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3Rs for Water Security in Asia and the Pacific

(Background Paper for Plenary Session 6 of the Programme)

Final Draft

This background paper has been prepared by Prof. C. Visvanathan, for the Sixth Regional 3R Forum in Asia and the Pacific. The views expressed herein are those of the author only and do not necessarily reflect the views of the United Nations.

3Rs for Water Security in Asia and the Pacific

(Final Report)

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ACRONYMS

3R	Reduce Reuse Recycle
ADB	Asian Development Bank
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
FAO	Food and Agriculture Organization
GAP	Ganga Action Plan
GRACE	Gravity Recovery and Climate Experiment
LPCD	Litres per Capita per Day
NWSI	National Water Security Index
PPP	Public Private Partnership
PUB	Public Water Utility (Singapore)
RO	Reverse Osmosis
SDGs	Sustainable Development Goals
SIDS	Small Islands Developing States
USEPA	United States Environmental Protection Agency
WDM	Water Demand Management
WELS	Water Efficiency Labelling Scheme
ZLD	Zero Liquid Discharge

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Summary

This background paper on "3Rs for Water Security in Asia and the Pacific" has been prepared to serve as a reference point for discussion at the Sixth Regional 3R Forum in Asia and the Pacific. The paper gives a detailed overview on water security definition, status, challenges, and 3R solutions utilizing alternative water resources such as municipal and industrial wastewater, rainwater, and storm water. With specific focus on Asia and the Pacific, this background paper discusses the potential opportunities of incorporating 3Rs as a response to water security, i.e., water use reduction (water demand management), and strengthen the importance of water resource management through reuse and recycling (closing the water loop by recirculating the treated wastewater for various reuse purposes at many sectors). The paper summarizes the important issues related to enabling policy, technology, finance, and water governance factors for the successful application of 3Rs in the context of water security in the region.

Water is at the core of human existence, livelihood, wellbeing, economic growth, and key to sustainable development. Food security, energy production, transportation, economic activities involving manufacturing and industrial processes, service sectors, human health and ecosystem functioning are dependent on the availability of adequate quantity and quality of water resources. The agricultural sector is by far the biggest user of freshwater, with a global level withdrawal of 70%, followed by 19% industrial and 11% municipal withdrawals. All economic activities in the world that depend on water have a combined market value of US$70.2 trillion - including US$2.8 trillion for the water-handling economy that involves direct management of water, US$720 billion for water-related equipment and services, and US$557.8 billion for water treatment and distribution[1].

The freshwater availability for consumption is less as compared to the earth's total water supply, and is unevenly distributed. Although Earth, also known as blue planet, is endowed with a total water volume of ~1.4 billion km^3, only 2.5% (~ 35 million km^3) of this total water volume is freshwater resources. Huge proportion of this limited available freshwater is locked up in glaciers and permanent snow cover, making it difficult to direct consumption. In fact, the actual total usable freshwater supply for ecosystems and humans is only ~ 200,000 km^3 of water, i.e., less than 1% of all the freshwater resources[2].

Freshwater availability is low but both demand and threats are enormous. With the unprecedented urban population growth, demand for freshwater is growing, water is become scarcer, and quality is depleting too. Asia and the Pacific region is a water-stressed region that faces many water challenges, including increasing water demand, relatively higher groundwater extraction, ecosystem degradation, and aquatic pollution load, limited coverage of sewerage networks and wastewater treatment systems, as well as extreme climatic events such as floods and droughts. According to the FAO statistics, by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity (<500 m^3/capita/year), and two-thirds of the world's population could be living under water stressed (<1700 m^3/capita/year) conditions[3]. Efficient management of water resources is therefore a priority concern in many Asia Pacific countries.

The UN defines Water security as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability." Similarly, the Asian Development Bank defines five key dimensions of national water security as; •Key Dimension 1: Household Water Security- is the cornerstone of water security, which addresses the access to piped water supply, and access to improved sanitation and hygiene; •Key Dimension 2: Economic Water Security- measures the productive use of water to sustain economic growth in the food production, industry, and energy sectors of the economy; •Key Dimension 3: Urban Water Security- measures the creation of better water management and services, wastewater treatment and drainage systems; •Key Dimension 4: Environmental Water Security- assesses the health of rivers and measures progress on restoring rivers and ecosystems to health on a national and regional scale; and •Key Dimension 5: Resilience to Water-Related Disasters- this dimension looks into water-related disaster risks, and the coping strategies and capacities.

Water security is challenged not only by freshwater depletion but also by the increasing volume of wastewater and the associated pollution issues. On the one hand, countries are dealing with limited freshwater resources, and on the other, struggling with untreated wastewater risking water quality, human and environmental health. It is estimated that up to 90% of all wastewater in developing countries is discharged untreated directly into local water bodies. 80% of Asia's rivers are in poor

[1] WssTP The European Water Platform, 2014. Water Innovation Europe 2014- 'Water in Europe: Green tape or Blue Gold?' Event Report – Key messages. wsstp.eu/files/2014/07/Final-Report_WIE2014.pdf
[2] http://www.unep.org/dewa/vitalwater
[3]http://www.unwater.org/statistics/statistics-detail/en/c/211807

health, only as little as 22% of wastewater discharge is treated in South Asia[4]. The burden of such damage to freshwater resources threatens annually up to US$ 1.75 trillion in ecosystem services, such as agricultural and fisheries production, and environmental and biodiversity benefits[5].

3Rs (reduce-reuse-recycle) in water sector can be the way forward to water security and developing circular water economy. Considering the finite freshwater on earth and growing wastewater problem, sustainable water management through application of reduce, reuse, recycle (3R) principles should be given due consideration in addressing the challenges of freshwater security. Application of effective strategies for water use reduction can address the water scarcity challenges through demand side management, while recycling and reclaiming alternative water sources such as rainwater, stormwater and treated domestic and industrial wastewater can augment the supply of water. Wastewater recycling and reuse becomes a potential solution to this looming water crisis, with wastewater also offering water, energy, and nutrient recovery opportunities, hence closing the loop of water use and wastewater discharge. This shift to a circular water economy will transform the linear economy (take-make-use-dispose) model into 'take-make-reuse-repair-refurbish-and-recycle' model by encouraging industries to include water component into their value chain and life cycle of a product design/production/ distribution and their end of life stages through recycle and a reuse cycle. The Asia Pacific region can therefore spearhead 3R concepts in water sector to achieve water security as it successfully promotes 3Rs for solid waste management in the region.

Enabling policy, technology, finance, and institution is required for making 3R principles achieve water security. Good water governance is an integral element of water security. Wastewater acts as both "problem" and a "resource." If reclaimed and reused, wastewater provides as alternative water resource as well as a green economy opportunity. The total global wastewater treatment market has a value of US$388 billion for the period of 2010-2016 with a European market share of 27.3%, preceded only by the East-Asia Pacific region, with a market share of 37.6%[6]." Water use charges, taxes, subsidies, soft loans, environmental service payments, and other instruments could be explored as part of innovative financing proposals, depending on the local socio-economic-political context. Wastewater reclaim and reuse needs to be economically and financially viable, and socially and culturally acceptable. A paradigm shift is now required in water security policies and plans, technology innovation, financing and multi-stakeholder engagement to emphasize that wastewater is seen as a resource. 3R guidelines for safe reuse of reclaimed wastewater should be included into local and national plans for water management. Most of the countries do have standards for drinking water and wastewater discharge, but lack wastewater reuse standards and guidelines. Similarly, there is hardly any formal institutional arrangement for handling wastewater reuse aspects. It has to be noticed that market for recycled materials, metals, and energy from solid waste has been a driver for successful 3R integration in solid waste sector. Similarly, the market for treated wastewater can be one precursor for private sector to venture into wastewater recycling and reuse business. Therefore, a complete package of enabling policy, institutional framework, and innovative financing is required for successful application of 3Rs in water sector.

Public acceptance is a critical component for successful implementation of treated wastewater reuse options. Usually there is social, cultural, economic and religious stigma attached to reuse of treated wastewater as 'rich man's excreta as poor man's drinking water.' This issue can however be addressed by popularizing the use of treated wastewater by distributing it equally to all strata of the society, not limited only to urban poor. Continuous awareness, education and campaign, and strict standards for the treated water quality can break such bottlenecks.

Water scarcity is the main driver for application of 3R principles, which offers a unique opportunity for bringing a shift towards water and wastewater management. However, for this, a holistic water management framework that addresses not only water supply, but also wastewater collection, treatment, and reclamation and reuse is essential. The Sixth Regional 3R Forum in Asia and the Pacific is therefore an excellent venue to explore innovative, effective, and smart solutions (policy, institution, technology, infrastructure, financing and partnerships) towards effective implementation of 3R in water sector.

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[4] Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

[5] Nakao, T. (2013). Leadership for Water Security in Asia and the Pacific. Statement by ADB President Takehiko Nakao on 20 May 2013 at the 2nd Asia-Pacific water Summit, Chiang Mai, Thailand. http://www.adb.org/news/speeches/leadership-water-security-asia-and-pacific

[6] WssTP The European Water Platform, 2014. Water Innovation Europe 2014- 'Water in Europe: Green tape or Blue Gold?' Event Report – Key messages. wsstp.eu/files/2014/07/Final-Report_WIE2014.pdf

1. Introduction

Water is a common thread that links all aspects of human development securing political, health, economic, personal, food, energy, and environmental sustainability. However, water is becoming a scare and competitive resource, hence posing tough challenges to the overall development goals. Despite the abundance of water resources on planet earth, what makes water a scare resource is a combination of many factors such as; erratic distribution and availability of freshwater resources in different geographical and geo-political regions, increasing global water demand from an expanding population growth, urbanization, growing economies, impacts of climate change on water resources, industrial pollution, and overall poor water management. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity (<500 m^3/capita/year), and two-thirds of the world's population could be living under water stressed (<1700 m^3/capita/year) conditions[7]. In 2030, 47% of world population will be living in areas of high water stress; most affected population will be the ones inhabiting developing countries, mainly in regions that are already experiencing water stress and in areas with limited access to safe drinking water and adequate sanitation facilities[8]. By 2050, global water demand is projected to increase to 55%, mainly due to growing demands from industrial and domestic activities[9].

The global demand for freshwater is soaring and the supply is becoming more uncertain. Expanding urban population growth coupled with industrialization, and extensive agricultural development are putting a great deal of stress on water resources, contributing to degradation of fresh water sources. Release of untreated sewage, industrial effluent and poor agricultural practices is adding a huge pollution load to the rivers. About 80 percent of pollution in Yamuna River in India is the result of discharge of raw sewage[10]. The river receives more than three billion liters of waste per day. Not only the freshwater resources like rivers and lakes, but also groundwater resources that satisfy basic daily water needs of 2.5 billion people globally, are also diminishing[11]. An estimated 20% of the world's aquifers being over-exploited[12], leading to serious consequences such as land subsidence and saltwater intrusion in coastal areas. Over-extraction of ground water often exceeding the natural recharge rate have caused ground subsidence and the salinization of freshwater resources, especially in Small Islands Developing States (SIDS). Such damage to freshwater resources threatens annually up to US$ 1.75 trillion in ecosystem services, such as agricultural and fisheries production, and environmental and biodiversity benefits[13].

