Expert Group Meeting on "Municipal Waste Water Use for Irrigation"
Water and Environment Center - Sana'a, Yemen, 4-7 November, 2006

FINAL REPORT

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Sana'a Statements on Waste Water Use in Agriculture

"Farmers are in desperate need for water and we should not close our eyes on this".

(HE the Minister of Water and Environment of the Republic of Yemen, Dr.Abdul Rahman Al-Eryani)

We, a group of experts on different aspects of municipal waste water use for irrigation, gathered in Sana'a, Yemen, from 4-7 November 2006, agree on the following statements as a result of our intensive discussions:

1- There is a need to acknowledge municipal wastewater as a valuable water resource that can be used for irrigation.

2- Wastewater can play an important role in supporting a livelihood for poor people in urban and peri-urban areas, through increasing food and income security.

3- Planning and design of waste water collection, treatment and distribution infrastructure should be based on the ultimate use of the effluent. Legislation and its enforcement should be in accordance with objectives for use and state of available and best practicable technology.

4- Researchers should develop guidelines, based on new and current knowledge to advise farmers, policy and decision makers on the safe use of wastewater through crop selection, technology selection, irrigation water management and crop handling.

5- Pilot projects should be developed as full scale research facilities to fine-tune technological and institutional approaches in a water-chain approach, and to facilitate awareness of all stakeholders in the urban/peri-urban water-chain.

Sana'a, Yemen
7 November 2006

SUMMARY of key questions for research

The questions below are an overview of the key questions raised by the participants of the Waste Water Expert Meeting at Sana'a, Yemen, and are presented to the RCUWM for consideration. All have a common conceptual approach, which is the Water Chain. In the water-chain, the water is followed from its source to its ultimate use as irrigation water. The research questions are categorised according major thematic fields.

Treatment technologies

Questions are raised on the appropriateness of present treatment approaches in which centralised and western type technologies are dominant. These systems are highly knowledge intensive and expensive to operate and are often overloaded. In their design, the envisaged effluent use is generally not appropriately considered. Research should focus on:

a- How to select the best suitable and cost-effective technologies for the treatment of urban waste water, considering the preferred use of its effluent and produced sludge.
b- How could decentralization of wastewater collection and treatment and the introduction of anaerobic systems increase productivity and flexibility in effluent use, with consideration of costs and benefits.

Storage of treated wastewater

When envisaging the use of (treated) wastewater for irrigation one is immediately confronted with a mismatch between supply and demand, both quantitatively and qualitatively. An operational mismatch could be solved by the construction of storage facilities below the treatment plant. For seasonal storage aquifers are often indicated as an option.

a- What is the (local) best method for infiltration of treated waste water into the aquifers and what aquifer conditions are required
b- What techniques can be developed to optimise effluent quality for irrigation (post-treatment; storage; blending)

Handling wastewater at field and farm level

Farmers need water to irrigate their fields. They tend to accept poor quality water if no other fresh water resources are available or affordable. By using (treated) wastewater the farmer introduces health risks and nutrients. However, most farmers are often not aware of the composition of the water and lack insights in the appropriate water management that is required to safely use this source of water.

a- Develop simple calculation models for farmers or farmer groups to validate nutrient value of (treated) wastewater
b- Develop irrigation techniques and optimise irrigation water management, related to crop selection and crop management well adapted to water quality

Institutional-Social

When considering a Water Chain approach, in which the water is followed from its source to its ultimate use as (treated) wastewater, one observes that a multitude of stake-holders is involved from upstream to downstream the water chain. Institutional development to cover full water chain in urban water management is needed.

a- How to integrate decision makers and stakeholders, including farmers, at early stages of design to accommodate possibly conflicting needs and uses
b- How to develop effective conceptual approaches to monitoring and quality control, as basis for a proper socio-economic performance of wastewater use systems in a suitable regulation framework

Environmental sustainability

It is increasingly accepted that (treated) wastewater is being applied for productive uses, although discussion remains on the conditions of use. Certainly, the use of wastewater can have an enormous positive impact on food production and income generation. However, few research has been done to understand what long term effects could be, specifically in terms of irreversible damage to soils, groundwater reserves and more generally the environment.

a- What are possible long-term effects of the use of (treated) wastewater on soil and groundwater properties
b- How can we guarantee to limit locally the groundwater pollution effects related to the periodic changes of infiltration and withdrawal?

CHAPTER 1: Objectives and Programme

Introduction

World-wide water resources are under consideration: on the one hand fresh water resources are increasingly scarce. On the other hand, the flows of waste water are increasing. Domestic waste water is, directly or indirectly, increasingly being used for agricultural production, under various circumstances. A modern challenge is to channel and manage these flows properly, considering food safety, developmental and environmental issues, institutional arrangements, and national and regional policies.

In this respect, Wageningen University and Research Centre (WUR) has proposed to organize and co-finance a regional expert group meeting on Municipal Waste Water Use for Irrigation as a starting point for further focused and collaborative research in close cooperation with the Regional Centre on Urban Water Management-Tehran (RCUWM) under the auspices of UNESCO and the Water and Environment Centre (WEC), University of Sana'a.

Objectives of the Expert Meeting

To formulate a regional research agenda on the use of waste water on the basis of an exchange of knowledge and information by a selected group of regional and international experts. The Expert Meeting will have the task to critically review and comment existing insights and knowledge and to discuss priority research on cross-cutting issues related to the use of (treated) domestic waste water in agriculture. The overall issue has important links to fresh water availability, productivity, health and environment.

