Reclaimed Wastewater as a Resource for Sustainable Water Management

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Summary:

Population growth accompanied by higher standard of living and ongoing drought conditions caused by changing climatic patterns tend to make water availability as a key national issue not only at present but for the decades to come. The urban cities located around the coastal areas look for the possibility of desalination of sea water whereas the inland cities explore wastewater reuse as a last resort for indirect potable use to meet the envisaged water shortage. Toowoomba City Council acknowledged that Toowoomba would run out of water in two years if the current drought persisted and, therefore, is planning to augment the present water supply with highly treated wastewater using the best technologies available. The concept of reclaimed wastewater to be considered as a resource rather than a waste has been a subject of debate. There are many instances of communities practicing the unplanned indirect potable reuse unknowingly. Tertiary treated wastewater and sometimes untreated industrial and agricultural wastes are returned to the water body from where downstream utilities withdraw water for potable uses. The receiving water bodies have the natural assimilative capacity to clean up the waste discharged into them; however, their limits have been exhausted during the last decade or so due to increased loading discharged containing synthetic chemicals. Planned indirect potable reuse aims to remove these contaminants present in the tertiary treated effluent using advanced treatment technologies with multiple barriers before discharging them into the water bodies to augment the drinking water supply downstream or of their own. Considering the facts that many conventional sources of fresh water become scarcer and more contaminated but emerging innovative state-of-the-art technologies are available to remove the contaminants, planned indirect potable reuse could be a promising solution for sustainable water resources management. This has been reflected in that many utilities around the world have either been planning or already implementing the advanced reuse systems. This paper reviews some indirect potable reuses practiced in the world, the treatment methodologies adopted and discusses how stakeholders can contribute for continued sustainable supply of these water resources.

1 INTRODUCTION

Water utilities around the world are under growing pressure to combat the water shortage issues caused by severe droughts, uneven distribution of water resources and population growth. There are only two options available, one to reduce the water demand and the other to increase the water supply. Having exploited possible existing water supplies and explored all the possible water conservation and demand management, several municipalities in the world have been considering the reclaimed wastewater as a resource not to be wasted. This has become a possibility due to the innovation and installation of state-of-the-art technologies with multiple barriers to remove the trace organic contaminants that may be present in the tertiary treated effluent. Toowoomba City Council is planning to implement planned indirect potable use of reclaimed wastewater as a last resort to augment the existing water supplies. In light of this new initiative, this paper reviews reclamation and subsequent potable reuse practices in the world, and discusses how stakeholders can contribute for continued sustainable supply of these water resources.

2 TYPES OF WASTEWATER RECLAMATION AND REUSES

When discussing wastewater reclamation and reuse of treated municipal wastewater for potable uses, we need to be aware of the distinctions between *direct* and *indirect* potable reuses and *planned* and *unplanned* ones.

2.1 Unplanned Indirect Potable Reuse (UIPR)

Unplanned indirect potable use occurs when a water supply is abstracted for potable purposes from a natural source (surface or groundwater) that is fed in part by the discharge/disposal of treated or non-treated wastewater effluent. The subsequent potable use of the wastewater was not an intentional part of the effluent disposal plan and therefore, the wastewater discharged is not treated to a much higher degree as it is with the planned indirect potable reuse. This type of indirect potable reuse occurs whenever an upstream water user discharges wastewater into a water source that serves as a water supply for a downstream user (Figure 1). [2, 3]