All these staggering statistics on water lead to the same conclusion: that water is getting scarcer globally. However, the Asia and Pacific region suffers multiple water related challenges. Asia and the Pacific, on the one hand has the highest annual water withdrawal of all the world's regions, owing to its geographic size, large population and irrigation practices, and on the other, suffers water pollution due to lack of proper treatment of wastewater. In South Asia, as little as 22% of wastewater discharge is treated, and 80% of Asia's rivers are in poor health[14]. Access to a secure and clean supply of freshwater resources will be a common challenge across Asia in 2030, as the region is already bearing a great deal of stress on the region's water resources. Freshwater crisis in the region is attributed to degradation of fresh water sources due to expanding industrialization, urbanization, and extensive agricultural development. On top of it, cities in Asia and the Pacific, especially the island countries are at risk of climate related disasters such as typhoons, hurricanes, cyclones, and rising sea level making their freshwater resources more vulnerable. UN Water Statistics show that by 2050 the number of people vulnerable to flood disaster is expected to

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[7] http://www.unwater.org/statistics/statistics-detail/en/c/211807/ (Accessed on 4 May 2015)

[8]UNESCO. (2009). The 3rd Edition of the UN World Water Development Report (WWDR3). Water in a Changing World. United Nations Educational, Scientific, and Cultural Organization.

[9]WWAP. (2015a). The United Nations World Water Development Report 2015: Water for a Sustainable World. United Nations World Water Assessment Programme. Paris, UNESCO

[10] Narain, S. (2002). The Flush Toilet is Ecologically Mindless. Down to Earth February 28, 2002, p 34. Centre for Science and Environment (CSE)

[11]UNESCO. (2012). World's Groundwater Resources Are Suffering from Poor Governance. United Nations Educational, Scientific, and Cultural Organization Natural Sciences Sector News. Paris, UNESCO. http://www.unesco.org/new/en/natural-sciences/environment/water/single-view-fresh-water/news/worlds_groundwater_resources_are_suffering_from_poor_governance_experts_say/ (Accessed on 4 May 2015)

[12]Gleeson, T., Wada, Y., Bierkens, M.F.P. and van Beek, L.P.H. (2012). Water Balance of Global Aquifers Revealed by Groundwater Footprint. Nature, 488: 197-200, DOI: 10.1038/nature11295

[13]Nakao, T. (2013). Leadership for Water Security in Asia and the Pacific. Statement by ADB President Takehiko Nakao on 20 May 2013 at the 2nd Asia-Pacific water Summit, Chiang Mai, Thailand. http://www.adb.org/news/speeches/leadership-water-security-asia-and-pacific (Accessed on 4 June 2015)

[14]Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

increase to 2 billion. Similarly, climate change could force an additional 1.8 billion people to live in a water scarce environment by 2080[15].

Role of water security as a principal concern for sustainable development has been recognized in international forums like the Ministerial Declaration of the Second World Water Forum in The Hague, Netherlands in March 2000, and the outcome document of the 2012 UN Conference on Sustainable Development (Rio+20), 'The Future We Want.' Amidst growing concern over diminishing waters and increasing threats, there is a need for a holistic approach to address the crisis of freshwater resource management through putting values to alternative sources of water including treatment and reuse of wastewater. Some regional forums are into the realization that water reduction, reuse, and recycling (3R) can help conserve resources for future generation. The outcome of Ha Noi 3R Forum (2013) and Surabaya 3R Forum (2014), in particular, recognized the fact that 3R technology is important to manage and control pollution from wastewater. The Sixth Regional 3R Forum in Asia and the Pacific, under the theme of "*3R as an Economic Industry ~ Next Generation 3R Solutions for a Resource Efficient Society and Sustainable Tourism Development in Asia and the Pacific*" is expected to provide a unique opportunity to discuss various economic and employment opportunities in 3R areas keeping in mind the diverse socio-economic situation across the region.

On the backdrop of the Sixth Regional 3R Forum in Asia and the Pacific for facilitating a high-level policy dialogue to address the linkages of 3R with concepts such as Integrated Waste Management for innovative, effective and smart solutions towards effective implementation of Ha Noi 3R Declaration (2013-2023), this background paper entitled "3Rs for Water Security in Asia and the Pacific" is being prepared. This background paper thus presents a consolidated view of reduce, reuse and recycle principle for water and wastewater management and water security. The specific objectives include:

- Improve technical input to policy consultation/discussion in the Sixth Regional 3R Forum.
- Serve as an important guiding document to address global water crisis and water security through resource efficiency/3R measures and its implications for sustainable development.
- Provide a meaningful insight to water and freshwater nexus in the context of water security in Asia-Pacific, and its relevance for implementing post-2015 development agenda/Sustainable Development Goals (SDGs)

This background paper discusses the causes of Asia and Pacific's vulnerability to water security issues, and attempts to shed light on holistic solutions of 3Rs in water management for attaining water security in the region through wastewater reuse and recycling opportunities. The background paper details the status and availability of world's water resources in Section 2. Section 3 specifically discusses the status and challenges to water security in Asia and the Pacific. While section 4 responds to the region's water security challenges through integrated water resource management using 3R principles in making wastewater reuse as a favourable solution to water scarcity. Section 5 deals with the way forward in realization of water security in attaining SDGs. Section 6 concludes the background paper by identifying the need and scope for the 3R Forum for Asia and Pacific to take forward the 3R principles in water sector as successfully as it did for solid waste sector.

[15] http://www.unwater.org/statistics/statistics-detail/en/c/211650/

2. State of World's Freshwater Resources

2.1 Distribution of World's Freshwater Resources

"Water water everywhere and just a few drops to drink," this unfortunate reality may hit us soon, as water becomes a scarce resource. But, is water such a scare resource? Despite Earth, also known as the blue planet, being endowed with a total water volume of ~1.4 billion km^3, only 2.5% (~ 35 million km^3) of this total water volume is freshwater resources. About 68.9% of this limited freshwater is locked up in glaciers and permanent snow cover, making it difficult for direct consumption, 30.8% in groundwater, including soil moisture, swamp water and permafrost and only 0.3% of the freshwater is stored in lakes and rivers (**Figure 2.1**). Hence, the actual total usable freshwater supply for ecosystems and humans remain only ~ 200,000 km^3 of water, i.e., less than 1% of all freshwater resources[16].

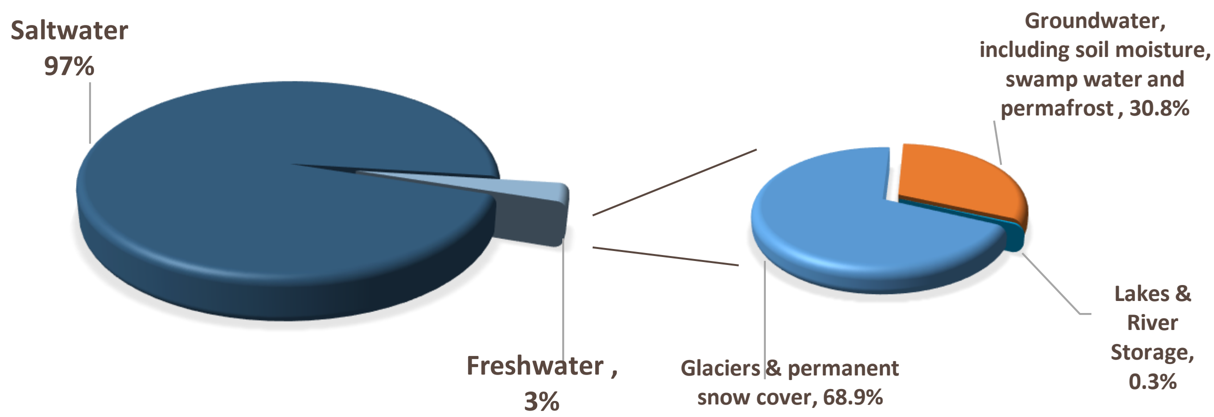

Figure 2-1: World's water resources

According to the United States Geological Survey (USGS), 96% of the world's frozen freshwater is at the South and North Poles, with the remaining 4% spread over 550,000 km^2 of glaciers and mountainous icecaps measuring about 180,000 km^3 [17]. **Figure 2.2** below summarizes the freshwater resource distribution across Continents. Groundwater is by far the most abundant and readily available source of freshwater, followed by lakes, reservoirs, rivers, and wetlands. An estimated 263 international river basins covering 45.3% (231,059,898 km^2), excluding Antarctica is estimated to have 2,115 km^3 of the total volume of water [18].

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[16] UNEP. (2008). Vital Water Graphics. United Nations Environment Programme http://www.unep.org/dewa/vitalwater

[17] UNEP. (1992). Glaciers and the Environment. UNEP /GEMS Environment Library No. 9, p8. Nairobi, United Nations Environment Programme
Untersteiner, F. (1975). Sea Ice and Ice sheets and their Role in Climatic Variations. Appendix 7 of the Physical Basis of Climate and Climate Modeling. GARP Publ. no. 16. Cited in Cires, U.R. (1978). Climatic Roles of Ice: A Contribution to the International Hydrological Programme (IHP) / Les rôles climatiques de la glace, Hydrological Sciences Bulletin, 23:3, 333-354, DOI: 10.1080/02626667809491808

[18] Groombridge, B., Jenkins, M. (1998). Freshwater Biodiversity: A Preliminary Global Assessment. World Conservation Monitoring Centre (UNEP-WCMC) - World Conservation Press, Cambridge, UK

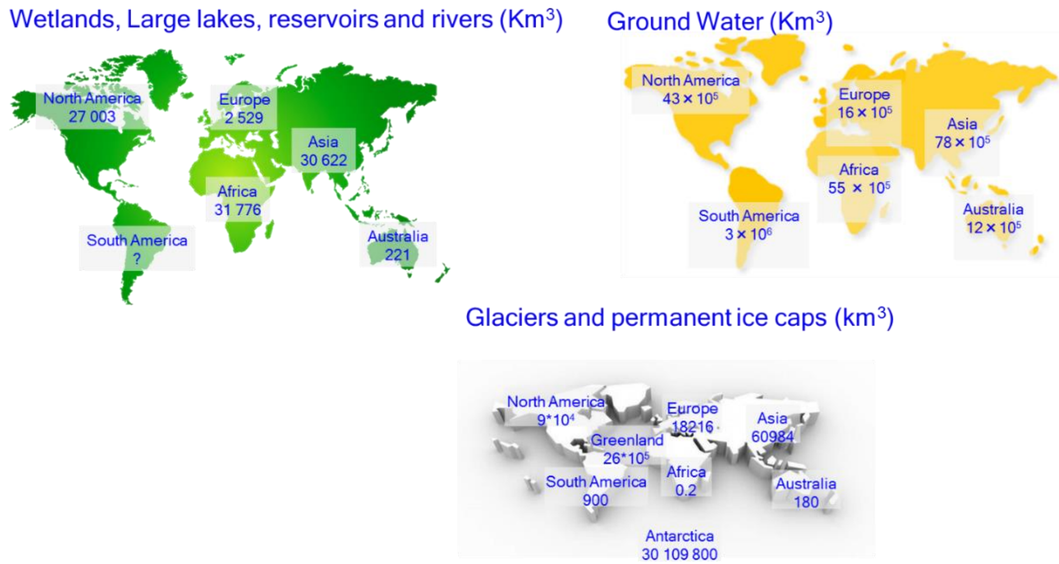

Figure 2-2: Freshwater resources-volume by continent (adapted from UNEP/GRID-ARENDAL)[19]

2.2 Freshwater Use by Sector

Water available on earth is removed by installing infrastructure for various consumption purposes. This removal of water is called water withdrawal. Water withdrawal is defined as "water diverted or withdrawn from a surface water or groundwater source." Consumptive water use is defined as "water use that permanently withdraws water from its source; water that is no longer available because it has evaporated, been transpired by plants, incorporated into products or crops, consumed by people or livestock, or otherwise removed from the immediate water environment"[20]. Not all quantity of water withdrawal is consumed. There is a significant loss of water during distribution and application. **Figure 2.3** shows the big gap in water withdrawal and consumption across the continents.