To create interest at donor agencies to financially support advanced research on the subject.

Thematic Areas

The Expert Meeting will be organized around 3 thematic areas that are closely linked one to the other:

- Waste water flows: Collection and treatment
- Waste water use: Management, health and productive value
- Sustainability: Long term environmental effects

These thematic areas should be covered with an integral approach, discussing technical, biological and institutional aspects. This will bring a number of issues under discussion, such as:

- Water and nutrient balance in urbanised areas
- Sanitation and water treatment strategies, linked to treatment technologies and (de)centralisation
- Irrigation management strategies that are productive and environmentally safe
- Assessment of long term environmental effects of wastewater irrigation on soils and groundwater reserves

- Water and Wastewater pricing
- Social acceptance of waste water irrigation
- Institutional design of waste water management options

Expected Output

Presentations on thematic issues by participating experts will be collected in a working document to be published by the RUCWM.

The expert meeting will prepare a document in which the most urgent research issues on waste water handling and waste water use in the region, as agreed upon during the meeting, are presented.

The expert meeting will prepare a draft document to be submitted to potential donor agencies, giving an outline of research priorities.

Organization and Format of the Expert Meeting

- A restricted number of researchers from different countries/regions and from different disciplines will be invited.
- For each of the 3 proposed thematic areas key-speakers will be asked to introduce a statement or to define a research area which is linked to the specific thematic area.
- All other participants are asked to prepare a discussion question and a short introduction to the discussion.

Participation

About 20 subject experts. Besides participation by experts from Wageningen University, RCUWM and the host country Yemen, researchers from the RCUWM-region are invited to join. Given the scope of the initiative the total number of participants is limited in order to stimulate in-depth discussions in small sub-groups as well as plenary.

Programme

Saturday 4 November:

8:30-9:00	Registration
9:00-9:05	Invitation to sit
9:05-9:10	Quran recital
9:10-10:15	Opening speeches by: Dr. Abdul Rahman Fadhl Al-Eryani (Minister of Water and Environment); Dr. Saleh Ali Ba Surah (Minister of Higher Education and Scientific Research); Dr. Jala Faqirah (Minister of Agriculture and Irrigation); Dr. Khalid Tamim (Rector Sana'a University) Dr. Reza Ardakanian (Director RCWUM - Tehran) Dr. Abdulah S. Babaqi (Drector WEC) Dr. Frans P. Huibers (Wageningen University and Research Center)
10:15-10:30	Break
10:30-12:00	Introduction of participants Short presentation of background document, followed by plenary discussion Inventory of existing international research initiatives and networks

Session A: Waste water flows: Collection and Treatment

14:00 – 15:00	Introduction to the specific subject of the session **Waste water flows: Collection and Treatment** (overview) (30 minutes) Plenary discussion (30 minutes)		
15:00 – 16:00	Sub-Group 1 1, 2 short presentations of discussion topic **Costs (O&M, investment) of various technologies used** Discussion	Sub-Group 2 1, 2 short presentations of discussion topic **Urban water flows (quantitative)/Urban water balance** Discussion	Sub-Group 3 1, 2 short presentations of discussion topic **Urban water management / Institutions in the water chain** Discussion
16:00 – 17:00	Sub-Groups report in plenary session (10 minutes each) Plenary Discussion and conclusions (30 minutes)		

Sunday 5 November:

Session B: Wastewater use: Management, Health and Productive Value

9:00 – 10:00	Introduction to the specific subject of the session **Wastewater use: Management, Health and Productive Value** (overview) (30 minutes) Plenary discussion (30 minutes)		
10.00 - 10.30	Break		
10:30 – 11:30	Sub-Group 1 1, 2 short presentations of discussion topic **Health risks at farm level** Discussion	Sub-Group 2 1, 2 short presentations of discussion topic **Productive, economic value** Discussion	Sub-Group 3 1, 2 short presentations of discussion topic **Legislation** Discussion
11:00 – 12:00	Sub-Groups report in plenary session (10 minutes each) Plenary Discussion and conclusions (30 minutes)		

Session C: Sustainability: Long Term Environmental Effects

14:00 – 15:00	Introduction to the specific subject of the session **Sustainability: Long Term Environmental Effects** (overview) (30 minutes) Plenary discussion (30 minutes)		
15:00 – 16:00	Sub-Group 1 1, 2 short presentations of discussion topic **Nutrient management** Discussion	Sub-Group 2 1, 2 short presentations of discussion topic **Groundwater** Discussion	Sub-Group 3 1, 2 short presentations of discussion topic **Decentralization** Discussion
16:00 – 17:00	Sub-Groups report in plenary session (10 minutes each) Plenary Discussion and conclusions (30 minutes)		

Monday 6 November:

Field visit and excursion

Tuesday 7 November:

9:00 – 12.30	Consolidation and wrap-up session Linking research to existing research networks Define research niche for RCUWM/research in the region Presentation of outcomes Closure

Organization

Coordinating agencies

The Expert Meeting is organised by WUR, RCUWM-Tehran and the Water and Environment Centre (WEC) of the University of Sana'a.

The Expert Meeting is initiated by Wageningen University and Research Centre (WUR), the Netherlands, as an activity of the Regional Centre on Urban Water Management-Tehran (RCUWM-Tehran) under the auspices of UNESCO, to which WUR is board member.

