Technological developments and innovations in

Water reuse

A background paper prepared by IWA for the UN-Water Task Force consultation on the Sustainable Development Goal for Water

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IWA Specialist Group on Water Reuse

Key messages

- Millions of tons of valuable resources (water, nutrients and organic matter) are wasted every year in the form of wastewater causing widespread pollution in water bodies.
- Recovering these resources for productive sectors (crop production, aquaculture, agro-forestry,industry *etc*) offers multiple opportunities for all: the sectors themselves, the inhabitants of cities and the environment.
- Technological advances enable new possibilities for wastewater management that enable energy and resource recovery and safe reuse.
- Examples of water reuse and resource recovery provide demonstrations of innovative solutions that provide commercially-viable solutions at scale.

Preface

Focusing on all residuals from different forms of sanitation system as well as other types of wastewater and sludge from commercial, industrial and agricultural activities; this week's topic of the global consultation on the proposed Sustainable Development Goal on Water focuses on the opportunities for water reuse and the benefits that these practices bring from perspectives of the environmental protection, natural resource management, urban water cycle management, climate change mitigation and sustainable socio-economic development.

The discussion is co-organized by UN-Habitat, AquaFed, UNEP, International Water Association and OECD. The stream aims to facilitate discussions on key priority issues for the inclusion of wastewater management in the future development agenda. The discussions will unpack experiences from the present MDG and focus on options and opportunities in wastewater management as an untapped resource and important contributor to public health. The Sub-Consultation on Wastewater Management and Water Quality takes place through discussions on five specific themes:

Week 1: Wastewater in an urbanizing world
Week 2: Impact of wastewater on oceans-nitrogen & phosphorous challenge
Week 3: Wastewater reuse – development and innovation
Week 4: Collecting and treating urban water after use
Week 5: Economic opportunities in wastewater

This background paper prepared by the International Water Association for UN-Water sub-consultation on Sustainable Development Goal for Week 3 draws the international community's attention to the opportunities for reuse of resources associated with different types of wastewater. The document is based upon a number of sources including the background paper submitted by the Japan Sewage Works Association for the Target on Wastewater Reuse for the Priority for Action on Integrated Sanitation at the World Water Forum in March 2012 and a document prepared for a discussion workshop on the topic of "Integrated Approaches to Sanitation" supported by UNESCO-IHP and organized by IWA at the IWA Development Congress in Kuala Lumpur in November 2011.

Contents

1. Introduction

This paper adopts the definition of wastewater as defined by UNEP/UN-Habitat's *Sick Water?* report, which includes domestic, commercial and industrial effluents, and all types of residual wastes (including different types of sludge) from sanitation and wastewater treatment systems that are hazardous to the aquatic environment when poorly managed. There are a wide variety of resources contained in wastewater that may, depending on the location and the demand, prove to be economically viable to recover and reuse. As well as water, these include nutrients (Nitrogen, Phosphorus and micro-nutrients such as Potassium) and large amounts of energy bound up in the carbonaceous waste, which otherwise contribute to depleted oxygen levels in aquatic systems that impact on biodiversity and productivity.

In urban areas, demand for water has been increasing steadily, owing to population growth, industrial development, and expansion of irrigated peri-urban agriculture. The overall demand for food is also rising which creates an increasing demand for fertilizer to support farming. Population growth is expected to be particularly large in urban areas of developing nations (see Figure 1).

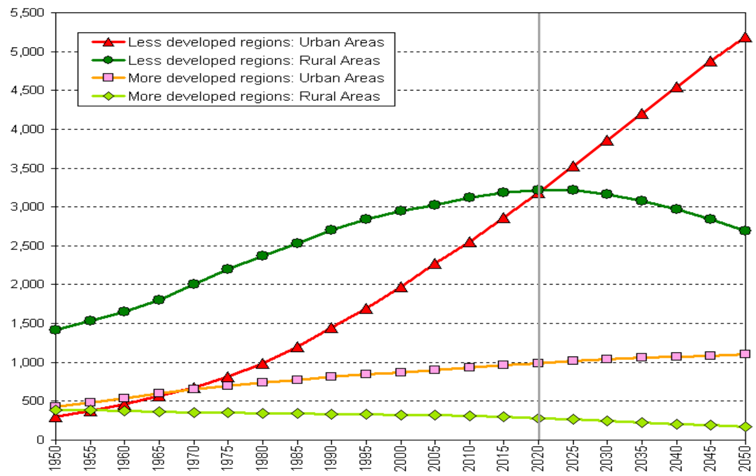

Figure 1 : Urban and rural population growth (in millions)[1]

The following sections discuss the issues in relation to the three main categories of resources associated with *wastewater: water, nutrients and energy.*

[1] - World Urbanization Prospects, 2009 Revision

1.1 Water resources

Water-related problems are increasingly recognized as one of the most immediate and serious environmental threats to humankind. Water use has more than tripled globally since 1950 and, according to the UNEP, one third of the World's population live in countries suffering from moderate-to-high water stress. In these areas, water consumption is more than 10% of renewable freshwater resources.