Annual global freshwater withdrawal has grown from 3,790 km^3 in 1995, to 4,430 km^3 in 2000, of which consumption accounted for 2,304 km^3 or 52% only. Annual global water withdrawal is expected to grow by about 10-12% every 10 years, reaching approximately 5,240 km^3 [21]. Annual freshwater withdrawals refer to total water withdrawals, not counting evaporation losses from storage basins.

There are mainly three types of water withdrawal: agricultural, municipal (including domestic), and industrial water withdrawal. The agricultural sector is by far the biggest user of freshwater, with a global level withdrawal of 70%, followed by 19% industrial and 11% municipal withdrawals[22]. **Figure 2.4** below depicts the trends in global water use by these three sectors.

[19] UNEP/GRID-ARENDAL (2008). Vital Water Graphics. An Overview of the State of the World's Fresh and Marine Waters - 2nd Edition http://www.unep.org/dewa/vitalwater/article32.html

[20] Vickers, A. (2001). Handbook of Water Use and Conservation. Amherst, MA: WaterPlow Press. ISBN 1-931579-07-5

[21] Shiklomanov, I. A. (1999). World Water Resources: Modern Assessment and Outlook for the 21st Century. (Summary of World Water Resources at the Beginning of the 21st Century, prepared in the framework of the IHP UNESCO). Federal Service of Russia for Hydrometeorology & Environment Monitoring, State Hydrological Institute, St. Petersburg

[22] UN FAO Aquastat database.

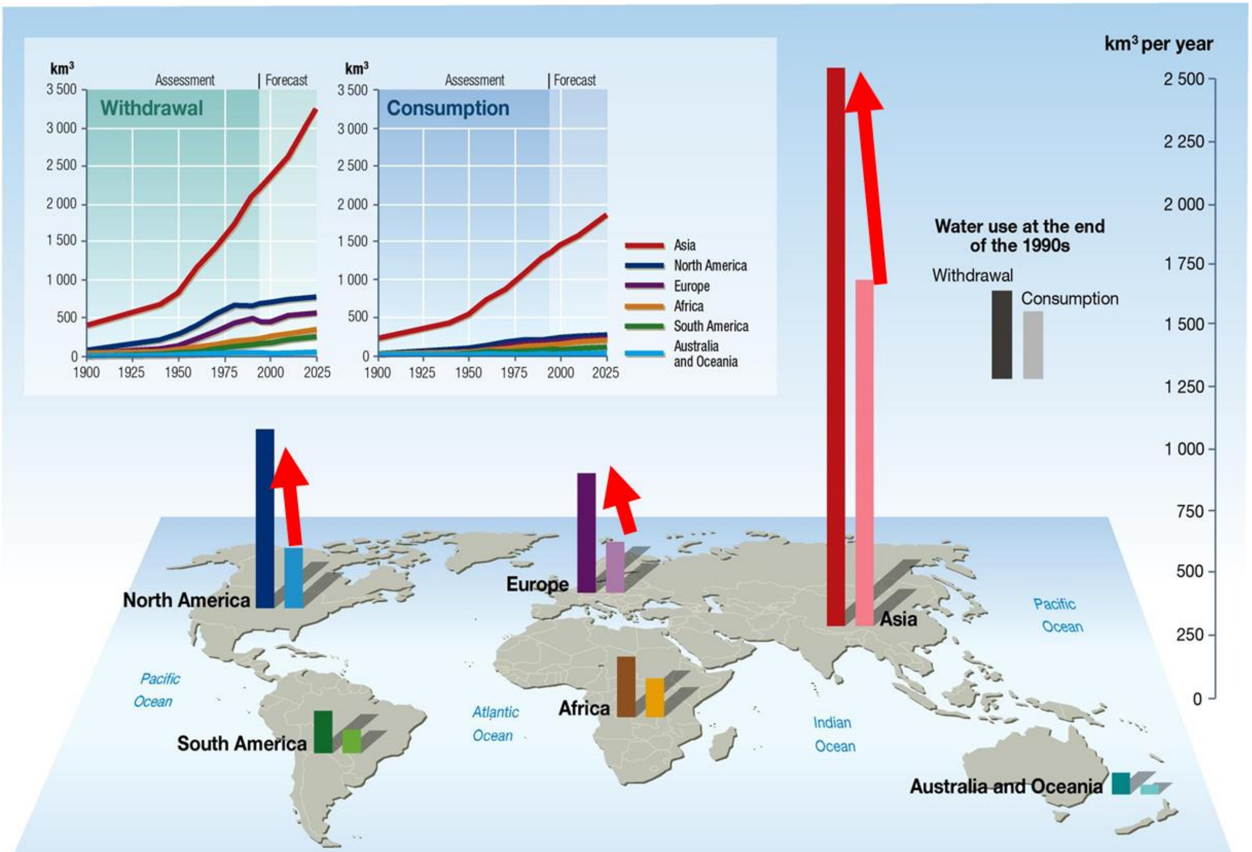

Figure 2-3: Water withdrawal and consumption: the big gap (adapted from UNEP/GRID-ARENDAL)[23]

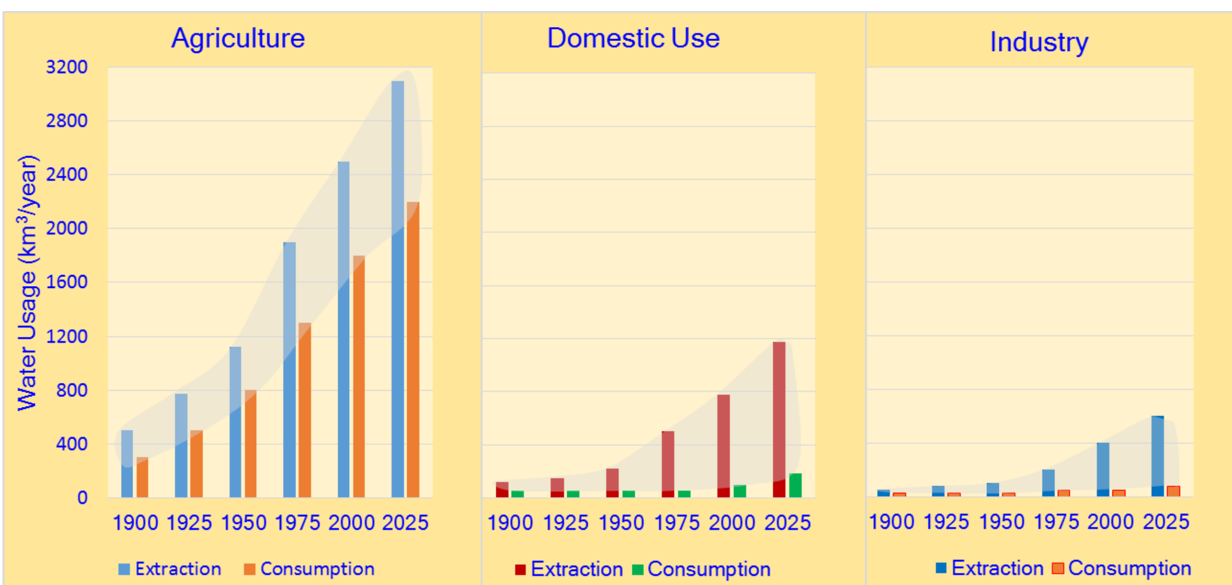

Figure 2-4: Trends in global water use by sector (adapted from UNEP/GRID-ARENDAL) [24]

[23] http://www.unep.org/dewa/vitalwater/jpg/0210-withdrawcons-cont-EN.jpg

[24] http://www.unep.org/dewa/vitalwater/article43.html

Agriculture is the most water intensive sector. Irrigation and livestock rearing are the major uses of water in agricultural sector. According to the FAO statistics, it is estimated that the daily drinking water requirement per person is only 2-4 L, but it takes between 2000 and 5000 L of water to create one person's daily food intake[25]. **Figure 2.5** gives a glimpse of extensive water requirement to grow and prepare some consumer food items.

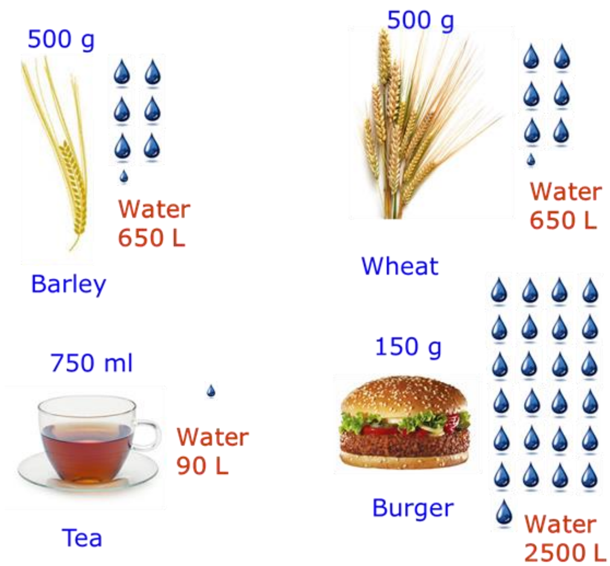

Figure 2-5: Water use in producing food items

The industrial sector uses freshwater stored in reservoirs and dams for hydropower generation and various industrial processes. Approximately 15–18 billion m^3 of freshwater resources are contaminated by fossil fuel production every year[26]. Domestic water use is related to the quantity of water available to populations in cities and towns. As of 2012, thermal power plants accounted for 66% of India's total power generation, which is responsible for approximately 88% of industrial water usage[27].