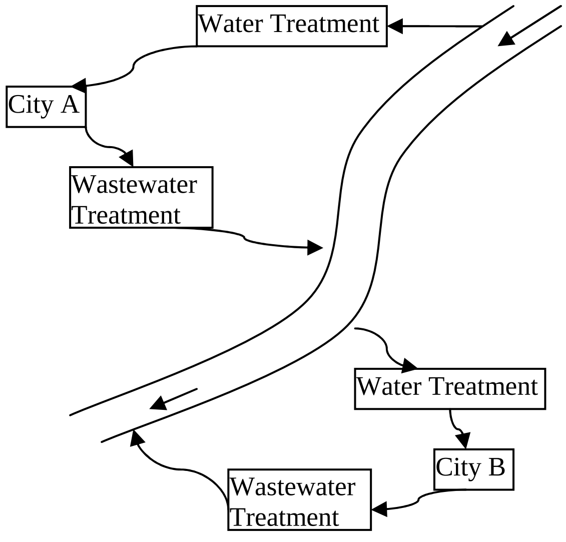

Figure 1: Unplanned Indirect Potable Reuse

2.2 Planned Indirect Potable Reuse (PIPR)

Planned indirect potable reuse involves intentional augmentation of natural water supply source such as river, lake, reservoir or underground aquifer for subsequent abstraction, treatment and distribution of water for drinking purposes. As shown in Figure 2, the wastewater discharged will be subjected to very high degree of treatment with multiple barriers to remove the contaminants before disposal into the natural water supply sources.[2, 3] With planned or unplanned indirect potable reuse, the storage provided between treatment and consumption allows time for mixing, dilution and natural physical, chemical, biological processes to purify the water. [2, 3]

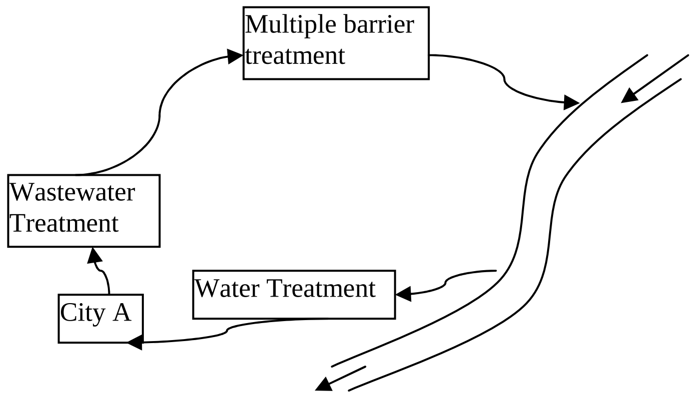

Figure 2: Planned Indirect Potable Reuse

2.3 Direct Potable Reuse (DPR)

Direct potable reuse refers to the introduction of highly treated wastewater with extensive processing beyond usual wastewater treatment directly into a water distribution system without intervening storage (Figure 3). Direct use of reclaimed wastewater for potable reuse without the added protection by storage in the environment is not considered as a viable option in Australia. [2, 3]

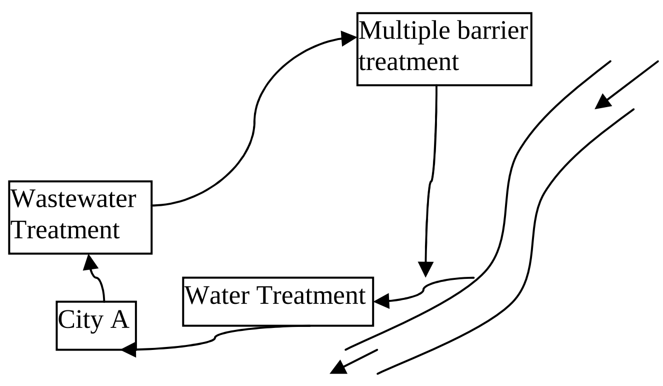

Figure 3: Direct Potable Reuse

3 CASE STUDIES

3.1 Unplanned indirect potable reuse (UIPR)

Many large communities unintentionally and unknowingly have been practicing UIPR. There are numerous examples world-wide of this practice. The most notable ones include the following: [4]

- Rhine and Thames rivers in Europe
- Mississippi River in the U.S.
- Yangtze River in China
- Mekong River in Indo-China
- Murray River in Australia.