As shown in Figure 1, many countries in Africa and Asia have very low or catastrophically low water availability[2].

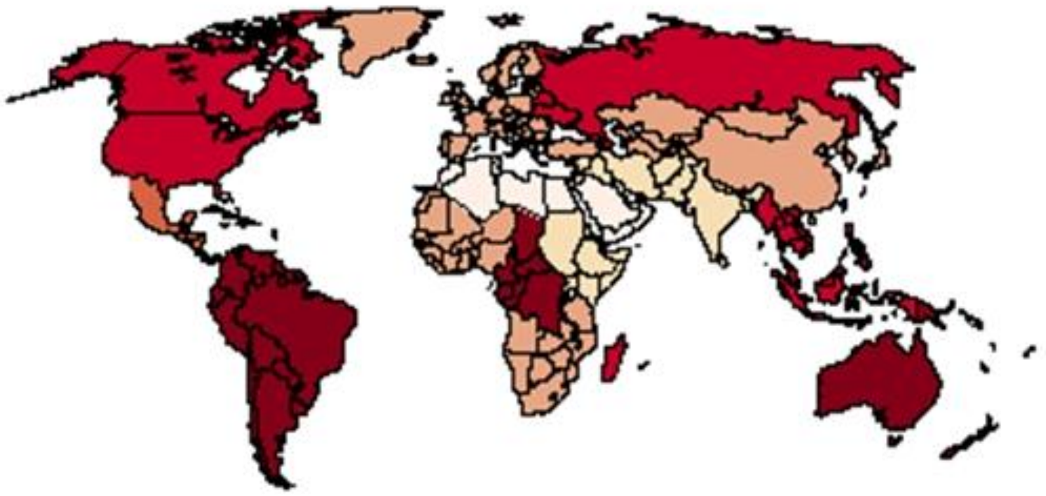

Figure 1: Water availability in 2000(Measured in terms of 1000m^3 per cap/year)

Poor water management is accelerating the depletion of surface water and groundwater resources. In urban areas, demand for water has been increasing steadily, owing to population growth, industrial development, and expansion of irrigated peri-urban agriculture. At the same time, water quality has been degraded by domestic and industrial pollution sources as well as non-point sources. In some places, water is withdrawn from the water resources, which become polluted owing to a lack of sanitation infrastructure and services. Over-pumping of groundwater has also compounded water quality degradation caused by salts, pesticides, naturally occurring arsenic, and other pollutants.

Many areas with adequate water resources and growing urban populations have experienced increased water consumption, both on a per capita and total basis. Meeting such a growing demand often requires the additional development of large-scale water resources and associated infrastructure. By meeting some of the water demand through water reuse and efficiency improvements, additional infrastructure requirements and the resulting financial and environmental impacts can be reduced or, in some cases, eliminated altogether.

[2] UNEP, 2002

1.2 Nutrient resources

Conventional sanitation systems dispose of around 50 million tons of fertilizer into the environment, with an equivalent market value of around $15 billion[3]. At the same time, unsustainable agricultural practices lead to soil degradation and depletion of nutrients in the soil. Mineral fertilizers on which modern agriculture practices depend upon are new-renewable resources. It is estimated that there will not be sufficient phosphorus supplies from mining to meet agricultural demand within 30 to 40 years and from a global perspective, 38% is of agricultural land has already been degraded since the end of World Water II[4].

Wastewater streams also contain valuable nutrients, such as nitrogen and phosphorous. The fertilizing equivalent of excreta is nearly sufficient for a person to grow its own food[5]. Each day, every person on the planet excretes approximately 10-12 g of Nitrogen, 2 g of Phosphorus and 3 g of Potassium. Most of the organic matter is contained in the faeces, while most of the nitrogen (70 to 80 per cent) and potassium are contained in urine[6]. The organic matter contained in faeces and organic wastes also plays an important role in soil fertility improvement, and the use of nutrient-rich water for agriculture and landscaping may lead to a reduction or elimination of fertilizer applications.