Groundwater reportedly provides drinking water to at least 50% of the global population and accounts for 43% of all water used for irrigation[28]. Worldwide, 2.5 billion people depend solely on groundwater resources to satisfy their basic daily water needs, and hundreds of millions of farmers rely on groundwater to sustain their livelihoods and contribute to the food security of so many others[29].Groundwater supplies are diminishing, with an estimated 20% of the world's aquifers currently over-exploited[30]. The recent data from National Aeronautics and Space Administration (NASA) shows than more than half of Earth's 37 largest aquifers are being depleted. Twenty-one of the world's 37 largest aquifers have passed their sustainability tipping points, according to gravitational data from the NASA's Gravity Recovery and Climate Experiment (GRACE) satellite system[31]. Unsustainable withdrawals of surface and groundwater can lead to serious consequences like land subsidence, saltwater intrusion in coastal areas, etc.

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[25] UNU. (2013). Water Security & the Global Water Agenda. A UN-Water Analytical Brief. United Nations University. ISBN 978-92-808-6038-2

[26] http://www.unwater.org/statistics/statistics-detail/en/c/211830/

[27] UNESCAP/K-water. (2015). Case Studies on Water and Green Growth in Asia and the Pacific. United Nations Economic and Social Commission for Asia and the Pacific and K-water

[28] http://www.groundwatergovernance.org/

[29] UNESCO. (2012). World's Groundwater Resources are Suffering from Poor Governance. United Nations Educational, Scientific, and Cultural Organization Natural Sciences Sector News. Paris, UNESCO. http://www.unesco.org/new/en/natural-sciences/environment/water/single-view-fresh-water/news/worlds_groundwater_resources_are_suffering_from_poor_governance_experts_say/

[30] Gleeson, T., Wada, Y., Bierkens, M.F.P. and van Beek, L.P.H. (2012). Water Balance of Global Aquifers Revealed by Groundwater Footprint. Nature, 488: 197-200, DOI: 10.1038/nature11295

[31] http://www.washingtonpost.com/blogs/wonkblog/wp/2015/06/16/new-nasa-studies-show-how-the-world-is-running-out-of-water/

2.3 Understanding Water Security

2.3.1 Definition and Key Dimensions of Water Security

Water security as defined by UN-Water (2013) is "the capacity of a population to safeguard *sustainable access to adequate quantities of acceptable quality water* for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability[32]." The UN definition of water security captures the dynamic dimensions of water and water-related issues and offers a holistic outlook for addressing water challenges.

The key aspects of water security

Many factors contribute to water security, ranging from biophysical to infrastructural, institutional, political, social, and financial. The UNU Analytical Brief presents a summary of core elements needed to achieve and maintain water security, synthesized from a broad range of sources, as follows:

- Access to safe and sufficient drinking water at an affordable cost in order to meet basic needs, including sanitation and hygiene, and safeguard health and levels of well-being;
- Protection of livelihoods, human rights, and cultural and recreational values;
- Preservation and protection of ecosystems in water allocation and management systems in order to maintain their ability to deliver and sustain functioning of essential ecosystem services;
- Water supplies for socio-economic development and activities (such as energy, transport, industry, tourism);
- Collection and treatment of used water to protect human life and the environment from pollution;
- Collaborative approaches to trans boundary water resources management within and between countries to promote freshwater sustainability and cooperation;
- The ability to cope with uncertainties and risks of water-related hazards, such as floods, droughts and pollution, among others; and,
- Good governance and accountability, and the due consideration of the interests of all stakeholders through: appropriate and effective legal regimes; transparent, participatory, and accountable institutions; properly planned, operated, and maintained infrastructure; and capacity development[33].

Though water availability and water scarcity are interrelated terms, sometimes they are not directly relatable. For instance, there may be natural water availability (resources); however, people may face water scarcity. Water scarcity can be defined as an imbalance between supply and demand of freshwater in a specified domain (country, region, catchment, river basin, etc.) as a result of a high rate of demand compared with available supply, under prevailing institutional arrangements (including price) and infrastructural conditions, as a result of which people lack sufficient water or else do not have access to safe water supplies. **Figure 2.6** below defines the level of water insecurity in a simpler numerical context.

If a country or region's annual renewable water supply is less than 1,000 m^3/person/year, then that country or region is considered as severely water scarce, and if its annual per capita renewable water is less than 1,700 cubic meters/ person/year then it is said to be water stressed country or region[34]. Basic water security situation is met when sufficient fresh water, of both quantity and quality, is available.

[32]UN-Water (2013). Analytical Brief on Water Security and the Global Water Agenda, 2013. http://www.unwater.org/topics/water-security/en/
[33]UNU. (2013). Water Security & the Global Water Agenda. A UN-Water Analytical Brief. United Nations University. ISBN 978-92-808-6038-2
[34]WBCSD (2005). Facts & Trends- Water. World Business Council for Sustainable Development ISBN 2-940240-70-1

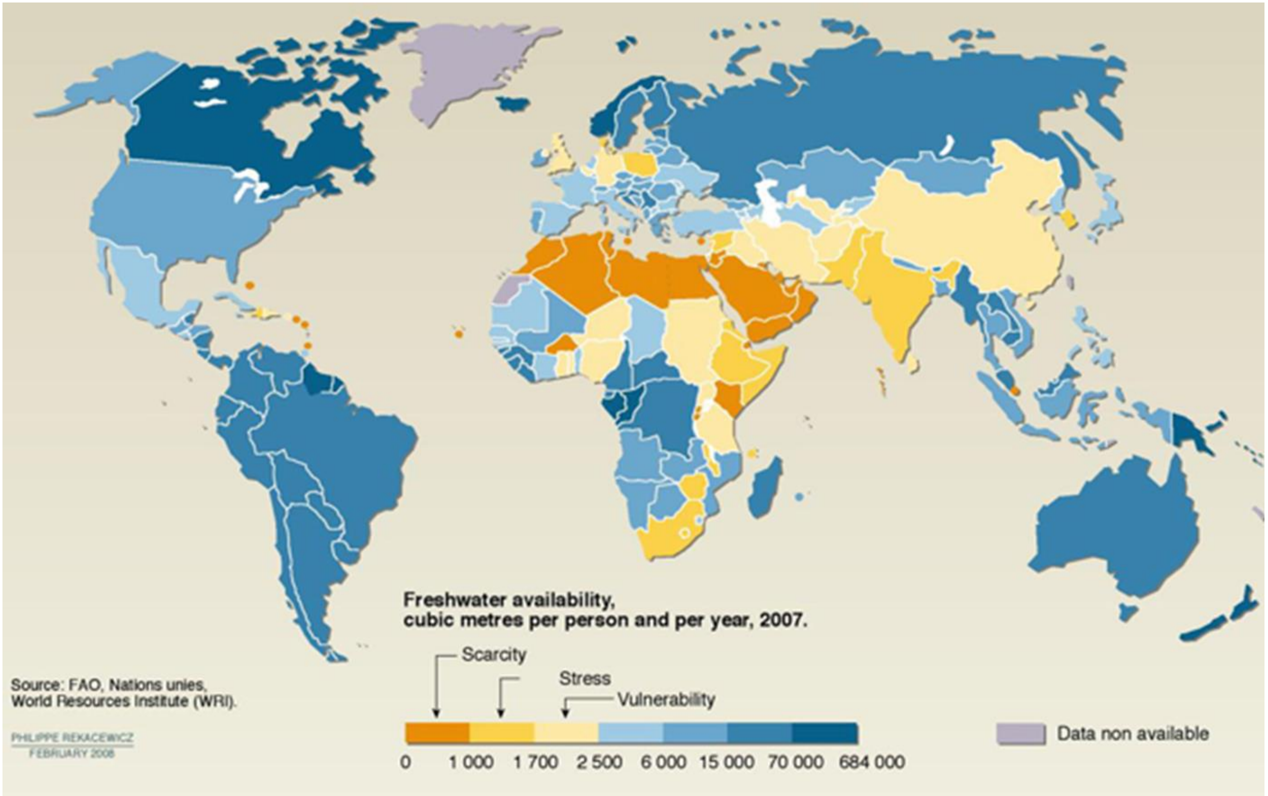

Figure 2-6: Total renewable water resources per capita (adapted from UNEP/GRID-ARENDAL)[35]

Water is central to the three dimensions of sustainable development, namely social, economic and environmental. The UN Analytical Brief 2015 illustrates the following three key dimensions to water security:

Poverty and social equity: Water is one of the very critical factors of human health and social dignity. Water security is therefore vital in realization of health and other livelihood opportunities. In 2012, 2.5 billion people did not have access to an improved sanitation facility.

Economic development: Water is an essential resource in the production and manufacturing of goods and services including food and energy. Hence, water security is critical element of a self-sustained economic development.

Environmental protection and ecosystem services: Adoption of 'ecosystem-based management' is key to ensuring long-term water sustainability. Replenishing the extracted freshwater resources back to the hydrological cycle through reuse of treated residential and industrial wastewater and agricultural run-off will sustain the capacity of ecosystem to provide water-related services for future[36].

Similarly, the Asian Water Development Outlook report also enlists five key dimensions of national water security[37]. These multiple dimensions of water security also include poverty reduction and governance as crosscutting perspectives.

[35] http://www.unep.org/dewa/vitalwater/article69.html

[36] WWAP. (2015a). The United Nations World Water Development Report 2015: Water for a Sustainable World. United Nations World Water Assessment Programme. Paris, UNESCO

[37] ADB. (2013). Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific. Mandaluyong City, Philippines, Asian Development Bank. ISBN: 978-92-9092-989-5 (PDF)

- **Key Dimension 1: Household Water Security**
  Household water security is the cornerstone of water security, which addresses access to piped water supply, and access to improved sanitation and hygiene.

- **Key Dimension 2: Economic Water Security**
  Economic water security measures the productive use of water to sustain economic growth in the food production, industry, and energy sectors of the economy.

- **Key Dimension 3: Urban Water Security**
  The urban water security indicators measure the creation of better water management and services, ***wastewater treatment*** and drainage systems.

- **Key Dimension 4: Environmental Water Security**
  The environmental water security indicator assesses the health of rivers and measures progress on restoring rivers and ecosystems to health on a national and regional scale.

- **Key Dimension 5: Resilience to Water-Related Disasters**
  This dimension looks into water-related disaster risks, and the coping strategies and capacities.

The Asian Development Bank (ADB) measures the national water security index (NWSI) using the above five key dimensions. The NSWI is classified in the scale of 1-5. The NWSI = 1 or Stage 1 refers the national water security situation to be *hazardous* and there is a large gap between the current state and the acceptable levels of water security, and at NWSI Stage 5, the country may be considered as water-secure.

2.3.2 Threats to Water Security

Freshwater resources, including rivers, lakes and wetlands, are degrading at a greater rate posing as a key threat to water security and related ecosystem services. Unsustainable development pathways are to be blamed for most of the water insecurity cases. Population growth, urbanization, migration, and industrialization, along with increases in production and consumption, have generated ever-increasing demands for freshwater resources. In addition, climate induced water disasters are also big threats to world's water resource.