National research council concluded that "In US alone, more than two dozen water utilities in Philadelphia, Cincinnati and New Orleans, which draw water from the Delaware, Ohio and Missisipi rivers, serving populations from 25, 000 to 2 million people, draw from rivers in which the total wastewater discharge accounts for more than 50% of stream flow during low flow conditions". [2]

"The Thames basin covers an area of approximately 13,000 square kilometers and supports a population in the order of 12 million including that of London. On average, about 3.7 and 1.4 million m^3/d are provided for public water supply and direct abstractions for industry respectively. The public water supply requirement represents about 55% of the natural runoff from the freshwater portion of the catchment in an average year and correspondingly more in a dry year. In addition, there are some 370 waste-water treatment works processing an average of 4.3 million m^3/d per day, the bulk of which is discharged to the tidal portion of the Thames. On average about 12% of resources for public water supply are derived from indirect effluent re-use, and during a dry summer this figure can rise to 70% locally" (http://www.ess.co.at/WATERWARE/thames.html).

In Australia, this happens mainly in inland areas, for example, Canberra wastewater is discharged into Molonglo River and thereby into Murrumbidgee River, and the residents on the Murrumbidgee River below the Molonglo River draw this water for potable purposes. During low flow and dry weather conditions, the percentage contributed by the wastewater effluent for drinking water facility can be considerably higher.

3.2 Planned indirect potable reuse (PIPR)

Table 1 gives the details of some case studies related to where PIPR is in place, when these plants were commissioned, what their project motives are and also where the reclaimed water is discharged. [5, 3, 6] This type of potable use is becoming more common as other viable water sources have become scarcer and more contaminated due to population growth and also urbanization. There are a number of successful PIPR in operation in US, in California, Virginia and Texas that provide safe drinking water, some of them, for over 25 years. NEWater from Singapore has commissioned its plant as recently as 2000.

Toowoomba is expected to commission its proposed plant in 2009, when Cooby dam will be augmented with the highly treated water from Wetalla wastewater treatment plant. The project motives include: [7]

- Severe drought accompanied by low rainfall, high evaporation and low runoff which cause the water levels in the dam to continuously recede.

- Demand management implemented by way of higher level water restrictions, mandatory installation of rainwater tanks, rebate policies for those switching to water saving appliances – but not expected to meet the growing water demand
- Alternate water resources explored but not feasible - The supply of water from Wivenhoe Dam or the construction of a new dam at Emu creek are highly unlikely to get approval from Queensland Government.
- Application for additional bore water supply from artesian basin made – but still not enough to meet the projected demand.

Having explored all the possibilities, Toowoomba city council has opted for PIPR as a last resort that aims to combat the water shortage issues.

Table 1: Case studies of planned indirect potable uses and the project motives [3, 5, 6]

Location	Description	Year started	Project motives	Discharged to
California	Wittier Narrows (near Los Angeles)	1962, upgraded 1978	To reduce the overdraft condition of the basin by roughly two/thirds To reduce the area's dependence on imported supplies	Groundwater recharge
	Water Factory 21 (orange county water district, Southern California)	1976	Demand management implemented –but not meet the projected water requirements Seawater desalination-too expensive compared to water reclamation To avoid dependence on imported water – costly, may not be available To protect coastal groundwater quality by providing sea water intrusion barrier To replenish the local aquifers	Aquifer injection
Virginia	Upper Occoquan sewage authority reclamation plant (Centreville)	1978	Development and population growth caused indirect potable use Deterioration of water quality on the receiving water Major upgrade to reclaim water	Surface water augmentation
Arizona	Scottsdale water campus	1980	To meet the water demands of rapidly growing population	Aquifer injection
Texas	Fred Harvey Water reclamation plant (EI Paso)	1985	To augment the groundwater supplies To prevent the salt water intrusion from Rio Grande alluvium.	Aquifer recharge
	Wilson Creek wastewater treatment plant North Texas		To improve the water quality of the stream that is tributary to Lake Levon, the water supply for the entire water district, by discharging highly treated wastewater into it.	Surface water augmentation
Nevada	Tahoe-Truckee Sanitation Agency Water Reclamation Plant (Reno)		To improve the water quality of the Truckee River, which is the source of the City of Reno's water supply	Surface water augmentation
Singapore	NEWater	2000	About 50% of the Island's fresh water supplies are imported from Malaysia, which is subjected to ongoing negotiations. To reduce the above reliance by sea water desalination and water reclamation	Surface water augmentation