1.2 Energy resources and climate change

Due to increased numbers of people using increasing amounts of electricity, world energy consumption is expected to double by 2035 relative to 1998, and triple by 2055[7]. Drinking water and wastewater plants are typically the largest energy consumers of municipal governments (up 30-40 per cent) in the US[8]. Electricity consumption of the water and wastewater sectors is predicted to grow globally by 33 per cent based on 2002 statistics in 2025[9]. According to the US Environmental Protection Agency (EPA), water and wastewater treatment and conveyance account for up to 4 per cent of the energy used in the United States[10], adding over 45 million tons of greenhouse gases annually[11].

In England and Wales, almost 1 per cent of the average daily electricity consumption is used to treat wastewater[12]. Aerobic wastewater treatments are particularly energy demanding and emit nitrogen into the atmosphere, which is derived from chemical fertilizers which required tremendous amount of energy to capture nitrogen from the atmosphere as part of the fertilizer production process. It is predicted that wastewater-related emissions of methane and nitrous oxide could rise by 50 per cent and 25 per cent respectively between 1990 and 2020[13].

[3] Werner (2004); Rosemarin et al (2008); Rosemarin et al. (2011)
[4] Scherr (1999)
[5] Drangert (1998).
[6] Strauss (2000)
[7] Barry (2007)
[8] US-EPA (2011)
[9] James (2002)
[10] Brown and Caldwell (2011)
[11] US-EPA (2011)
[12] Parliamentary Office of Science and Technology (2007)
[13] Corcoran et al. (2010)

2. Technological developments and innovation in water reuse and resource recovery

Faced with these challenges, water reuse for both environmental and economic reasons. Waater reuse has a long history of applications, primarily in agriculture, but additional areas of applications, including industrial, household, and urban, are becoming more prevalent[14].[15] With adequate treatment, wastewater can meet specific needs and purposes, such as toilet flushing, cooling water, and other applications. The reuse of treated wastewater is particularly attractive in arid climates, areas facing demand growth and those under water stress conditions. Recycled water can also serve as a more dependable water source, containing useful substances for some applications. The quantity and quality of available wastewater may be more consistent compared to freshwater, as droughts and other climatic conditions tend to have a less pronounced effect on wastewater generation.

By reusing treated wastewater for these applications, more freshwater can be allocated for uses that require higher quality, such as for drinking, thereby contributing to more sustainable resource utilization. Thus, water reuse reduces water consumption and treatment needs, with associated cost savings. In many applications, reusing purified wastewater is less costly than using freshwater, with savings stemming from more efficient water consumption and a reduced volume of additional wastewater treatment, as well as associated compliance cost savings (Asano et al. 2007; Lazarova et al., 2013). The infrastructure requirements for advanced water and wastewater treatment may also be reduced.

Innovation involves the uptake of products at scale in the commercial market place. This may involve may involve new scientific advances but often involves the adoption and replication of existing reuse approaches, which are already proven in other locations. Although a specific solution may be seen to be a tried and tested solution in one location, its application in another context/country may be innovative. Innovation should therefore not to be confused with invention and is just as much to do with development of appropriate management and institutional arrangements as technological advancement.

However, in the past decade, practical applications of a variety of new wastewater treatment technologies have led to new ways of managing urban water systems and water resources[16]. New treatment regimes involving the integration of urban-water and waste-management systems promise to dramatically improve the sustainability of our water resources. In particular, membrane technologies for removing particulate matter (micro- and ultra-filtration) and dissolved substances (nanofiltration and RO) are increasingly being used. When

[14] Asano, T., F. L. Burton, H. Leverenz, R. Tsuchihashi, and G. Tchobanoglous (2007) Water Reuse: Issues, Technologies, and Applications, McGraw-Hill, New York.

[15] Lazarova et al. (2013) Milestones in Water Reuse: The Best Success Stories. IWA Publishing, London, UK.

[16] Daigger (2003)

particle removal membranes are coupled with biological systems, they can create membrane bioreactor (MBR) processes, which are fast becoming an essential water reclamation process (Judd, 2006[17], Daigger et al., 2005; DiGiano et al., 2004). Advanced oxidation processes include combinations of ozone, Ultraviolet (UV) light, and hydrogen peroxide to create the highly reactive hydroxyl radical (OH). In addition, activated carbon is being widely used for water reclamation applications[18].

2.1 Water reuse for food production

At a global scale, agriculture is the largest user of water. In 2000, it received 67% of total water withdrawal and accounted for 86% of consumption[19]. In Africa and Asia, an estimated 85 - 90% of all the freshwater use is for agriculture. By 2025, agriculture is expected to increase its water requirements by 1.2 times[20]. Large-scale irrigation projects have accelerated the disappearance of water bodies, such as the Aral Sea, the Iraqi Marshlands, and Lake Chad in West Africa. Thus, agricultural irrigation is crucial for improving the quality and quantity of production and more efficient use of agricultural water through wastewater reuse is essential for sustainable water management.