Water security is a double-edged sword: one edge is the increasing water demand, and the other is the decreasing water quality. As water is extracted and used along the supply chain both quality and quantity is reduced. A significant quantity of the extracted water is lost during distribution and consumption, and quality of the returned water may be less than the quality when it was originally removed. This wastewater pollutes the already limited resource affecting the availability of usable water quality.

Unpredicted population growth affects access to freshwater. As the world's population is growing by about 80 million people per year and is predicted to reach 9.1 billion by 2050[38], demand for water is expected to increase in all sectors of production. By 2030, the world is projected to face a 40% global water deficit under the business-as usual (BAU) scenario. The number is further projected to increase by 55%, mainly due to growing demands from manufacturing, thermal electricity generation and domestic use. By 2050, agriculture will need to produce 60% more food globally, and 100% more in developing countries[39], as a result of which the water use in agricultural sector is going to increase sharply. Global water demand for the manufacturing industry is expected to increase by 400% from

[38] USCB. (2012). International Programs. World Population. United States Census Bureau. http://www.census.gov/population/international/data/worldpop/table_population.php

[39] Alexandratos, N., Bruinsma, J. (2012). World Agriculture towards 2030/2050: The 2012 Revision. ESA Working Paper No. 12-03. Rome, Food and Agriculture Organization of the United Nations (FAO)

2000 to 2050[40], much larger than any other sector. Most of this increase will be in emerging economies and developing countries, with implications for water supply, allocation, and quality.

Rapid Urbanization is another serious threat to water security. Rise in urban population is also expected to increase localized pressures on freshwater resource availability. In 2014, 3.9 billion people, or 54% of the global population, lived in cities, with 30% of all city dwellers residing in slums. By 2050, two-thirds of the global population will be living in cities[41]. The increase in the number of people without access to water and sanitation in urban areas is directly related to the rapid growth of urban slum population. The world's slum population is expected to reach 889 million by 2020[42].

Pollution and wastewater from domestic and industrial sector is aggravating the water scarcity by polluting already scarce freshwater resources. It is estimated that over 80% of the waste water worldwide is not collected or treated, and urban settlements are the major point source pollution. The number goes up to 90% of wastewater in developing countries being discharged untreated directly into rivers, lakes or the oceans, causing major environmental and health risks[43]. Prioritizing wastewater management is therefore necessary for water security.

Climate change and water-related disasters: The natural water balance, water availability, and demand for water are highly likely to be affected by climate change induced disasters, including rainfall variability, floods, droughts, risk to water and sanitation infrastructure because of extreme events and sea level rise. Such climate induced challenges to freshwater security is high in the island countries.

In conclusion, one can see that the demand for water from all four main sources, namely, agriculture, production of energy, industrial uses, and human consumption are increasing dramatically, at the same time freshwater resources are threatened with water pollution and climatic hazards. It is therefore very unlikely that this ever-increasing demand for water will be met unless water security issue is prioritized through better management of water resources and wastewater.

2.3.3 Water Security and Sustainable Development

Good management of water resources is a key sign of prosperity, agriculture and food security, good health and hygiene. Such interlinkages of water with development aspects have brought the issue of water security in a global political, social, economic, and environmental discussion arena. Reflecting the importance of sound water management in the promotion of sustainable development, the outcome document of the 2012 UN Conference on Sustainable Development (Rio+20), 'The Future We Want', has recognized water as the core of sustainable development. Efforts have been made to address the issues of water security as one of the proposed Sustainable Development Goals. The proposed Sustainable Development Goal No. 6 deals with "Ensuring availability and sustainable management of water and sanitation for all." Goal 6.3 specifically address the target to increase wastewater recycling and safe reuse. Hence, placing the water-related SDGs will provide the basis for a more comprehensive framework, addressing the water needs of all sectors leading to sustainable development.

[40]OECD. (2012). Environmental Outlook to 2050: The Consequences of Inaction, Key Facts and Figures. Paris, Organization for Economic Co-operation and Development
[41]UNDESA. (2014). World Urbanization Prospects: The 2014 Revision, Highlights. (ST/ESA/SER.A/352). New York, United Nations Department of Economic and Social Affairs http://esa.un.org/unpd/wup/
[42]UN-Habitat. (2010). State of the World's Cities 2010/2011 Report: Bridging the Urban Divide. Nairobi, United Nations Human Settlements Programme
[43]Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

Goal 6: Ensure availability and sustainable management of water and sanitation for all[44]

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all

6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

***6.3** By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and increasing recycling and safe reuse by [x] % globally*

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

6.5 By 2030, implement integrated water resources management at all levels, including transboundary cooperation as appropriate

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling **and reuse technologies**

6.b Support and strengthen the participation of local communities in improving water and sanitation management

The recommended actions needed to move towards sustainable development goals through achieving water security requires embedded plans and policies into comprehensive development frameworks. The frameworks also needs a sectoral integration (agriculture, industry, hydropower, domestic usage) for making efficient use and reuse of water within these sectors.

[44] UNGA. (2015). Open Working Group Proposal for Sustainable Development Goals. United Nations General Assembly.http://www.un.org/ga/search/view_doc.asp?symbol=A/68/970 (Accessed on 2 June 2015)

Chapter 3

3. Status and Challenges to Water Security in Asia and the Pacific

3.1 Status of Water Security

Water availability varies greatly across Asia and the Pacific, which is largely a water-stressed region. South-East Asia has more than 150,000 m^3 of available natural water resources per Km^2, whereas the Pacific subregion (including Australia and New Zealand) has less than 30,000. The Pacific has high per capita water availability with around 50,000 m^3 of water available per person annually. Other Asia-Pacific subregions with high population densities have limited water availability per capita; for example, East and North-East Asia and South and South-West Asia have less than 2,500 m^3/capita/ year[45].

The Asia-Pacific region faces water challenges, including lack of access to adequate quantity and quality of drinking water supply, limited coverage of sewerage networks and (often non-existing) wastewater treatment systems, increasing water demand for multiple uses and the concurrent pollution loads; ecosystem degradation, and prone to disaster events such as floods and droughts. Ground water extraction and pollution is relatively high in the region. 32% of Asia's population drinking water supply is from groundwater. India, PR China, Nepal, Bangladesh, and Pakistan alone account for nearly half the world's total groundwater use[46]. Groundwater is also the main source of supply for rural communities in Asia that are not connected to a drinking water network; for example, 60% of such

[45]UNESCAP. (2011). Statistical Yearbook for Asia and the Pacific 2011- Water Availability and Use. United Nations Economic and Social Commission for Asia and the Pacific. e-ISBN: 978-92-1-054994-3

[46]IGRAC. (2010). Global Groundwater Information System (GGIS). Delft, The Netherlands, International Groundwater Resources Assessment Centre. http://www.un-igrac.org/publications/104

a population in Cambodia and 76% in Bangladesh depend on tube wells[47]. In large urban areas, the use of groundwater by industry is usually more than its domestic use. Land subsidence because of groundwater abstraction is seen in a number of coastal Asian cities including Bangkok[48]. Land subsidence resulting from groundwater exploitation has been observed in Bangkok, Bandung, Ho Chi Minh City, and Tokyo. In eastern Bangkok, land subsidence rates of 10 cm per year or higher have been measured, and in several locations in Bandung, they have reached as high as 24 cm per year[49]. A study conducted by the IGES in 2007 about the groundwater use in selected Asia countries, it found three different trends; (i) intensive use in the past but now stable use under strict control of groundwater abstraction (Osaka and Tokyo); (ii) general trend of increase but with fluctuations in abstraction (Bangkok, Bandung and Tianjin); (iii) trend of continuous increase (Ho Chi Minh City). Groundwater is used mainly for industrial purposes in Bandung, HCMC, and Bangkok, and for agricultural purposes in Tianjin[50]. Extensive groundwater abstraction in the Pacific Small Islands Developing States (SIDS) has led to alarming saltwater intrusion conditions. The problem is expected to be exacerbated by the rise in sea-level resulting from climate change[51].

Experts estimate that groundwater irrigation contributes US$ 25 to US$ 30 billion per year to the Asian economy, including earnings from groundwater sales for irrigation[52]. Groundwater pollution from anthropogenic contaminants such as fertilizers and pesticides used in agriculture; mining, tanneries, and other industries; landfill and garbage dumps; and inadequate sanitation and wastewater disposal are prominent in the region. PR China extensively uses groundwater for agriculture. Investigations by the Chinese Ministry of Water Resources in 118 cities revealed that 97% of groundwater sources are polluted, with 64% of cities having seriously polluted drinking water from groundwater sources[53]. The demand for water in PR China's urban areas is growing more than 10% annually, and it is expected to increase 40% by 2020[54]. Coastal cities such as Calcutta, Dhaka, Jakarta and Shanghai are experiencing saltwater intrusion in groundwater supplies due to uncontrolled groundwater abstraction as a result of the inadequacy of public water supply systems. The situation is worse in SIDS; Tuvalu and Samoa are increasingly dependent on bottled water because of lower than average rainfall in recent years and saltwater intrusion of underground reserves from rising sea levels[55].

The overall status of the national water security in Asia and Pacific has been measured by the ADB in 2013, using the National Water Security Index (NSWI) of 1 to 5, as shown in **Table 3.1**.

Table 3.1: Description of national water security stages

National Water Security Index	National Water Security Stage	Description
5	Model	Sustainable local agencies and services; sustained sources of public financing for water and environmental protection and management; sustainable levels of public water consumption; and government demonstrating new models of water governance, supporting advanced technology, supporting research and development, and initiating or leading international partnerships.
4	Effective	Water security initiatives built into key national, urban, basin, and rural development master plans; high priority on national development agenda; public investment reaching appropriate levels; effective regulation; and public awareness and behavioural change are a government priority.

[47]Shrestha, S. (2014). Towards Sustainable Groundwater Management in Asian Cities. Bangkok, Water Engineering, and Management, Asian Institute of Technology. Cited in WWAP, 2015b. Facing the challenges Case studies and indicators. WWDR 2015

[48]WWAP. (2015a). The United Nations World Water Development Report 2015: Water for a Sustainable World. United Nations World Water Assessment Programme. Paris, UNESCO

[49]IGES. (2007). Sustainable Groundwater Management in Asian Cities - A Final Report of Research on Sustainable Water Management in Asia. Chapter 1 Comparative Study of Groundwater Management- based on the case studies in Asian Cities. Kanagawa, Japan, Freshwater Resources Management Project, Institute for Global Environmental Strategies. ISBN 4-88788-039-9

[50] ibid

[51]IPCC. (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge/New York, Cambridge University Press

[52]Shah, T., Roy, A.D., Qureshi, A.S. and Wang, J. (2003). Sustaining Asia's Groundwater Boom: An Overview of Issues and Evidence. Natural Resources Forum – A United Nations Sustainable Development Journal, 27 (2), pp130-141

[53]World Bank. (2007). Cost of Pollution in China: Economic Estimates of Physical Damages. Washington, DC, The World Bank

[54]Asia Society. (2009). Asia's Next Challenge: Securing the Region's Water Future. https://asiasociety.org/files/pdf/WaterSecurityReport.pdf

[55]WWAP. (2015b). Facing the Challenges. Case Studies and Indicators. Paris, United Nations World Water Assessment

3	Capable	Continuous capacity building; improving rates of public investment; stronger regulation and enforcement; national development agenda prioritizing water and environment; and focus shifting toward improving local technical and financial capacity.
2	Engaged	Legislation and policy supported by government capacity-building programs; institutional arrangements improving; and levels of public investment increasing (although these rates may still be inadequate).
1	Hazardous	Some legislation and policy on water and environment, and inadequate levels of public investment, regulations, and enforcement.