3.3 Direct potable reuse

It is the immediate addition of reclaimed water to the potable water distribution system. This is often referred to as "toilet-to-tap" because of the closed loop cycle without any intermediate natural storage involved. [4]

The only documented case of an operational direct potable reuse system is in Namibia, in Southern Africa since 1968. The plant has consistently produced water of acceptable quality for 30 years. Namibia was experiencing low rainfall, high evaporation and low runoff, and the water utilities have exploited all the water sources within 500 km of the city, further water sources were expensive and obtaining them controversial with maximum ground water utilization already occurring and demand management had already been implemented. So they had to resort to wastewater reclamation. [6] The recycled water is blended with treated water from treatment plant before distribution, with the maximum blend being 1:1 during drought periods. The average blend since 1968 has been 1:3.5. [4]

A direct potable reuse demonstration project was designed to examine the feasibility of converting secondary effluent from a wastewater treatment plant to water of potable quality that could be piped directly into the drinking water distribution system in Denver, USA. This city conducted a 10-year potable water reuse trial using a 3.8 ML/d demonstration water reclamation facility.[2] However, Denver presently has no plans for direct potable reuse.

3.4 Comparison of indirect potable reuse with direct potable reuse

A comparison was made for indirect potable reuses with direct potable reuse and Table 2 gives the details.

Table 2: Comparison of indirect and direct potable uses

Description	Unplanned indirect potable reuse	Planned indirect potable reuse	Direct potable reuse
Treatment	Secondary and sometimes advanced treatment prior to discharge to waterways.	Multiple barrier treatment before surface augmentation or aquifer injection.	Demands extensive treatment of the wastewater prior to reintroduction directly to the drinking water facility.
Contaminants	Subjected to dilution, mixing and natural physical, chemical and biological treatment in the receiving body prior to abstraction into drinking water facility	Less or no contaminants undergo dilution, mixing and natural treatment in the receiving body before abstraction into drinking water facility	Certain chemicals have the tendency to concentrate over time when repeatedly recycled
Community reactions	Even though downstream communities uses the water that contain upstream discharge of wastewater, communities are not aware so do not protest.	Newly introduced PIPR, though highly treated than unplanned discharge, tends to upset the communities.	Very negative
Discharge	Wastewater effluent is discharged downstream for raw water diversion for drinking water	Wastewater effluent is normally discharged upstream for subsequent abstraction.	No discharge outside
Responsibility for clean up	Downstream communities clean up the upstream waste	The same community reaps the benefits of treatment	The same community

4 TREATMENT PROCESSES

4.1 Unplanned indirect potable use

In UIPR that is widely prevalent, wastewater collected at a sewage facility is subjected to primary, secondary and advanced treatment before being disposed to a receiving body as shown in Figure 4. Pretreatment removes about 60% of the suspended solids in raw sewage and 35% of the biochemical oxygen demand (BOD), the pollutants that either settle or float. The suspended solids that escape the pretreatment and also the soluble BOD that is not removed from the pretreatment processes are treated in the secondary treatment using biological processes. Although significant amount of BOD and suspended solids are removed in the secondary processes, it does not remove significant amounts of nitrogen, phosphorus or heavy metal and pathogenic bacteria and viruses. [1] Advanced waste treatment processes involve nitrification, denitrification with enhanced phosphorus processes that remove nitrogen and phosphorus. During the biological processes, the organic and inorganic pollutants are broken down to harmless carbon dioxide, water and nitrogen gas, with additional bacterial cells produced, which are removed as sludge and treated further. The effluent discharged will be free from biodegradable organics and nutrients.

In Australia, there was no advanced sewage treatment plant until the 1990's and some cities were still piping primary treated effluent into high energy coastlines and relying on dispersion. [8] The outbreaks of blue-green algae issues and detection of high coliform counts have raised the awareness for the need for advanced treatment. Most of the sewage treatment plants in the cities are now offering advanced treatment and the resultant effluent is discharged either into the sea in coastal areas, or to the tributaries in the inland area.