Member countries of the RCUWM-board are Afghanistan, Bangladesh, Egypt, Germany, India, Iran, Kuwait, Lebanon, Oman, Syria, and Tajikistan. Other countries in the RCWUM region are Yemen, Saudi Arabia, Qatar, Pakistan, Uzbekistan, Turkmenistan, and Turkey. Institutions represented in the RCUWM-board are IWA, TIWA, UNESCO, Wageningen University and Research Centre.

Contacts

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CHAPTER 2: Background Document

DOMESTIC WASTEWATER AND IRRIGATED AGRICULTURE

Background paper* to an Expert Meeting on Municipal Waste Water Use for Irrigation, Sana'a , Yemen, 4-7 November 2006

Regional Centre on Urban Water Management (RCUWM), Tehran, Iran
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ABSTRACT

The use of domestic wastewater for irrigation is a fact of life in most developing countries although this practice is generally not officially recognized or even banned altogether by local governments. The practise allows for an almost year-round production and can save poor people money as the nutrients present in wastewater replace at least part of the currently applied chemical fertilizers. From a sanitation perspective soil application is an accepted and cheap sewage treatment system. Yet, precautions should be taken in water and crop management, considering the health risks related to the use of wastewater. In this paper, some basic concepts and definitions related to wastewater irrigation are introduced together with a brief overview of recent developments. Typical situations encountered when wastewater is used for irrigation are discussed and a conceptual design framework to deal with wastewater flows and irrigation issues is proposed, based on a so-called "Water Chain Approach".

INTRODUCTION

The production and discharge of domestic wastewater from urban areas is rapidly increasing in developing countries due to population growth, urbanization, and economic development. There is, however, a lack of investing capacity worldwide for the construction and operation of adequate treatment facilities (van Lier and Lettinga, 1999), which threatens the quality of surface waters, soils and groundwater to which wastewater is discharged. At the same time, the water demand increases rapidly in urban and peri-

* Abstracted and adapted from: Huibers *et al.* (2006)

urban areas, for the production of food (particularly fresh vegetables) as well as to provide income to a large group of city-dwellers and small farmers. These two trends cause an increasing use of partially treated and untreated wastewater in irrigated agriculture in and downstream of urban centres. It has been recognized that such use has additional beneficial effects, as the used water often contains important nutrients. However, unbalanced application of these nutrients as well as the presence of pollutants in wastewater has also been identified as a threat to resources (van der Zee and Shaviv, 2002; van der Zee *et al.*, 2004). The technical problem to be resolved for protecting resources is complex and broad, due to the large variety of pollutants and nutrient concentrations, of soil and geo-hydrological conditions, crops, and agricultural management (Van Asten *et al.*, 2003, 2004). Moreover, institutional problems related to risk externalities and asymmetric information among the stakeholders in the food supply chain, complicate appropriate management of wastewater irrigation and may cause failure of the wastewater for the irrigation market. The management question involves socio-economic and cultural factors which are related to e.g. policy regulations and the degree to which these are enforced, costs, benefits, and public acceptance of waste water use in irrigated agriculture, which differ between countries and sometimes within countries. In view of the commonly regional setting of watershed hydrology, and the above mentioned complexity, the development of concepts for sustainable waste water use, and their implementation in sustainable practice are a considerable optimisation problem (Huibers *et al.*, 2002). At present, many scientific gaps on disciplinary detail issues (Kaledhonkar *et al.*, 2001), as well as the lack of a methodology for the integrated interdisciplinary problem, prevent the development of truly sustainable strategies. Hence, both scientifically and in practice the increasing wastewater production and growing water scarcity form an opportunity as well as an environmental conflict that has been characterized as a paralyzed situation (van Lier and Huibers, 2004).

Several initiatives have been undertaken in recent years to place the issue on the international agenda of both science and policy makers. Under the guidance of the International Water Association (IWA) a workshop was organized in Wageningen, The Netherlands, that built upon the interdisciplinary approach (Huibers and Kaspersma, 2002). An expert meeting, organised by the International Water Management Institute (IWMI) held in Hyderabad, India, in November 2002 was concluded with The Hyderabad Declaration (http://www.iwmi.cgiar.org/home/wastewater.htm), which aimed at alerting policy makers and the research community world-wide of the importance of giving urgent attention to using wastewater for irrigation (Scott *et al.*, 2004). In many geographical regions that span major parts of the different continents international and national institutes as well as networks address problems related with sanitation, waste water treatment and the use of effluent for irrigation as well as side effects thereof. The objectives of this work can be summarized as follows:

1. Raise the issue of wastewater irrigation
2. Introduce basic concepts and definitions related to this issue
3. Provide a rapid overview of recent developments in the field
4. Explore the best study approach to tackle this subject.

DEFINITIONS

A good starting point for a successful multidisciplinary effort is to share a pool of basic concepts that are key to the subject. In this sense, some terms and items must be carefully defined in order to have a common language. In this section, a number of issues regarding wastewater irrigation will be introduced.

