protection plan for large projects or those in more than one district.

Annex 15. Maximum limits for parameters of surface water quality

No.	Parameters	Unit	Limit value
1	pH		6,5 - 8,5
2	Dissolved oxygen (DO)	mg/l	≥ 4
3	Total suspended solids (TSS)	mg/l	100
4	Total dissolved solids	mg/l	1000
5	Nitrite (NO_2^- calculated per N)	mg/l	0,02
6	Nitrate (NO_3^- calculated per N)	mg/l	5
7	Ammonium (NH_4^+ calculated per N)	mg/l	1
8	Cyanides (CN^-)	mg/l	0,01
9	Arsenic (As)	mg/l	0,02
10	Cadmium (Cd)	mg/l	0,005
11	Lead (Pb)	mg/l	0,02
12	Chromium VI	mg/l	0,02
13	Copper (Cu)	mg/l	0,2
14	Mercury (Hg)	mg/l	0,001
15	Organochlorine chemical substances for plant protection Aldrin Chlordane DDT Dieldrin Endrin Heptachlor Toxaphene	µg/l	 3,0 2,4 1,1 0,24 0,09 0,52 0,73
16	Herbicides 2,4 D 2,4,5 T Paraquat	mg/l	 0,2 0,1 1,2
17	Total oil and petrolatum	mg/l	0,05
18	Phenol (total)	mg/l	0,005
19	Surface activators	mg/l	0,2

Source: Loan (2013)

TT	Parameters	Unit	Limit values
1	pH		5,5-9
2	Dissolved oxygen (DO)		≥ 2
3	Total dissolved solids	mg/l	2000
4	Sodium absorption ratio (SAR)		9
5	Chlorine (Cl-)	mg/l	350
6	Sulfate (SO_4^{2-})	mg/l	600
7	Bo (B)	mg/l	3
8	Arsenic (As)	mg/l	0,05
9	Cadmium (Cd)	mg/l	0,01
10	chromium (Cr)	mg/l	0,1
11	Mercury (Hg)	mg/l	0,001
12	Copper (Cu)	mg/l	0,5
13	Lead (Pb)	mg/l	0,05
14	Zinc(Zn)	mg/l	2,0
15	Fecal, Coli (only for irrigating water for vegetables and fresh serve vegetables)	Quantity of bacteria /100ml	200

Annex 16. Maximum limits for water quality parameters of water used for irrigation

Source: Loan (2013)

Annex 17. A Residential Community Undertaking Water and Sanitation Management

Rainbow Drive (RBD) is a private, residential layout that is representative of an increasingly common land-use pattern in Bangalore. Like many other private layouts, RBD is situated outside the reach of the BWSSB and its residents were left to fend for their own water needs after the inevitable departure of the developer. RBD's Plot Owners' Association (POA) has responded to this problem with sustainability in mind. Led by one particularly water-conscious member, the POA has acted on the notion that water demand is the most effective rallying point for galvanizing action toward sustainability measures.

The 34-acre campus of RBD layout was developed 10 years ago with 360 plots. It had community borewells of which four were intended to be for backup only. The current occupancy is 222 homes, 78 of which are filled by tenants and 144 by the owners. From the beginning some residents noticed high water wastage, for example, people hosed their cars daily, overhead tanks and household sumps regularly overflowed and water was used liberally by crews building new homes. They also noticed that their borewell was becoming harder to pump, which concerned them as neighbouring complexes were already reliant on tankers for their water. Flooding was another issue as RBD had been built on a natural water drainage path. As these concerns grew, residents became dissatisfied with the management of RBD by the developer and formed the Rainbow Drive POA in 2004 to manage their common resources.

The POA is a registered society with 12 elected members. It was established to ensure the orderly maintenance of the layout and its infrastructure and to safeguard the interest of plot owners. The POA is vested with the authority to create rules regarding its objectives that apply to all RBD residents. New rules and policies voted on, and though not required, consensus is preferred.