The traditional practice of applying wastewater containing human excreta to the agricultural land has maintained soil fertility in many countries of Eastern Asia and the Western Pacific for over 4,000 years and remains the only agricultural use option in areas without sewerage facilities[21] . The reuse of pre-treated domestic wastewater or sewage sludge for irrigation and fertilisation of energy crops in short rotation plantations is a new approach, which aims at using the nutrients contained in waste residues for an enhanced biomass growth.

According to WHO (1989, 2006), the potential benefits of wastewater reuse for agriculture include the following:

- Conservation and more rational allocation of freshwater resources, particularly in areas under water stress;
- Avoidance of surface water pollution;
- Reduced requirements for artificial fertilizers and associated reduction in industrial discharge and energy expenditure;
- Soil conservation through humus build-up and prevention of land erosion;
- Contribution to better nutrition and food security for many households

[17] Judd S. (2006) The MBR Book, Principles and Applications of Membrane Bioreactors in Water and Wastewater Treatment. Elsevier, Oxford, UK.

[18] Daigger (2012)

[19] UNESCO (2000)

[20] Shiklomanov (1999)

[21] WHO (1989)

2.2 *Wastewater reuse for industry*

Industrial water use accounts for approximately 20% of global freshwater withdrawals. Power generation constitutes a large share of this water usage, with up to 70% of total industrial water used for hydropower, nuclear, and thermal power generation, and 30 to 40% used for other, non-power generation processes. Industrial water reuse therefore has the potential for significant applications, as industrial water demand is expected to increase by 1.5 times by 2025[22].

Technological advancements now make it possible to treat wastewater for variety of industrial reuse (e.g. petroleum industry, paper industry, food industry, semiconductor facilities, etc.). Most industries in even developing countries are already moving towards water reuse and source separation and treatment of separated effluents is gaining more attention. Water reuse potential in different industries depends on waste volume, concentration and characteristics, best available treatment technologies, operation and maintenance costs, availability of raw water, and effluent standards. Radical changes in industrial water reuse have to take into consideration rapidly depleting resources, environmental degradation, public attitude and health risks to workers and consumers[23].

Water reuse and recycling for industrial applications have many potential applications, ranging from simple housekeeping options to advanced technology implementation. Water reuse for industry can be implemented through the reuse of municipal wastewater in industrial processes, internal recycling and cascading use of industrial process water, and non-industrial reuse of industrial plant effluent, as summarized below. In addition, industrial water reuse has the potential reduction in production costs from the recovery of raw materials in the wastewater and reduced water usage, heat recovery and potential reduction in costs associated with wastewater treatment and discharge.

Table 1: Types and examples of industrial water reuse

Types of water reuse	Examples
Reuse of municipal wastewater	Cooling tower make-up water Once-through cooling Process applications
Internal recycling and cascading use of process water	Cooling tower make-up water Once-through cooling and its reuse Laundry reuse (water, heat, and detergent recovery) Reuse of rinse water Cleaning of premises
Non-industrial use of effluent	Heating water for pools and spas Agricultural applications

[22] Shiklomanov (1999)

[23] The Potential For Industrial Wastewater Reuse - Visvanathan, C and Asano, T.

Cooling systems generally consume 20 to 50% of a facility's water usage, and also present a significant potential for reuse. Cooling systems remove heat from air-conditioning systems, power stations, oil refining, and other various industrial processes. Many facilities operate cooling towers, in which warm water is circulated and cooled continuously. Water (commonly referred to as make-up water) is added to replace evaporative loss and pollutant discharge. Some facilities also use once-through water to cool heat-generating equipment and discharge water after heat transfer. In both systems, adequately treated wastewater can be used as cooling water or make-up water, with or without mixing with tap water. Once-through cooling systems also present additional opportunities for water reuse, such as connection to a recirculating cooling system to reuse water, and cascading use of cooling water in other applications.

2.3 Urban applications

In urban areas, the potential for water reuse is high; contributing to reduced water consumption and reducing the pollutant load discharged into the environment (Asano et al., 2007; Lazarova et al., 2013). A large percentage of water used for urban activities does not need quality as high as that of drinking water. Dual distribution systems (one for drinking water and the other for reclaimed water) have been utilized widely in various countries, especially in highly concentrated cities of the developed countries. This system makes treated wastewater usable for various urban activities as an alternative water source in the area, and contributes to the conservation of limited water resources. In most cases, secondarily treated domestic wastewater followed by sand filtration and disinfection is used for non-potable purposes, such as toilet flushing in business or commercial premises, car washing, garden watering, park or other open space planting, and firefighting[24].