Wastewater and sewage

Sewage is the wastewater generated by a community, namely: a) domestic wastewater, from bathrooms, toilets, kitchens, etc., b) raw or treated industrial wastewater discharged in the sewerage system, and sometimes c) rain-water and urban runoff (van Haandel and Lettinga, 1994). Domestic wastewater is the main component of sewage, and it is often taken as a synonym. Sand and coarse material (paper, bottles, etc.) are not considered part of sewage. They are transported by sewage but handled as solid waste when they arrive at a treatment facility. The sewage flow rate and composition vary considerably from place to place, depending on economic aspects, social behaviour, type and number of industries in the area, climatic conditions, water consumption, type of sewers system, etc. Besides, there are seasonal, monthly, weekly, and hourly variations in both flow rate and composition. The main pollutants in sewage are (a) suspended solids, (b) soluble organic compounds, (c) faecal pathogenic micro-organisms, and (d) nutrients, but sewage is not just made up of human excrement and water. A variety of chemicals like heavy metals, trace elements, detergents, solvents, pesticides, and other unusual compounds like pharmaceuticals, antibiotics, and hormones can also be detected in sewage. With urban runoff come potentially toxic compounds like oil from cars and pesticides that may reach a treatment plant and, eventually, a water body. Direct discharge of raw or poorly treated sewage into the environment is one of the main sources of pollution on a global scale (Gijzen, 2002).

Improved sanitation would have a significant impact on people’s lives in terms of safety, privacy, convenience, and dignity (United Nations, 2003). Sanitation is also a good starting point for addressing long-term poverty issues and reducing children mortality because children are more susceptible to suffer from inadequate water supply and sanitation services. The lack of water, sanitation, and hygiene for all was dubbed as “…one of the biggest scandals of the last 50 years” (WSSCC, 2003). Simple, affordable, and efficient sewage treatment systems are urgently needed, especially in developing countries, where most of the conventional technologies currently in use in industrialized nations are too expensive and complex (Grau, 1996). Sustainable sewage treatment technologies will help to preserve water ecosystems and their biodiversity, indispensable for the provision of clean water, flood control, and other vital services.

Wastewater treatment

Wastewater treatment implies the purification of a given wastewater until its characteristics achieve a certain objective, generally related to health, environmental, or economic matters. There are several technological options available for sewage treatment ranging from traditional waste stabilization ponds (WSP) to conventional aerobic systems (like trickling filters or activated sludge), from anaerobic reactors to integrated systems in which a variety of biological processes can be applied. Anaerobic processes are attracting more and more the attention of sanitary engineers and decision-makers, especially the upflow anaerobic sludge bed (or blanket) (UASB) reactor developed in the early 1970s by Lettinga and co-workers (Lettinga *et al.*, 1980). Anaerobic sewage treatment in UASB reactors is an absolute success in tropical countries like India and Brazil, but it's also finding its way in other regions, even in subtropical and more temperate countries. Recent studies showed that it can be successfully applied at temperatures as low as 15°C for a variety of different types of sewage (Mahmoud, 2002; Halalsheh, 2002; Seghezzo, 2004). Sewage treatment can be roughly classified in the following levels:

- Preliminary treatment aims at the elimination of coarse material like bottles, rugs, dead animals, stones, and so on, as well as the sand that comes with sewage. The removal is mainly due to physical actions like screening, flotation and settling. The objective of preliminary treatment is to protect pumps and pipes and further treatment units.
- Primary treatment intends to remove most of the remaining suspended solids through physical processes like flotation and settling. The objective is to protect further treatment units and protect water bodies from receiving these solids. The main units are sedimentation tanks (settlers), but also systems like septic tanks can be classified as mainly primary treatment units.
- Secondary treatment aims to the elimination of organic matter through biological action (by means of bacteria, fungi, algae, protozoa, etc.). The main objective is to protect water bodies, although the production of a usable effluent is also increasingly important. Biological treatment can be accomplished either with aerobic (so as ponds) or anaerobic treatment systems (so as UASB reactors).
- Tertiary (and even quaternary) treatment, sometimes also called post-treatment, intends to remove pathogens and nutrients, via chemical, photochemical, and biological action (pH, light, bacteria, algae, and fungi). The objective is to protect public health, water bodies, and to produce a usable effluent for more stringent purposes. Biological systems are mainly aerobic.

There are systems or processes that can cover two or more categories in the same treatment unit. The level of treatment to be applied depends very much on the objective set up by the administration and includes the use that the effluent will be given. However, in the vast majority of countries, tertiary treatment is simply not affordable. Therefore, a delicate balance must be struck between the desired level of treatment, the costs of the facilities needed, and the risks related to the discharge or use of the effluent.

Wastewater irrigation

It is now acknowledged as a fact that wastewater is an important and reliable water source in many regions of the world, and that the nutrients present in wastewater may replace fertilizers saving money to farmers. In addition to that, it is also recognized that soil application can be considered as a sewage treatment system (Martijn and Huibers, 2001). Farmers not only use raw or partially treated sewage for irrigation, but also wastewater diluted with fresh water or fresh water polluted with different types of wastewater. In a sense, the use of wastewater for irrigation, after whatever level of treatment, can be classified as direct (when it is used as such in the field) or indirect (when it was first discharged in a water body). Consequently, the treatment, disposal, and use of sewage can then take different ways as can be derived from Figure 1.