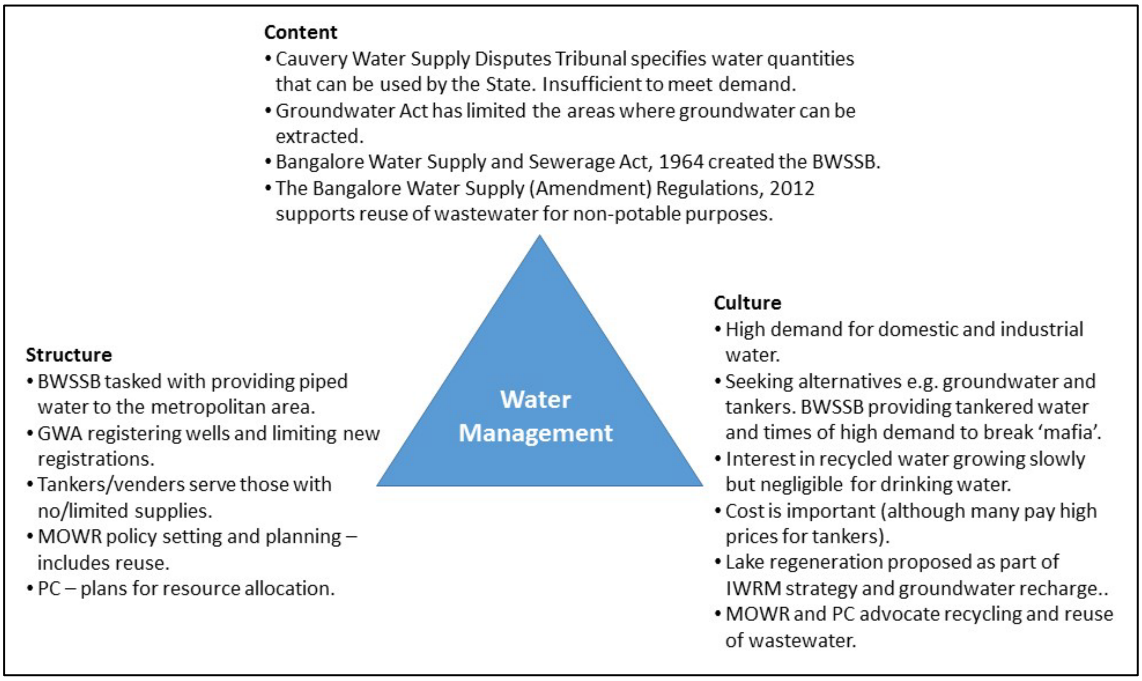
By 2006 the number of residents had increased and the water management problems were severe. A newly elected member of the POA was extremely active and interventions in water management started in earnest. The POA hired staff to manage RBD's water infrastructure including two onsite STPs and the borewells. The POA banned the digging of private wells, hired a hydrogeologist to better understand the groundwater situation and undertook a consumption survey. They discovered that one third of the residents used 50 percent of the supply; that new constructions used a huge amount of water because builders had no incentive to save money; and that the flat rate of 6 INR/kL (0.09 USD/kL) was far too low to provide an incentive for water conservation and did not cover maintenance or STP costs. Rather, STP costs, which are much greater than supply costs, were rolled into the layout maintenance fee that was divided equally among residents. The POA determined that the true production cost of water was 16-17 INR/kL (0.24-0.25 USD/kL).

In response the POA banned new constructions from utilizing borewell water. This was facilitated by the fact that the electricity utility deemed construction a commercial activity and had billed the whole layout at the higher commercial rate because they could not separate the pumping cost for households and construction companies. After that water for construction was bought from tankers. They also implemented rainwater harvesting and groundwater recharge, and initiated a tariff systems, based on consumption blocks, that covered WSS costs.

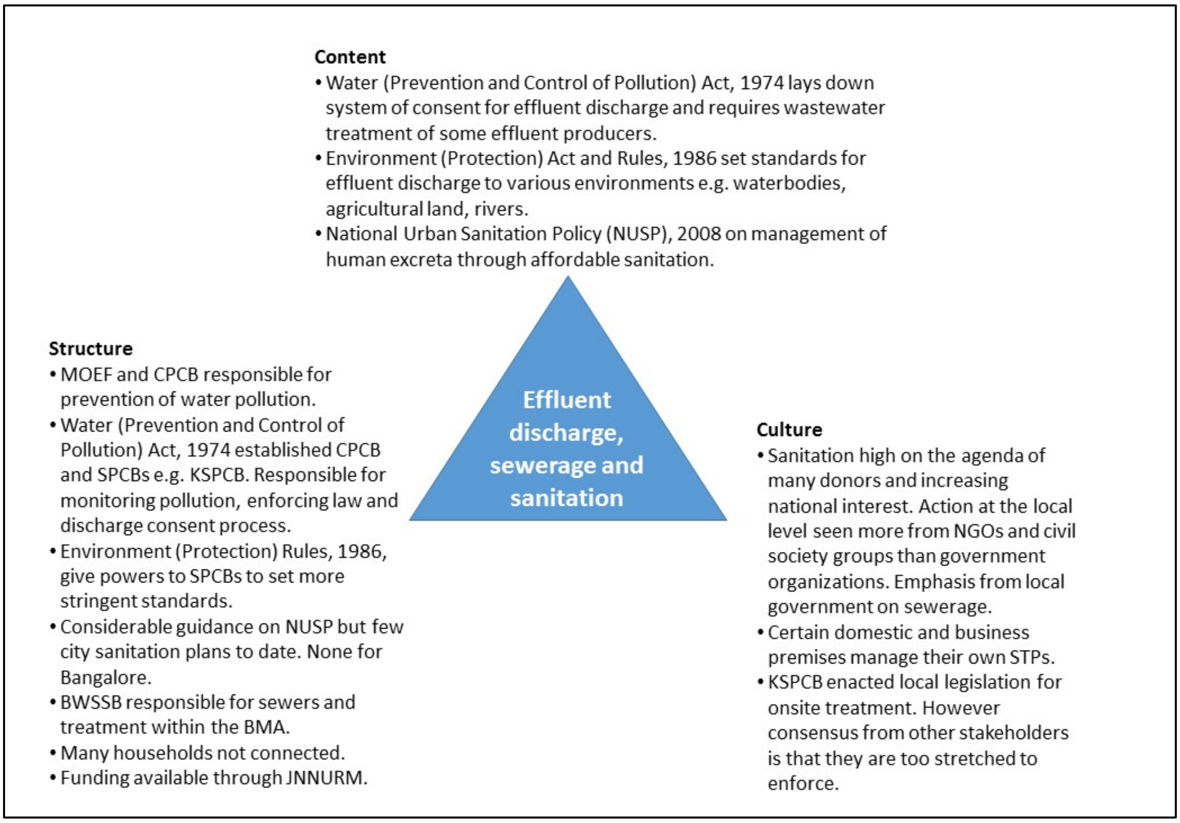
Although most of these examples are not directly related to wastewater treatment and use, the example is significant because it shows a group of residents organizing themselves specifically for the purpose of managing water and sanitation. They are aware of the costs of sanitation provision, including wastewater treatment, and they are prepared to take measures to ensure that the community adhere to institutional arrangements that support a sustainable water supply and effective sewage treatment.