Treated wastewater can also be reused to enhance the urban environment, e.g for augmentation of natural/artificial streams, fountains and ponds. The key benefit for environmental enhancement is the increased availability and quality of water sources, which provide public benefits such as aesthetic enjoyment and support ecosystem recovery (Asano et al., 2007; Lazarova et al., 2013). The restoration of streams or ponds with reclaimed water has great significance for creating 'ecological corridors' in urban areas; contributing to the revival of fish and other aquatic life and creating comfortable urban spaces and scenery.

The benefits of water reuse for urban applications include the following:

- High volume of wastewater generation, and a large number of potential applications and volume for water reuse, which may benefit from the economy of scale
- Reduction in the wastewater volume to be treated by municipal wastewater treatment plants, which are over-extended and in need of expansion in many cities in developing countries.

[24] Japan Sewage Works Association (2005)

2.4 Groundwater recharge

Groundwater recharge has been used to prevent the decline in groundwater levels and to preserve the groundwater resource for future use. Direct injection is utilized when aquifers are deep or separated from the surface by an impermeable layer. The method requires advanced pretreatment of applied water, including sufficient disinfection to alleviate health concerns. Compared to conventional surface water storage, aquifer recharge has many advantages, such as negligible evaporation, little secondary contamination by animals, and no algal blooming. It is also less costly because no pipeline construction is required. Furthermore, it protects groundwater from saltwater intrusion by barrier formation in coastal regions, and controls or prevents land subsidence.

2.6 Energy production

Increased fuel costs, concern about climate change and the pressure to find better biosolids management options underline the increasing convergence between the sanitation and energy sectors. Integrated sanitation systems have a high potential, not only to reduce energy consumption but also to reuse energy in form of heat or to recover it in the form of fuel (e.g. pellets, biogas) or biomass (e.g. in short rotation plantations)[25]. Moreover, low-energy alternatives to conventional intensive wastewater plants (e.g. activated sludge) such as natural extensive systems (e.g. constructed wetlands) can be applied in an integrated sanitation approach.

Biogas generation is more effective for energy recovery. Anaerobic digestion for biogas generation is already applied in large-scale plants in many industrialised countries, using the sewage sludge at the „end of the pipe“. Anaerobic systems applied on high-strength effluents (sanitation products streams containing little water) are more efficient. Producing biogas from human and animal waste in decentralised systems is also a proven energy source, especially where the coverage with energy supply is low. This approach has been successfully implemented, even at national scale in India, Nepal and China where it has led to an economical gain due to the prevention of deforestation.

Dried sludge and faeces products can also be used directly as a fuel in the industrial sector. In Switzerland for instance, dried sludge from the WWTP of Bern is brought to the cement factories, which are sufficiently large to provide flue gas filters, which allow for incineration of this sludge, considered as a “special waste” by the Swiss legislation.

[25] Lazarova V., Choo K.H. and Cornel P. (2012) Water-Energy Interactions in Water Reuse. IWA Publishing, London, UK.

3. Have your say in the global consultation

During the week 28th January – 1st February, the sub-consultation on the topic of "Wastewater reuse - development, innovation" which forms part of a wider discussion about the post-2015 Development Goal on "Water" and the proposed target on "Wastewater management and water quality" will take place. This is an opportunity for you to contribute directly towards the formulation of the global target which will influence all of our different lines of work in the water sector for the next 15 years and beyond.

The outcome of the different discussions will be summarized into policy recommendations presented, first to a High-level Panel on Water Resource Management and Wastewater at the end of February and later to a High-Level Panel on Post-2015 Development at the end of March. The final outcome of the thematic Consultation will be presented by the Secretary-General to the UN General Assembly in September.

The questions that are put forward to the international community are:

1. What are the best and most appropriate uses for properly treated wastewater?
2. Would you consume products produced with reused water? If yes, what types of products and with what type of reused waters?
3. What are the main obstacles to implement and replicate water reuse practices and how to overcome these obstacles?
4. What examples of good practice in wastewater reuse at scale are you aware of?
5. How should we define international target for wastewater reuse and how to measure progress towards achieving this target?

Fifteen minutes of your time next week to submit your responses to one or more of these questions would demonstrate to political community that reuse and resource recovery is an important area that needs to be represented in the global discussion of the international sustainable development goal for water.

Joint the global debate and have your say on-line at : www.worldwewant2015.org/water/wastewater

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