In a situation where an intended, direct use of (treated) wastewater is envisaged, a number of typical issues arise and should be considered:

- Design choices in sanitation, collection and treatment. There are several technological alternatives for sewage collection and treatment. Traditional systems like the Waste Stabilization Ponds have to be revisited in the light of the need of avoiding evaporation that reduces the amount of water while increasing the salinity of the remaining water. The adequate degree of decentralization needs also a careful site-specific assessment, as well as an environmentally safe sludge management.
- Mismatch between supply and demand of water. Certain water storage capacity may be needed that may accommodate effluent surplus (for operational or seasonal reasons), provide water in periods of high demand and act as buffer in case of calamities may be needed. Constructed storage in an irrigation scheme is mostly expensive, but could, at the same time, serve as a post-treatment step.
- Nutrient management. The amount and quality of the nutrients present in the wastewater have to be known by technicians and farmers in order to guarantee a proper application. The need of varying effluent quality during different periods of the crop period may also be an issue to discuss between farmers, irrigation experts, and treatment plant operators.
- Irrigation techniques. Techniques may vary according to the type of effluent being used and the region (watering cans, surface irrigation, drip irrigation). Special care needs to be taken to avoid contamination of the field labourers, the crops, the soil, and the surface or groundwater.
- Cropping system. Water and nutrient availability may induce significant changes in the optimal cropping system, linked to water demand, nutrient demand and seasonal aspects.
- Participatory design (farmers, engineers, policy makers). The system becomes more complex and the participation of different actors becomes indispensable to ensure a smooth process.
- Economic (costs, benefits, efficiency), social, environmental and institutional aspects that are an inextricable part of the long-term sustainability of the system.
- Risk management. Risks have to be appropriately handled at field level (through appropriate crop choice, proper irrigation and management techniques, contact prevention, adequate information to farmers) and at the food chain level (restricted irrigation during the days before harvesting, washing produce with clean water, adequate information to farmers and consumers).

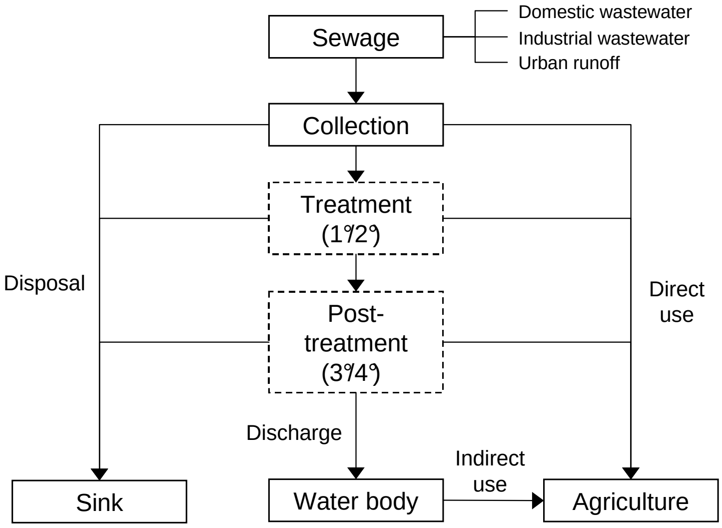

Figure 1. Basic pathways for sewage collection, treatment, disposal, and use in agriculture

LESSONS LEARNED

It is a fact that illegal, informal, unguided, or unplanned direct and indirect use of raw, partially treated, or diluted wastewater is carried out in many regions of the world. On the other hand, wastewater production from urban areas will double, if not triple, in most cities of the world in the coming 20-25 years and so will urban food requirements. In many locations people will need this water for production in a period of expected decreasing water availability. Otherwise, these flows need to be disposed of without endangering the downstream environment.

Typical situations

From experiences of wastewater irrigation developed in many countries of the world a number of common features has arisen, summarized in Figure 2. In urban areas like Accra, Ghana (Figure 3, left), the farmer can be seen as moving to the flow of wastewater. Farming there is performed on small plots of land situated near the water flows all year round. Mostly vegetables are grown for own consumption, while surplus is sold in the local market. It is basically a livelihood issue and the main risk is the contamination of crops with untreated wastewater. In a so-called peri-urban area like that found in Cochabamba, Bolivia (Figure 3, centre), wastewater that is produced in the urban areas is conveyed to the outskirts where farming actually takes place. So, here we find a situation where the wastewater flows towards the farmer. The production is mainly seasonal; farms tend to be larger with more secured land tenure and better equipped than in the case of urban agriculture. Lesser vegetables and more staple crops are grown. The main health risk found in this case is the direct contact with the wastewater, while there is a potential pollution problem downstream originated by the surpluses that are discharged untreated into surface waters. Finally, in a case like Nabeul, Tunisia (Figure 3, right), wastewater irrigation takes place in a formal scheme. One may say that the wastewater flow and the farmers moved towards each other. There is an infrastructure, institutional arrangements and specific legislation and control that regulate the system.

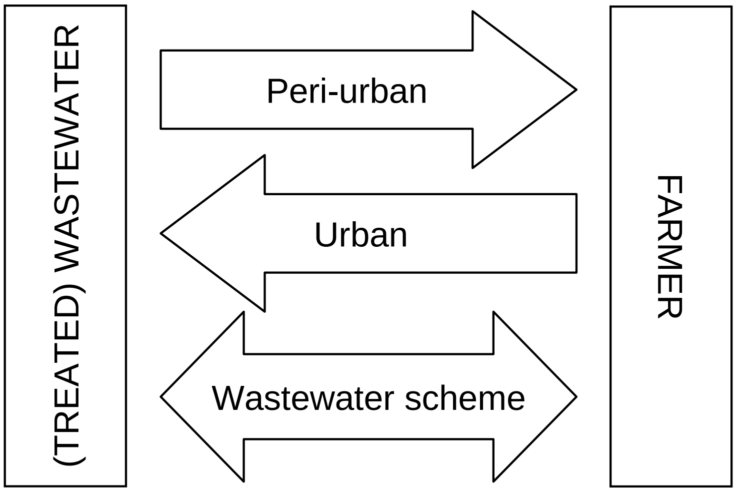

Figure 2. Typical situations encountered in wastewater irrigation around the world.