According to this study, more than 75% of the countries (i.e., three out of four Asia-Pacific countries) in Asia and the Pacific are experiencing a serious lack of water security (**Figure 3.1**), with many of them facing an imminent water crisis[56].

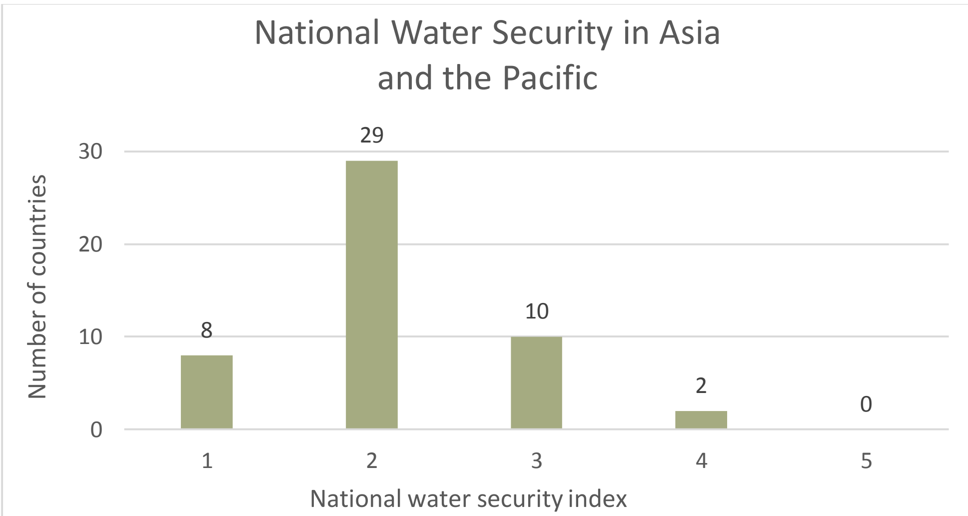

Figure 3-1: National Water Security Index in Asia and the Pacific (Source: adapted from ADB, 2013)[57]

National Water Security Index (NWSI) values

NWSI = 1: Afghanistan, Bangladesh, Cambodia, India, Kiribati, Nauru, Pakistan, and Tuvalu.
NWSI = 2: Azerbaijan, Bhutan, People's republic of PR China, Cook Islands, Federated States of Micronesia, Fiji, Georgia, Indonesia, Kyrgyz republic, Lao People's Democratic Republic, Maldives, Marshall Islands, Mongolia, Myanmar, Nepal, Niue, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Sri Lanka, Thailand, Timor-leste, Tonga, Turkmenistan, Uzbekistan, Vanuatu, and Viet Nam.
NWSI = 3: Armenia; Brunei Darussalam; Hong Kong, PR China; Japan; Kazakhstan; Malaysia; Republic of Korea; Singapore; Taipei, PR China; and Tajikistan.
NWSI = 4: Australia and New Zealand.
NWSI = 5: None.

Amongst the 49 countries examined for national water security, no countries in Asia and the Pacific were found to have reached stage 5 by 2012. So far, 37 developing countries in the region are either suffering from low levels of water security or have barely begun to engage in the essential task of improving water security, and remaining 12 countries are shown to have established the infrastructure and management systems for water security.

[56]ADB. (2013). Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific. Mandaluyong City, Philippines, Asian Development Bank. ISBN: 978-92-9092-989-5 (PDF)
[57] ibid

3.2 Challenges to Freshwater Security

Heavy population, accelerated urbanization rate, intensified industrial development, extensive agricultural development, and frequent disasters are putting a great deal of stress on water resources in Asia and the Pacific. Increasing pollution of freshwater resources (river, lake, and ground water pollution) is also the prime cause of the region's poor water security state.

Urbanization and lack of access to water, sanitation, and drainage system
Asia and the Pacific is one of the most rapidly urbanizing (2.4% annual growth of the urban population) regions in the world. In 2012, 47.5% of the total population (over 2 billion) lived in urban areas and by 2015, it is estimated that 2.7 billion people will be living in urban areas[58]. Currently, seven of the world's mega cities (with populations of 10 million or more) are in Asia-Pacific, which by 2025 is expected to have 21 such mega cities. Such unprecedented urban population growth is placing considerable stress on the water resource, with insufficient water supply (%), wastewater treatment (%), and drainage management in cities. Asia and the Pacific has the highest annual water withdrawal of all the world's regions.

A WHO record shows an estimated 2.6 billion people lack access to adequate sanitation globally. If the current trend continues, by 2015 there will be 2.7 billion people without access to basic sanitation[59]. Although the percentage of people with access to improved sanitation facilities increased from 36% in 1990 to 58% in 2010, 1.74 billion people in Asia and the Pacific still continue to live without access to improved sanitation[60]. Even some big cities in Asia do not have adequate sanitation infrastructure. Jakarta, with a population of 9 million generates 1.3 million m^3 of sewage each day, of which only 3% gets treated[61]. According to WHO and UNICEF, 2014[62], nearly 1.7 billion people in the region (with more than half of these living in rural areas) still did not have access to improved sanitation in 2012. More than 60% of households live without safe, piped water supply and decent sanitation. In South Asia, as little as 22% of wastewater discharge is treated, and 80% of Asia's rivers are in poor health. The burden of such poor water quality leads to infectious disease and mortality. WHO estimates that worldwide some 2.2 million people die each year from diarrhoeal disease, 3.7% of all deaths and at any one time over half of the world's hospitals beds are filled with people suffering from water related diseases[63]. For an estimated 88% of diarrhoea cases the underlying cause is unsafe water, inadequate sanitation, and poor hygiene. The burden also leads to economic costs. Such damage to freshwater resources threatens annually up to US$ 1.75 trillion in ecosystem services, such as agricultural and fisheries production, and environmental and biodiversity benefits[64].

Wastewater and Pollution
Freshwater resources in Asia and Pacific countries are threatened by pollution. Eighty percent of rivers in the region are in poor health, as measured by the river health index[65]. It is estimated that up to 90% of all wastewater in developing countries is discharged untreated directly into local water bodies, causing major environmental and health risks. Wastewater-related emissions of methane and nitrous oxide could rise by 50% and 25%, respectively, between 1990 and 2020[66]. Agricultural pollution along with domestic wastewater and industrial waste is of a grave concern to water security in developing countries.

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[58]UNDESA. (2014). World Urbanization Prospects: The 2014 Revision, Highlights. (ST/ESA/SER.A/352). New York, United Nations Department of Economic and Social Affairs http://esa.un.org/unpd/wup/

[59]WHO (2011). 10 Facts on Sanitation. World Health Organization http://www.who.int/mediacentre/factsheets/fs392/en/

[60]ADB. (2013). Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific. Mandaluyong City, Philippines, Asian Development Bank. ISBN: 978-92-9092-989-5 (PDF)

[61]Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

[62]WHO and UNICEF (2014). Progress on Drinking Water and Sanitation: 2014 Update. New York, World Health Organization/United Nations Children's Fund Joint Monitoring Programme for Water Supply and Sanitation

[63]UNDP. (2006). Human Development Report, 2006. Beyond Scarcity: Power, Poverty and the Global Water Crisis. 440p http://hdr.undp.org/en/media/ HDR06-complete.pdf

[64]Nakao, T. (2013). Leadership for Water Security in Asia and the Pacific. Statement by ADB President Takehiko Nakao on 20 May 2013 at the 2nd Asia-Pacific water Summit, Chiang Mai, Thailand. http://www.adb.org/news/speeches/leadership-water-security-asia-and-pacific (Accessed on 4 June 2015)

[65]Vörösmarty, C.J, McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S. E., Sullivan, C. A., Reidy Liermann, C. and Davies, P. M. (2010). Global Threats to Human Water Security and river Biodiversity. Nature 467:555–561.

[66] Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

Sewage is the largest source of municipal (domestic) sector wastewater. Developing countries lack proper sanitation and sewage treatment, polluting natural water bodies. Poor solid waste management represents an ongoing threat to the health of residents and contributes to the pollution of lakes and the riparian environment. In Indonesia only 53% of population gets water from sources that are more than 10 meters from a waste dump site. In Jakarta, the faecal coliform can be found in 1/6th of shallow well samples, thus it has high risk of water borne diseases, especially for children[67]. Industry generates a substantial proportion of total wastewater. In much of Asia and the Pacific, the industrial wastewater production is relatively high and cannot be ignored. According to the World Water Assessment Programme, in developing countries, 70% of industrial wastes are dumped untreated into waters where they pollute the usable water supply[68]. The **Figure 3.2** below indicates the wastewater treatment (%) in Asia and the Pacific. In South Asia, as little as 22% of wastewater discharges are treated[69].

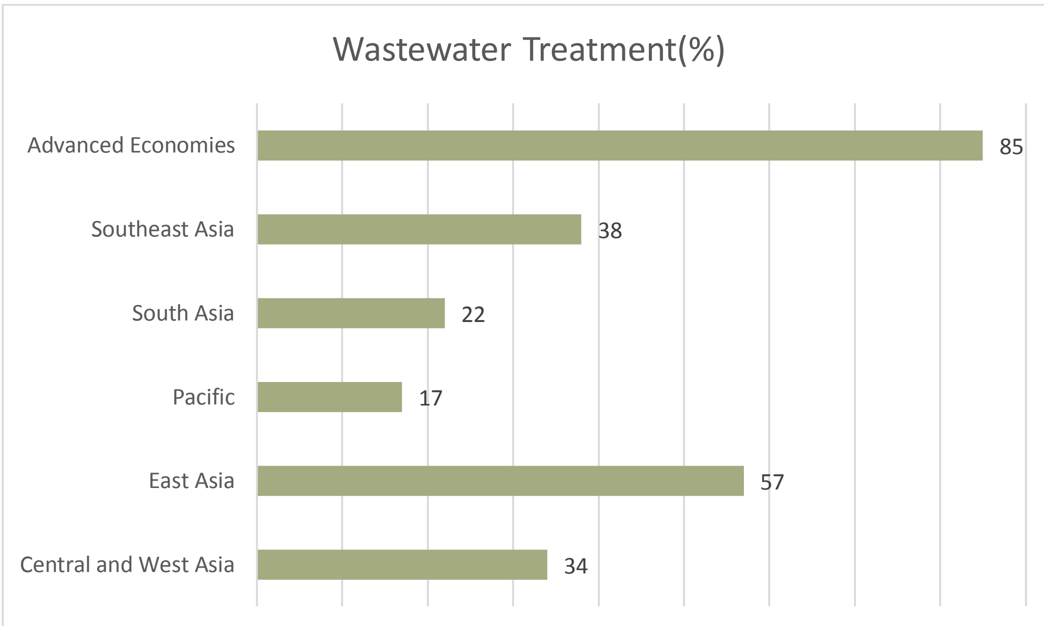


Figure 3-2: Urban wastewater treatment (%) by subregion (population-weighted) (Source: adapted from ADB, 2013)[70]

Agriculture uses an estimated 70% of total global fresh water, returning the majority of this water back to the system. The wastewater produced from rural agriculture and livestock production includes a considerable amount of organic and inorganic contaminants; originating from dissolved contents of fertilizers, chemical runoff (such as pesticides), human waste, livestock manure and nutrients. Wastewater from agriculture sector, however, is being recirculated into agricultural fields for irrigation since historical times. Salinization induced by irrigation is already affecting almost 20% of irrigated areas in Pakistan, 23 %in PR China and 50 %in Turkmenistan[71].By 2050, if farmers cannot increase productivity, South Asia will need to divert up to 57% more water to agriculture, and in East Asia this will account for up to 70%[72].