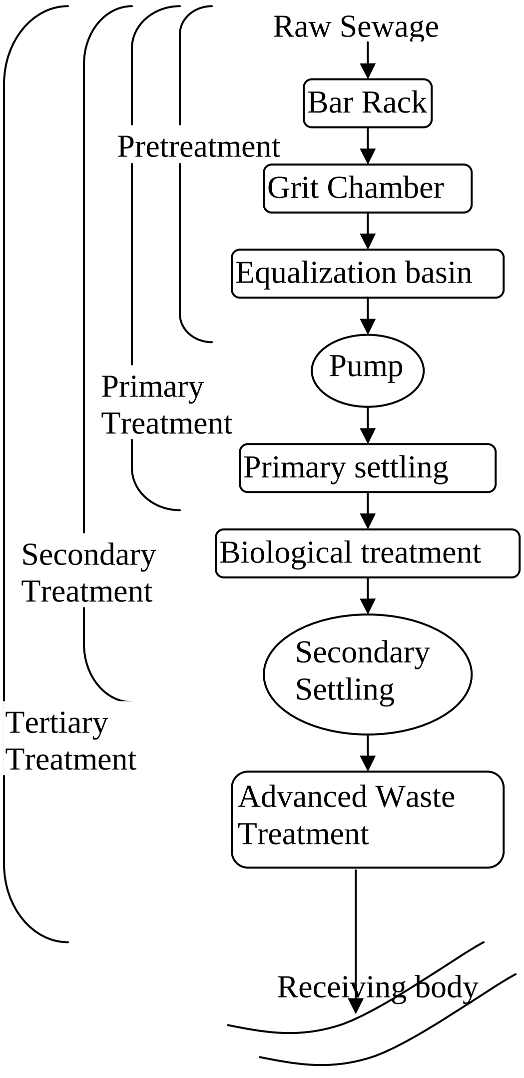

Figure 4. Degrees of treatment [1]

Environmental licensing by the environmental protection agency for each wastewater treatment facility is dependent on the receiving water or the level of effluent reuse. Existing wastewater licenses are generally based on the organic and nutrient concentrations rather than the total mass loads. Stringent guidelines have been imposed continuously to improve the effluent quality causing the wastewater utilities to upgrade their facilities to meet the standards.

When the tertiary treated effluent is discharged into a river, it is mixed and diluted. Besides, rivers have some capacity for self-purification termed as assimilative capacity. The biodegradable organics in the treated effluent undergoes further treatment and assimilation in the river.

However, during the last decade, there has been considerable research in the US and Europe on the occurrence of newly emerging trace organic contaminants termed as endocrine disrupting chemicals (EDC) [9], pharmaceutical and personal care products (PPCP) [10] and disinfection-by-products (DBP)[11] present in the tertiary treated effluent and subsequently in the surface and ground waters in very low dosages. The considerable use of synthetic chemicals and their continuous discharge into the sewerage facilities have resulted in additional load that is poorly treated. They have been found to occur in drinking water supplies since conventional drinking water treatment cannot remove these contaminants.

EDCs are chemicals that tend to mimic or block the natural hormones, alter the hormone levels and thus affect the function controlled by hormones.
A wide range of chemicals are suspected to be EDCs as follows: [12]

- Synthetic and natural hormones
- Alkyl phenols (nonylphenol and octylphenol)
- Persistent organochlorines and organohalogens (PolyChlorinated Biphenyls (PCBs), Dioxins and Furans etc),
- Pesticides (Dichloro-diphenyl-trichloroethane (DDT), Tributyltin (TBT) etc)
- Heavy metals (cadmium, lead, mercury)
- Phytoestrogens (isoflavoids, lignans)

PPCP include a large number of chemical contaminants that can originate from human usage and excretion.