Figure 3. Wastewater irrigation in Ghana (left), Bolivia (centre), and Tunisia (right).

The Water Chain Approach

In view of the physical and institutional complexities of wastewater irrigation systems, a so-called Water Chain Approach is proposed. This approach would help to think along the line of the physical water flow. The produce or outflow of each link in the chain is the inflow of the next. The chain starts at the level of the fresh water resources from which water for domestic use is taken. Subsequently the water is delivered in a distribution network and transported to the actual users of domestic water. They use and manipulate this water and produce wastewater of a certain quality, which enters the next link in the chain, which is collection and transport. What potentially follows is treatment, agricultural use and drainage into surface or sub-surface water bodies. All links make up a chain and using this approach gives the most appropriate basis to come to an integrated design of water measures at each link of the chain. This ultimately supports an environmentally safe and productive use of water in urban areas and downstream. The water chain approach was discussed by Martijn and Huibers (2003), who proposed a conceptual design framework to deal with wastewater irrigation issues as shown in Figure 4.

CONCLUSIONS

- Wastewater irrigation has a great potential in many (developing) countries.
- It is a complex issue and should be dealt with in an integrated fashion.
- Different disciplines are required to design a wastewater irrigation system.
- Adequate water, crop, and nutrient management are required to ensure a sustainable system.
- Proper irrigation techniques need to be used according to the local situation.
- A balance between objectives, costs, and risks must be struck in each different case.
- Information must be available to all stakeholders, including the farmers.

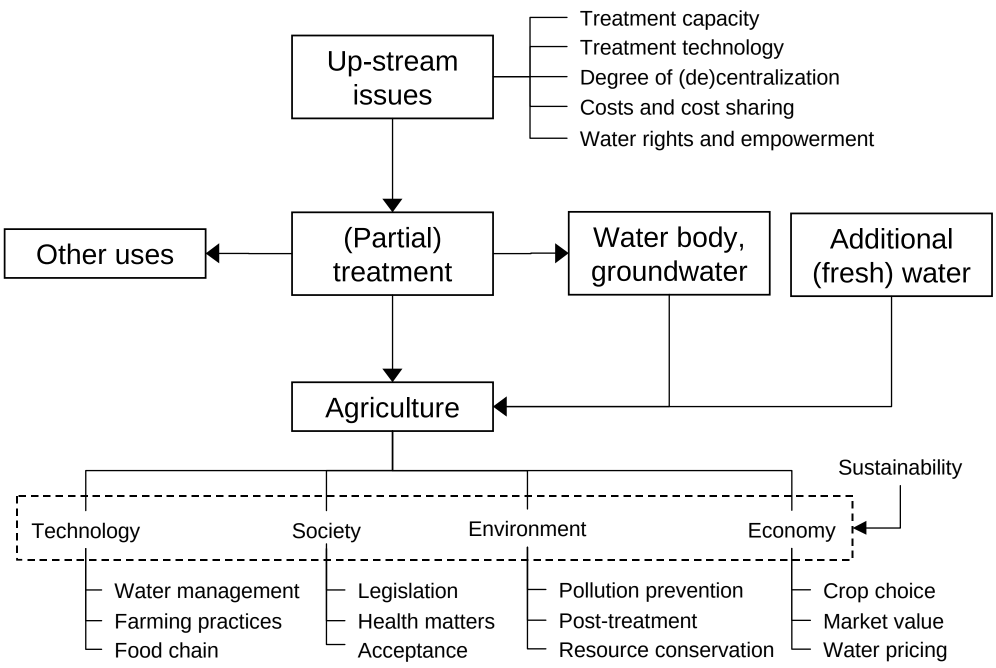

Figure 4. Conceptual design framework in wastewater irrigation.

POSSIBLE APPLICATIONS

The application of wastewater irrigation systems to any situation is an open question and a challenge that needs to be solved locally. Some questions arise, like: Are the situations described above applicable to any particular situation? Who are the relevant actors in the local context? Where are the gaps in knowledge that need to be investigated and how to bridge these gaps? The relevant issues may be different depending on the type of situation, and so will be the research questions that need to be answered. For example, avoiding contamination and safeguarding health could be a hot issue in urban agriculture, while soil, surface water, and groundwater pollution may be more important in peri-urban areas. In any case, the adequate means to provide adequate information to all stakeholders seems to be particularly relevant.

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CHAPTER 3: Results of the Thematic Discussions

Session A: Waste water flows - Collection and treatment

To study the flows of urban wastewater and its use in agriculture an integrated water resources management approach is needed. Too often a focus is laid upon technologies only (f.e. sewerage system or treatment plant) ignoring a system-solution in which the technology has to perform. Next to engineering questions a social-economical and institutional approach has to be adapted toward the site specific demands, including the position of all stake-holders in the urban water chain.