Source: Biome Environmental, 2009b

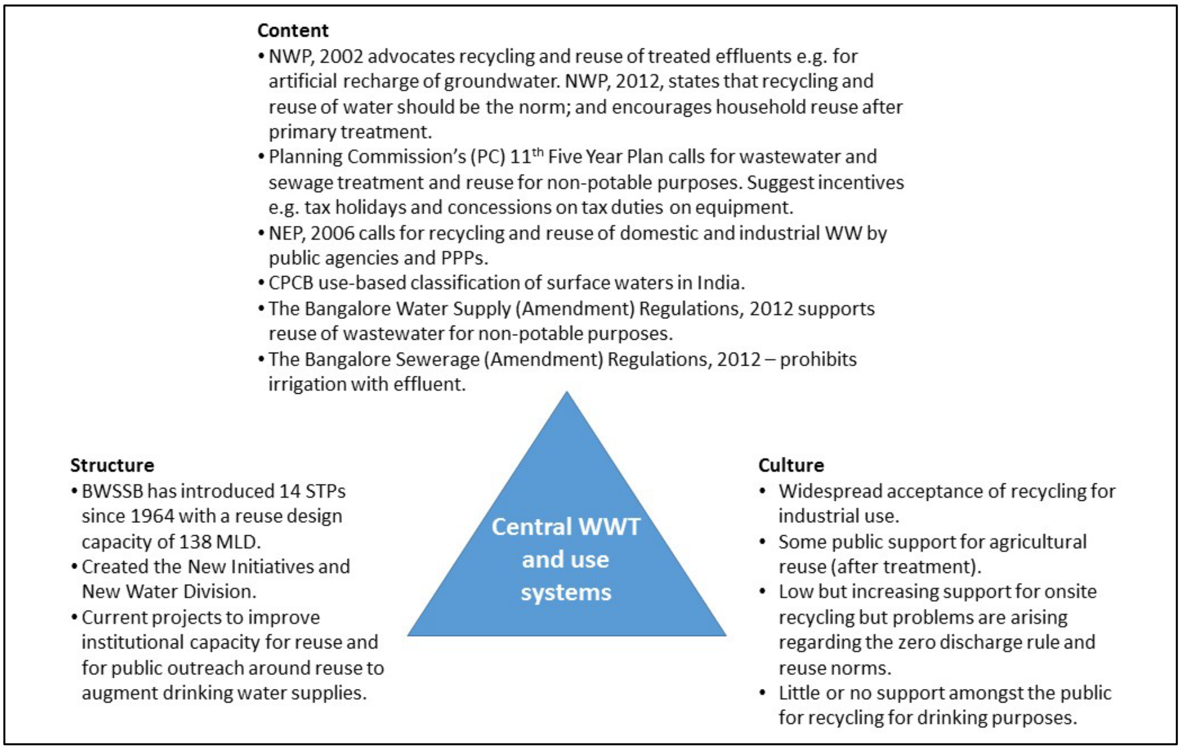
Annex 18. Set of Triangle Analysis Diagrams for Institutional Arrangements in Bangalore



Triangle analysis of water management in Bangalore
Source: Author (2015)



Triangle analysis for effluent management in Bangalore
Source: Author (2015)



Triangle analysis for centralized wastewater treatment and use in Bangalore
Source: Author (2015)

Triangle analysis for decentralized wastewater treatment and use in Bangalore
Source: Author (2015)

Triangle analysis for agriculture in Bangalore
Source: Author (2015)