- Prescription and non-prescription drugs
- Detergents and cleansers
- Personal care products

Disinfectants are used to kill the harmful microorganisms, however, they are powerful oxidants that oxidize the organic matter and bromide naturally present in most source waters forming DBPs. [11]

- Trihalomethanes and 5 Haloacetic acids
- Bromate and Chlorite

In the case of unplanned indirect potable use, when the effluent is discharged into a water body, these contaminants undergo mixing, dilution with some physical and biological treatment within the water body before abstracted by the downstream drinking water facility. However, the prevalence of these newly emerging contaminants in the water bodies indicate either the natural assimilative capacity of the river is exhausted or the synthetic nature of the contaminants makes them intractable. The concern of these contaminants present in the drinking water would be higher for those cases where unplanned indirect potable reuse is practiced since no advanced treatment is rendered to remove these contaminants from the sewage facilities.

4.2 Planned indirect potable reuse and direct potable use

In the case of planned indirect potable reuse, the secondary/tertiary treated effluent from the sewage facility undergoes multiple barrier protection that prevents the trace organic contaminants entering the surface water body. Table 3 gives the details of the technology employed successfully in Namibia, Water factory 21, California and also Singapore. [6, 2] The Windhoek treatment facility sends the water directly to potable use facility without the intervening storage. The technology employed in 1968 will be unlikely to be employed again. It underwent four technology changes and upgrades since then, the most recent being in 2000, when an ultrafiltration (UF) membrane was installed (6). There is an obvious shift of technology leaning towards membrane filtration. During the last decade, several researchers in the west have been concentrating on evaluating the effectiveness of different treatment processes in removing the newly emerging organic contaminants like EDCs, PPCA (pharmacologically active components (PhACs) and personal care products (PCAs). The summary of treatment methodologies and their effectiveness as reviewed by Snyder *et.al*. is given in Table 4, [13] which indicates that the reverse osmosis process is excellent in removing all types of contaminants followed by ultrafiltration. Activated carbon is also excellent in removing EDCs but good to excellent in removing PhACs and PCPS.

Advanced oxidation processes show vast range of performance depending on the contaminant concerned. Therefore, a multiple barrier technique making use of activated carbon, ultrafiltration and reverse osmosis could potentially remove almost all the newly emerging contaminants from the tertiary treated wastewater effluent.

Table 3: Comparison of Technologies [6]

Windhoek (Namibia) 1968	Windhoek (Namibia) 2000	Water factory 21 1974	Singapore 2002
Secondary treatment followed by • Algae flotation • Foam fractionation • Chemical clarification • Sand filtration • Granulated activated carbon • Chlorination	Improved secondary treatment by: • Pre-ozonation (for Fe and Mn) • Dissolved air flotation • Sand filtration • Ozonation • Granulated activated carbon • Membrane filtration (UF) • Chlorination	Secondary treatment followed by: • High lime treatment • Clarification • Recarbonation • Sand filtration • Granulated activated carbon • Reverse osmosis • Chlorination	Secondary treatment followed by: • Membrane filtration (MF or UF) • Reverse osmosis • UV disinfection • Stability control • Chlorination
Reclaimed water flow : 4.8 ML/d Reclaimed water contribution: 4%	Reclaimed water flow : 21 ML/d Reclaimed water contribution: 25%	Reclaimed water flow : 200 ML/d Reclaimed water contribution: 10-45 %	Reclaimed water flow : 1% initially and increasing

Table 4: Unit Processes and operations used for EDCs and PPCPs removal [13]