[67]Asia Society. (2009). Asia's Next Challenge: Securing the Region's Water Future. https://asiasociety.org/files/pdf/WaterSecurityReport.pdf

[68]WWAP. (2009). The United Nations World Water Development Report 3: Water in a Changing World. Paris, UNESCO, and London, Earthscan. World Water Assessment Programme http://unesdoc.unesco.org/images/0018/001819/181993e.pdf

[69]ADB. (2013). Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific. Mandaluyong City, Philippines, Asian Development Bank. ISBN: 978-92-9092-989-5 (PDF)

[70] ibid

[71] ibid

[72]UNESCAP. (2013). The Status of the Water-Food-Energy Nexus in Asia and the Pacific. Discussion Paper. Bangkok, United Nation Environment and Development Division

In many Asian cities, groundwater is contaminated by both natural sources (e.g. arsenic, fluoride) and human activities. Anthropogenic pollutants sources are from industrial and agricultural activities, domestic wastewater, and inefficient solid waste management practices (e.g. leakages from landfills). For instance, in Bandung, shallow groundwater is not fit for direct consumption as it is contaminated by domestic and textile factories effluents in the city. Groundwater of Hyderabad has high concentrations of sulphates (>400 mg /L) due to industrial activities, and the concentration of fluoride in deeper groundwater at certain locations is beyond permissible limits. Excessive groundwater abstraction may also result in aquifer salinization. Ho Chi Minh City's aquifers are all affected by salinity to some extent. In Bangkok, the increased concentration of chloride and total dissolved solids in groundwater is a serious concern[73].

As industrial and urban growth in Asia is rapid, but the absence of environmentally sound wastewater disposal strategies in the region is threatening water quality hence the water security in general. The following examples of freshwater resources (rivers, lake and groundwater sources) pollution give an alarming picture of looming freshwater crisis in the region.

Citarum River Basin, Indonesia

Citarum river is the longest (300 km) river in West Java Province, Indonesia (9 districts and 3 cities), covers an area of approximately 13,000 Km^2. The river provides nearly 80% of surface water to Jakarta's water supply authority, irrigates farms that supply 5% of Indonesia's rice, and provides water for 2,000 factories.

Green Cross of Switzerland and the Blacksmith Institute named Citarum river as one of the 10 most polluted places on earth. Citarum river pollution is mainly caused by waste and wastewater discharge. More than 500 factories release 280 tonnes of industrial waste and wastewater every day. Every day 400 tonnes of livestock waste, 25,000 m^3 of household waste is dumped into the river. Over 200 textile factories along the river banks discharge lead, arsenic and mercury. Field investigations conducted by the Blacksmith Institute found levels of lead at more than 1,000 times the USEPA standard in drinking water. The river is in very poor state with no aquatic life. A carpet of plastic, packaging, and other solid waste floats in the water. Locals instead of fishing, salvage for recyclable plastic bottles.

Compiled from:
http://www.worstpolluted.org/projects_reports/display/123
www.worstpolluted.org/files/FileUpload/files/.../Citarum%20River.pdf
http://www.greencross.ch/en/news-info-en/case-studies/environmental-reports/ten-most-polluted-places-2013/2013.html

Kalimantan, Indonesia (Martapura, Tabalong, Kahayan and Barito Rivers)

The United Nations Industrial Development Organization (UNIDO) estimates that about 30% of the world's anthropogenic mercury emissions i.e., 1,000 tonnes of mercury/year from the Artisanal Small scale Gold Mining (A.S.G.M) in the Central and Southern provinces of Kalimantan area of Borneo islands in Indonesia end up in water bodies like Martapura, Tabalong, Kahayan and Barito Rivers. Residents depending on these rivers for domestic uses and irrigation purposes are being exposed to unusual and highly unsafe levels of mercury. Mercury level in the Kahayan River, Central Kalimantan is 2,260 ng/L i.e., more than twice Indonesia's standard for total mercury in drinking water (1,000 ng/L). The use of mercury is not only regional issue but also an international issue as mercury vapours travel far in the atmosphere.

Compiled from:
http://www.greencross.ch/en/news-info-en/case-studies/environmental-reports/ten-most-polluted-places-2013/2013.html
http://www.greencross.ch/en/news-info-en/case-studies/environmental-reports/ten-most-polluted-places-2013/2013.html

[73]Shrestha, S. (2014). Towards Sustainable Groundwater Management in Asian Cities. Bangkok, Water Engineering and Management, Asian Institute of Technology. Cited in WWAP, 2015b. Facing the challenges Case studies and indicators. WWDR 2015

Yellow River, PR China:

The second longest river and the hub of Chinese civilization, the Yellow River originates in Tibet and flows more than 5,400 Km passing through many important cities of PR China before emptying into Yellow Sea. More than 400 million people live in this basin, it supplies water to 155 million people (12% of the Chinese population) and irrigates up to 15% of country's 18 million acres agricultural land.

Increasing industries (petrochemical, tanneries, paper mills, etc.), population, and mining activities is threatening the Yellow River's water. Two thirds of the river is heavily polluted by industrial waste and is unsafe to use. About 4 billion tonnes of wastewater flows annually into the river; COD up to 5 mg/L and NH_3-N >1mg/L has been measured along the river.

Already 50% of the river has been designated as biologically dead and one third of fish species have already become extinct. Increasing waterborne diseases, birth and defects are common along the river; and cancer rates in some villages are so high that they have been designated cancer villages. Due to frequent contamination by chemical spills, and frequent diversions and damming, the Yellow river often runs dry and sometimes even turns red.

Compiled from:
http://factsanddetails.com/PR China/cat15/sub103/item448.html
http://www.unep.org/GC/GCSS-VIII/PR China%20IWRM.pdf
http://www.treehugger.com/slideshows/natural-sciences/worlds-dirtiest-rivers-and-lakes/page/5/#slide-top

Ganga River Basin, India

Hindus most sacred river Ganga supplies water for more than 37% of India's population and 47% of irrigation area in India. Extending over 1 million km^2 with basin area in India, Nepal, PR China and Bangladesh and occupying more than quarter of Indian land mass, Ganges is one of the longest rivers of the world.

In the Ganga basin approximately 12,000 million litres per day (mld) sewage is generated, but there are sewage treatment facilities for around 4,000 mld only, rest is discharged into the Ganga basin untreated. The contribution (volume-wise) of industrial pollution is about 20% and the major contributors are tanneries in Kanpur, distilleries, paper mills and sugar mills in the Kosi, Ramganga and Kali river catchments. DO falls to 5mg/L, BOD is as high as 10.5 mg/L, and Faecal Coliform range from 40-45000 MPN/100m making it highly unsuitable for ritual bathing or domestic purposes.

Compiled from:
National Mission for Clean Ganga, https://nmcg.nic.in/pollution.aspx
WHO/UNEP, 1997. Water Pollution Control - A Guide to the Use of Water Quality Management Principles. ISBN 0 419 22910 8

The Mekong River Basin, South-East Asia

The Mekong is the heart of South-East Asia. It sustains 65 million people's livelihood through fishing, aquaculture and irrigation. Dam construction and potential damage to aquatic ecosystem is of major concern regarding the Mekong. There has been conflict going on for this transboundary river among Laos, Cambodia, Vietnam, and Thailand. Portions of the Mekong River Basin contain hotspots of persistent organic pollutants that pose a significant threat to the residents and wildlife of the Mekong Basin, according to a new U.S. Geological Survey study. Of the 39 POPs tested in 531 sediment samples, dichlorodiphenyltrichloroethane (DDT) and its metabolites endosulfan, hexachlorobenzene (HCB), and endrin were most commonly detected. Even though DDT was banned in the 1990s, use of DDT may still be occurring in the Mekong Basin. The amount of metabolites for DDT—dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD)—found, however, suggests that use of DDT is on the decline throughout the region.

Compiled from:
http://pubs.usgs.gov/sir/2013/5196/

BuriGanga, Hazaribagh, Bangladesh

Dhaka's main water supply 'Buriganga River' receives almost 22,000 m^3 of toxic waste daily consisting of Hydrogen sulphide, Ammonia, Arsenic, nitrous oxides and cancer causing hexavalent chromium. Chemical waste from mills and factories, municipal solid waste, medical waste, sewage, dead animals, plastics, and oil are some of the Buriganga's pollutants. Out of 270 tanneries in Bangladesh, 90-95% are located at Hazaribagh area. The local residents of Hazaribagh and nearby areas depend on this contaminated Buriganga River for drinking water and domestic purposes.

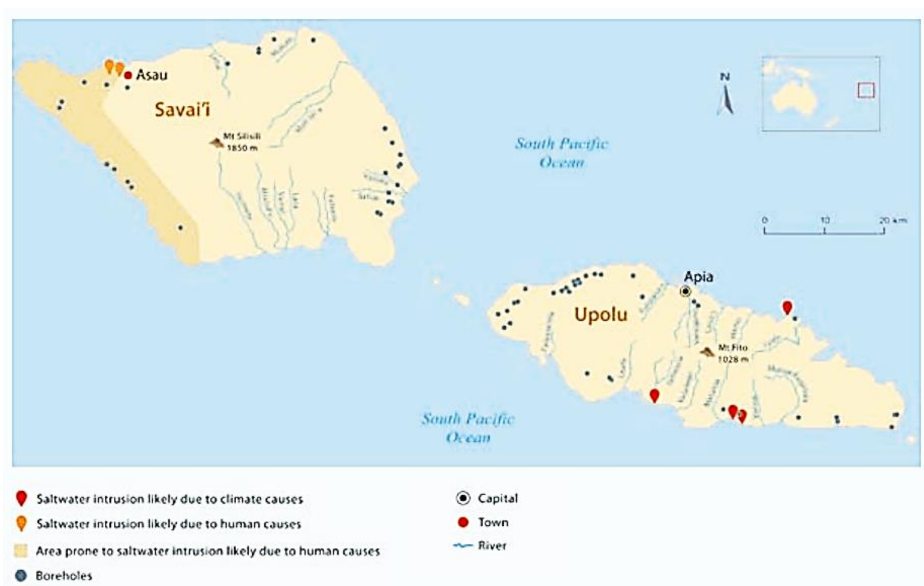
Chromium level was found to be 6 mg/L. DO was less than 2 mg/L at most of the sampling points and even 0 mg/L at some locations. Acid burns, dizziness, rashes, aches, and nausea are common problems being faced by local residents. This area also suffers high air pollution due to burning of scraps of leather.