This also leads to the observation that the monitoring of waste water flows, in quantity and quality, as well as that of the effluent from treatment plants is generally insufficient. Certainly, such monitoring and quality control should benefit all stakeholders in the waste water chain. A good monitoring is linked to the responsible institutions and involved stakeholders and requires new and original conceptual approaches, that are well-balanced, feasible and cost-effective.

Research questions:

Research is needed for preparing scenarios for decision makers:

1- Development of methods for the estimation of water budgets in an urban environment
2- Social-economical research for increasing awareness with stake-holders
3- Development of conceptual approaches to monitoring and quality control
4- Study of operation and maintenance costs of different technologies used
5- Institutional collaboration in the urban water-chain
6- Scope for decentralisation, including cost-benefit comparison between centralised and decentralised systems

In all cases, we should link waste water collection and treatment to envisaged downstream use. In this context we have to look for adaptation of technologies for regional conditions.

Session B: Waste Water Use: Management, Health and Productive Value

Millions of people worldwide depend on (treated) wastewater as their only source of irrigation and livelihood. Few of them would choose for wastewater as irrigation source if they would have a choice. Farmers access wastewater as they are desperately in need of water or they have no choice as their originally fresh water resource has been polluted by increasing wastewater flows.

The area under wastewater irrigation produces a huge quantity of food, including vegetables, close to important markets. This production adds positively to the availability of food and is a source of income for many, generally poor, farmers. The higher income also results in improved health conditions, if only through an easier access to medical facilities.

The use of wastewater in irrigation may lead to negative health effects. Yet, stopping the use of wastewater would be no solution, if at all feasible. We should find the best ways and means to reduce the risks and to make them manageable. We should therefore consider the risks in a wider context of health and welfare of the concerned population.

Irrigation with wastewater demands for careful water management using the most appropriate technology for a specific situation. Much depends on the availability of good information on water quality and its consequences for crop and soil. This lacks generally and if data are gathered, a communication of (understandable) information to stakeholders is missing.

The waste water is produced year around, but the demand for water will not be constant through the year. In particular, when cropping is seasonal due to climatic constraints, (treated) waste water should be stored, possibly in the aquifer.

Research questions:

1- How to minimize health risks, while optimizing farmers' income. This includes research to arrive at an approach to selects the type of crops in relation to actual water quality, irrigation technique, soil properties and management.
2- Development of monitoring approaches: Test and information systems which are cost-effective and sustainable. Responsibilities of different authorities should be agreed upon and clear.
3- What are the actual health effects (positive and negative) of the use of wastewater in relation to overall health situation, income position, etc. of the affected population?
4- What are the actual costs and cost-structure of wastewater collection, treatment and effluent distribution and how do these compare at regional level.
5- What are the technical options to mitigate the problem of the mismatch between supply and demand of wastewater, its trends and patterns considering: Operational needs; cropping pattern, growing stage, season etc.

Session C: Sustainability: Long term environmental effects

Domestic wastewater flows from urban areas is rapidly increasing due to population growth, urbanization, and economic development. There is, however, a lack of investing capacity worldwide for the construction and operation of adequate treatment facilities, which threatens the quality of surface waters, soils and groundwater to which wastewater is discharged. At the same time, the demand for irrigation water in peri urban areas is increasing, and farmers are increasingly using treated and untreated waste waters for irrigation.

This practice raises some serious questions with respect to long term impacts on soil, water bodies and aquifers. In particular, do benefits obtained by farmers of today have an impact on the future productive and aesthetic values of the land? Can the current generations demand and use of poor quality water for irrigation result in vast areas of land going out of production forever?

Not all nutrients available in the water are used by the crop. Furthermore, since farmers' are unaware of the nutrient load, they tend to apply chemical fertilizers to supplement the nutrients in waste water. This may leave surplus nutrients in the soil, and over a period some toxicity of micro and trace elements may build up. In addition part of the excess nutrients may end up in the aquifer. Continuous use of waste water for irrigation may lead to salinity or acidity.

Prevention of aquifer contamination requires quality control of treated waste water, and precise irrigation scheduling. Alternately, waste water irrigation may be banned in areas where groundwater is of drinking quality.

Research questions:

1. Determine nutrient management strategies for land which are irrigated by treated waste water, to prevent negative impacts on soil and the aquifer.
2. Determine the circumstances under which either a centralized treatment plant or decentralized plants are preferred.
3. By transferring waste water for irrigation, which use is traded off. What is the cost of this transfer?
4. How to translate the effects of national/regional and international legislation (wastewater and sludge quality) on local reality?

ANNEX 1: Attendance list for the opening session of the expert meeting 4-7 November 2006