Groups	Classification	AC	BAC	O_3/AOPs	UV	Cl_2/ClO_2	Coagulation/ flocculation	Softening/ metal oxides	NF	RO	Degradation (B/P/AS)
EDCs	Pesticides	E	E	L-E	E	P-E	P	G	G	E	E (P)
	Industrial chemicals	E	E	F-G	E	P	P-L	P-L	E	E	G-E (B)
	Steroids	E	E	E	E	E	P	P-L	G	E	L-E (B)
	Metals	G	G	P	P	P	F-G	F-G	G	E	P (B), E (AS)
	Inorganics	P-L	F	P	P	P	P	G	G	E	P-L
	Organometallics	G-E	G-E	L-E	F-G	P-F	P-L	P-L	G-E	E	L-E
PhACs	Antibiotics	F-G	E	L-E	F-G	P-G	P-L	P-L	E	E	E(B) G-E(P)
	Antidepressants	G-E	G-E	L-E	F-G	P-F	P-L	P-L	G-E	E	G-E
	Anti-inflammatory	E	G-E	E	E	P-F	P	P-L	G-E	E	E (B)
	Lipid regulators	E	E	E	F-G	P-F	P	P-L	G-E	E	P (B)
	X-ray contrast media	G-E	G-E	L-E	F-G	P-F	P-L	P-L	G-E	E	E (B and P)
	Psychiatric control	G-E	G-E	L-E	F-G	P-F	P-L	P-L	G-E	E	G-E
PCPS	Synthetic musks	G-E	G-E	L-E	E	P-F	P-L	P-L	G-E	E	E (B)
	Sunscreens	G-E	G-E	L-E	F-G	P-F	P-L	P-L	G-E	E	G-E
	Antimicrobials	G-E	G-E	L-E	F-G	P-F	P-L	P-L	G-E	E	F (P)
	Surfactants/ detergents	E	E	F-G	F-G	P	P-L	P-L	E	E	L-E (B)

B – Biodegradation, P – photodegradation(solar), E -excellent (>90%); G-good (70-90%); F-Fair (40-70%); L-low (20-40%); P- poor (<20%); AC – Activated Carbon; BAC- Biological Activated Carbon; O3/AOPs- Ozone and Advanced Oxidation Processes; UV – Ultraviolet Disinfection; NF – Nanofiltration; RO- Reverse Osmosis, AS- Activated Sludge

Singapore NEWater conducted a comprehensive set of physical, chemical and microbiological tests in each of the processes for over two years, and concluded that NEWater is considered to be safe for potable use. [3] The quality consistently met the latest requirements of the U.S. Environmental protection agency's national primary and secondary drinking water standards and world health organization's drinking water quality guidelines.[3] A complete two-year chronic toxicity and carcinogenic study were conducted on the recycled water in Denver and the existing drinking water supply, with no adverse health effects detected. Reproductive studies on the recycled water and the existing drinking water supply detected no adverse health effects from either supply. [2] Toowoomba's proposed plant will use the treatment system similar to that of Singapore's. The results of the comprehensive sampling and monitoring program and health effects study conducted in Singapore and Denver would reinforce the council's initiatives to go on with the plan to augment the potable water supply from the reclaimed water from Wetalla wastewater treatment plant.

5 FUTURE CHALLENGES TO STAKEHOLDERS IN PIPR IN TOOWOOMBA

While the wastewater utilities persevere to treat and remove the contaminants from the wastewater effluent, the questions posed by many stakeholders are:

- Do the wastewater utilities have to take the sole responsibility for cleaning up the contaminants?
- Who else could be made countable for protecting the water resources?
- Where do these contaminants come from?
- How can the input of these synthetic chemical contaminants be minimized so that the environment can be chemical free?

Looking at Figure 5, main users of the water are the domestic sector, who consume 70.9% of water followed by commercials (16%) (http://www.toowoombawater.com.au/resources-and-forms/doc_details-47.html). The largest contributors to the sewer are, therefore, households followed by commercial with minimal industrial activities. While trade and industrial wastes are regulated, the wastes from households are not. The characteristics of the wastewater discharged into the sewer from households depend on the cumulative effect of the source water quality and then the additions of the chemicals in the households. When the potable water is used for everyday household activities, large quantities of detergents, cleansing agents, personal care and pharmaceutical products find their way into the sewer. Historically, potential detergent contamination of the environment followed when soap-based detergents changed to synthetic ones using varieties of chemicals. [14]