No.	NAME	Affiliation
1	Abdul Rahman Fadhl Al-Eryani	Minster of Water and Evnironment
2	Hussein Al-Junaid	Deputy Minster of water and Environment
3	Saleh Ali Ba Surah	Minster of high education and scientific research
4	Jalal Faqirah	Ministry of Agriculture and irrigation
5	Khalid Tamim	Sana'a Univerisity Rector
6	Abdulkarim Al-Subari	Vice rector Sana'a university
7	Mohamed Al-Kohali	Dean Faculty of Science
8	Mansour Al-Hawshabi	Dean Faculty of Agriculture
9	Abdulla Saleh Babaqi	Water and Environment Centre
10	Fadhl Ali Al-Noaily	Water and Environment Centre
11	Abdulla Abdul Kader Noaman	Water and Environment Centre
12	Mr. Jahan F. L. Blankenberg	Netherlands Ambassador
13	Saied Hussein Kamalian	Iranian Embassador
14	Saied Hasan Khalily	Culture Attache Iranian Embassy
15	Belqis Zabarah	Water and Environment Centre
16	Abdul Moamen Mutahar	NWSA chairman
17	Abdulwahab Salah	Sana'a Water and Sanitation Local Corporation (SWSLC)
18	Mohamed Al-Sharafi	SWSLC
19	Salem Ba Shuaib	NWRA chairman
20	Ali Al-Suraimi	GARWS chairman
21	Abdulwahab AlMujahed	Social Fund for development
22	Saeed Abdo Ahmed	Public Works Projects
23	Nagi Abohatem	World bank
24	Mohamed Shamsan	Ministry of Water and Environment
25	Mr. Ton Negenman	The Netherlands Embassy
26	Mohamed Al-Aroosi	The Netherlands Embassy
27	Mr. Gerhard Lichtenthaeler	GTZ
28	Han Blom	Nuffic
29	Yasin Abdu Ismael	NWSA
30	Mohamed Mohamed Al-Eryani	Journalist
31	Ahmed Aayedh Al-Sofi	Journalist
32	Samir Hijazeen	Hydrosult
33	Sharafaddine Saleh	WEC
34	Abdul Rahman Al-Eryani	WEC
35	Iskander Thabet	
36	Osama Al-Haj Hamdan	IWRM program- WEC
37	Nadia Al-Harithi	
38	Mona Mohamed Nagi	
39	Nooraldeen Mohamed. Abduh	
40	Khaled Baleidi	
41	Bashir Al-Nasiri	
42	Hisham Mohamed Al-Saeedi	
43	Anis M. Fadhel	
44	Ghaleb A. Kader Ghaleb	
45	Tawakkul Ahmed. Tawakkul	
46	Abdulkader Saeed	

ANNEX 2: List of International Participants

	Country/Organisation	NAME	Email
RCUWM Board Member Countries			
1	WUR/Netherlands	Dr Frans Huibers	Frans.Huibers@wur.nl
2	WUR/Netherlands	Ir Catharien Terwisscha van Scheltinga	Catharien.Terwisscha@wur.nl
3	Netherlands/Yemen	Jan Hoogendoorn	Jan.Hoogendoorn@vitens.nl
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5	RCUWM/Iran	Ms Saba B. Amini	sabaamini@yahoo.com
6	RCUWM/Iran	Sina Moshirvaziri	smvaziri@ut.ac.ir
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8	WEC/Yemen	Fadhl Ali Saleh Al Nozaily	d-fadl@maktoob.com
9	Germany	Dr Joachim Quast	jquast@zalf.de
10	Germany	Dr Roland Mueller	roland.mueller@ufz.de
11	India	Dr Anand Vashi (unable to attend due to last minute visa problems)	enviro@satyam.net.in
12	Oman	Salem Alhakawati	salemhakawati@omanwsc.com
13	Oman	Dr Sanmugam A. Prathapar	prathapar@squ.edu.om ; saprathapar@yahoo.com
Countries in the RCUWM region (Non RCUWM board countries)			
14	Afghanistan	Parvez Kakar (unable to attend due to last minute visa problems)	parvezkakar@yahoo.com
15	Uzbeckistan	Dr Malika Ikramova (unable to attend due to last minute visa problems)	dilmalik@tps.uz
16	Jordan	Dr Maha Halalsheh	halalshe@ju.edu.jo
17	Jordan	Dr Murad Bino	Muradinw@nic.net.jo ; inwrdam@nic.net.jo

ANNEX 3: Inventory of Initiatives*

	Training	Research	Implementation
Network			
RCUWM - Regional Centre for Urban Water Management, Tehran, Iran Dr Reza Ardakanian, Director. Tel: 0098 21 88 75 49 36 Fax: 0098 21 88 74 12 30 Email: info@rcuwm.org.ir Website: www.rcuwm.org.ir	x	x	
Institute			
WUR - Wageningen University and Research Center, Netherlands Dr Frans Huibers / Ir Catharien Terwisscha van Scheltinga Tel: 0031.317.484267 Email: Frans.Huibers@wur.nl Website: http://www.iwe.wur.nl/	x	x	
WEC - Water and Environment Center, University of Sana'a, Sana'a, Yemen Prof. Dr Abdulla Babaqi, Director Tel/fax: 967-1-464360/6/7 or 967-1-822112 Email: wec2@y.net.ye, wec@yemen.net.ye Website: http://www.wec.edu.ye/	x	x	
ICARDA/IWMI - International Center for Agricultural Research in the Dry Areas; International Water Management Institute, Aleppo, Syria Dr Manzoor Qadir Email: m.qadir@cgiar.org Website: http://www.icarda.org		x	
KISR - Kuwait Institute for Scientific Research Dr Abdallah Abusam Email: abusam3a@yahoo.com		x	
Project			
SMART - Sustainable Management of Water Resources with Innovative Technology Dr Mueller, Project Leader at UFZ. Palestine, Jordan, Israel, Germany Email: roland.mueller@ufz.de	x	x	x
EMWater project Dr. Ismail Al Baz, Project Director Email: emwater@batelco.jo Website: www.emwater.org			x

* This inventory is to be completed. Most member countries in the region have a specialised institute.