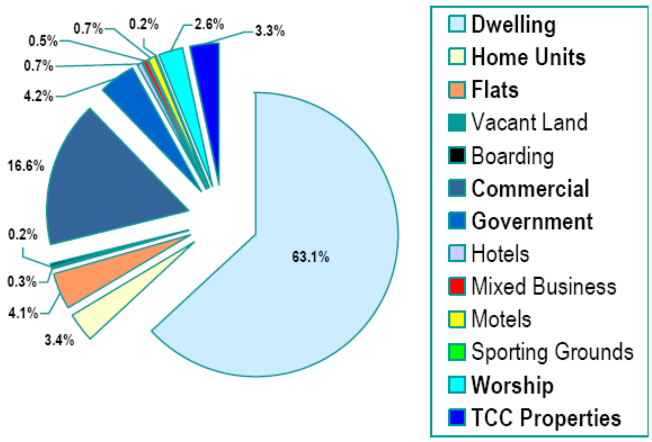

Figure 5 Water usages by sector
(Source: http://www.toowoombawater.com.au/resources-and-forms/doc_details-47.html)

Patterson highlighted the importance of a resident's role in minimizing nitrogen, phosphorus and salt in domestic wastewater and states that reuse initiatives start from the supermarkets. [15] He identified "many of the chemicals in the kitchen are poorly labelled and often give no indication as to the chemical constituents they contain. For example, a general anti-bacterial cleaner Pine-O-Clean state that its active ingredient is benzalkonium chloride 0.1%w/w that means 999 ml of each litre of Pine-O-Clean is a mixture of undisclosed chemicals. What is the effect of these undisclosed chemicals on persons or the wastewater treatment systems?" So he concluded that it is not possible for even an environmentally conscious resident to remain well informed about the chemicals that are in general use around the home and therefore, the impact on the septic tanks' contents almost impossible to predict. The study on the chemical characterization of the substances in the households revealed there were 900 different substances found to be potentially present in the greywater from the product information available in the list of common household and personal care products, among which 200 of them were identified as organic compounds that are foreign to microorganisms.[17] While pharmaceutical drugs are essential for well-being, a survey conducted in the USA reveals that the vast majority of the people disposed of unneeded medications via municipal sewage facilities (as cited in [16]). Is a safe system of disposal for outdated medicine available in Toowoomba? How are the other leftover, unused and outdated chemicals from households disposed? Are the people aware of the method of disposal? In light of reuse of reclaimed water, therefore, the challenges we face can be classified into two broad categories, one contaminant removal in the treatment plant and the other source minimization of these contaminants. The wastewater engineers and researchers need to:

- Conduct a complete sampling and monitoring studies of the contaminants
- Conduct a comprehensive inventory of the chemical input into the catchment from sources such as households, trades, industries and agriculture and evaluate their effects on biological processes in wastewater treatment and environment
- Investigate cleaner production of essential household products with minimum raw materials

Manufacturers introduce new products to the markets every day. They need to be encouraged to engage in cleaner production. For example, significant reduction of salt input into the sewer could be achieved by eliminating the usage of bulk agents in the production of detergents. Policies on mandatory labeling and life cycle assessment for the newly introduced products should be implemented on the manufacturers so that new chemicals will be evaluated for their environmental effects.

Communities need to be involved and educated by well-informed professionals on the selection and usage of common household products which are ecologically safe to minimize the environmental impacts for sustainable water resources management.

6 CONCLUSIONS

Fresh water resources are becoming very scarce, which have compelled utilities all over the world to consider reclaimed water as a resource than as a waste for sustainable water management. The innovative technologies with multiple barriers have made it possible to augment the water supplies with reclaimed water by removing the contaminants. Considering the numerous unplanned potable reuse in practice in the world and consequent concerns regarding the occurrence and prevalence of newly emerging contaminants in the surface water, most of the wastewater utilities will eventually have to upgrade the wastewater treatment plants. The initiatives by the Toowoomba City council for planned potable reuse is the last resort available for the inland community, and employ the innovative technologies to remove these contaminants. In light of this new initiative, this paper reviewed successful reclamation practices in the world, and discussed how stakeholders can contribute to continued sustainable supply of these water resources.

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