Compiled from:

http://www.greencross.ch/en/news-info-en/case-studies/environmental-reports/ten-most-polluted-places-2013/2013.html
http://www.researchgate.net/profile/Avit_Bhowmik/publication/232184716_Buriganga_Pollution_Reasons__Prospects/links/0c96052860b18dcd21000000.pdf
http://www.worstpolluted.org/projects_reports/display/111
http://www.takepart.com/photos/10-most-polluted-rivers-world

Saltwater intrusion in Samoa

Samoa relies on both surface water, which meets about 65% of the demand, and remaining 35% of the water supply is drawn from aquifers. However, during the dry season, surface water reserves become insufficient in some parts of the islands, leading to over abstraction of ground water, which in turn is causing salt water intrusion. Sea level rise, recurrent droughts, and floods are further aggravating challenges to water supply and saltwater intrusion in Samoa.



Compiled from:
WWAP (2015b). Facing the Challenges. Case Studies and Indicators. United Nations World Water Assessment Programme. Paris, UNESCO.

Marilao, Meycauayan and Obando River System (MMORS)—Philippines

Untreated waste water discharged by a range of registered and unregistered local industries is polluting the waterways affecting 161,000 people in the MMORS region. Effluent containing heavy metals from used lead-acid battery recycling facilities, gold smelting shops, tanneries is discharged into the river feeding directly into Manila Bay. Open dump sites, livestock farms, refining precious metals for local jewellery production and homes along the rivers have exacerbated the contamination. Water analysis of the river system in 2014 found high levels of cadmium, copper, lead, zinc and other toxic substances.

Compiled from:
Blacksmith Institute, 2014: Top Ten Countries, Turning the Corner on Toxic Pollution 2014. http://www.worstpolluted.org/projects_reports/display/123

Tai or Taihu Lake Basin, PR China

Lake Tai, also known as Taihu, in the southern coastal region of PR China is the third largest fresh water lake and one of PR China's most important water resources. It is the source of the Suzhou River, and also feeds the Huangpu River, the waterway passing along Shanghai's Bund.

This area is also famous for rice crops around it. But now it has about 2,800 chemical factories. Due to both agricultural runoff and industrial effluents, water pollution is at its worst. The eutrophication of the lake has caught international attention. Toxic cyanobacteria, commonly referred to as pond scum, turned the big lake ***fluorescent green.*** Tourism in the area is also declining. One billion tons of wastewater, 450,000 tonnes of garbage, and 880,000 tonnes of animal waste were dumped in the shallow lake in 1993 alone.

Compiled from:
http://www.nytimes.com/2007/10/14/world/asia/14PR China.html?pagewanted=all&_r=0
https://prezi.com/l7x7hbkxfqdr/5-most-polluted-lakes-on-earth/

Climate risks to water security

In the Asia-Pacific region, cities are at risk of water insecurity not only because of various impacts of urbanization but also climate change (floods, drought, and other natural disasters). Asia and the Pacific is one of the most disaster-prone regions in the world. In 2013, over 17,000 people died from water related disasters in the region, accounting for 90% of all water-related disaster deaths globally. Economic losses totalled more than US$ 51.5 billion[74].

Climate change threatens sustainable water resources management due to flooding affecting the availability of quality water through the contamination of surface and groundwater supplies, and the droughts affecting the quantity of water. In coastal regions, including parts of Bangladesh and much of South-East Asia, sea level rise threatens salinization of coastal aquifers, with potential effects on drinking water sources and coastal ecosystems. Reduced access to freshwater may lead to many profound consequences, including food insecurity, loss of livelihood security, and even large-scale migration within and across borders, and increased economic and geopolitical tensions and instabilities[75].

The multiple water-related challenges in Asia and the Pacific represent different components of water security at different levels – household, urban, and national scales. The challenges include; limited or no access to water, resource depletion, pollution, and climate related disaster[76]. Therefore, the region needs to promote sustainable freshwater management with all possibilities of recirculating water back to nature through technological, infrastructural, policy and management and behavioural innovations.

[74]CRED. (2014). EM-DAT, the International Disaster Database. Brussels, Université Catholique de Louvain. Centre for Research on the Epidemiology of Disasters. http://www.emdat.be/database
[75]Asia Society. (2009). Asia's Next Challenge: Securing the Region's Water Future. https://asiasociety.org/files/pdf/WaterSecurityReport.pdf
[76]ADB. (2013). Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific. Mandaluyong City, Philippines, Asian Development Bank. ISBN: 978-92-9092-989-5 (PDF)

4. Responding to Region's Water Security Challenges through 3R

Given the pressing circumstances of freshwater scarcity and quality deterioration in Asia-Pacific, this section discusses the potential responses, and solution encompassing a broad mix of the reduce, reuse, recycle (the 3R) strategies and principles for water-related issues: efficient water use and reducing water footprint, handling and treatment of wastewater from municipal, industrial, and agricultural sector for reuse and/or safe discharge to the environment. Implementing such holistic water management framework action is necessary to ensure sustainable water management for realizing sustainable development goals. Various innovative financing mechanisms and water governance aspects as response mechanisms to solve water security crisis in Asia and the Pacific are also presented in this section.

The 3R concept is usually well adopted for sustainable solid waste management. Nevertheless, this basic principle is equally useful and applicable for all kinds of resource management including water resources. Ensuring secure water supplies for the nation's water-scarce urban areas is local context-dependent. However, a common principle used for addressing water security issues is integrated water resource management including sustainable and resilient water supply, water demand management, and recycling and reuse of wastewater. Strategies for water management can be best addressed using the hierarchical approach of reduce, reuse, recycle (3R) principles. Wastewater management should be considered as the solution to circulate water from source to re-entry into the environment, hence closing the water cycle[77]. **Figure 4.1** explains the 3Rs as effective tools for both demand and supply side management of water. The first R- Reduce can lower the water demand by applying appropriate regulatory, economic, and technological strategies. The other two Rs - Water reuse and recycling address the supply side of water management, which increases the supply of water through wastewater reclamation.

Chapter 4

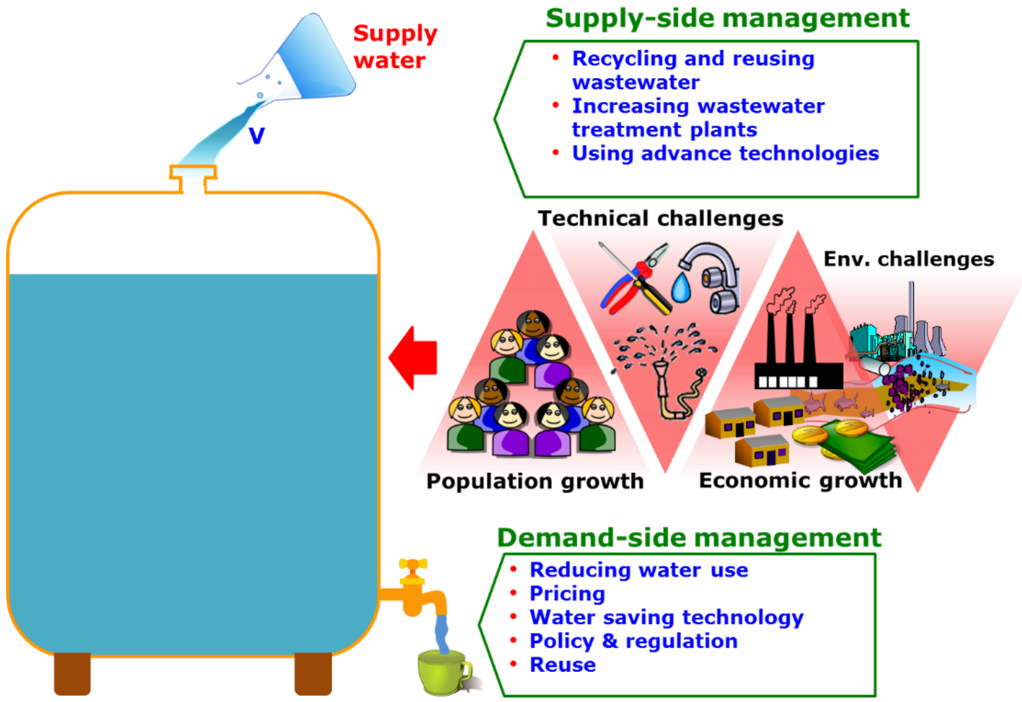


Figure 4-1: Use of 3Rs in demand-and-supply side management of water resources

[77] UN-Water. (2015). Wastewater Management A UN-Water Analytical Brief. http://www.unwater.org/fileadmin/user_upload/unwater_new/docs/UN-Water_Analytical_Brief_Wastewater_Management.pdf

A stronger technology, policy, and investment mix is therefore required to fight water security challenges in the region. A well-balanced water management planning with regulatory instruments involving the setting of allocation and water-use limits, and incentivization of water conservation efforts, and communication and information tools aiming to change behaviour for conserving scarce water resources, environmentally sound and advanced technologies for wastewater treatment and recycling, and various innovative financing mechanisms offers a complete response mechanism to water security crisis.

4.1 Reducing Water Footprint through Water Demand Management

In the current scenario of sharply escalating demand for water (and the forecast for further increase in demand) and diminishing supply of quality water due to pollution and extreme climatic events, water demand management (WDM) seems the most obvious step to water security. Water Demand Management is 'the management of the total quantity of water abstracted from a source of supply using measures to control waste and undue consumption[78]'. The primary objectives of demand management is to rationalize and control water use, reduce waste and increase use efficiency and equity in view of limited supplies. Demand management is cost-effective compared to supply-side management because it allows the better allocation of scarce resources than building expensive dams, water transfer schemes from one river basin to another, and desalination plants[79]. In particular, demand management promotes water conservation through changing practices, cultures, and people's attitudes towards water resources[80]. Demand management techniques involve reducing loss and misuse in various water sectors, optimizing water use by ensuring reasonable allocation between various users, and ultimately reducing the stress on water resources by reducing or halting unsustainable exploitation of water resources[81].

WDM may involve a wide range of tools including economic instruments, regulatory instruments, technological solutions, and awareness raising and capacity building. Economic tools embody concepts such as pricing the water use, cost recovery, and promoting well-regulated water markets for investments. The legislative tools consist of the rules and organizational arrangements for managing water use and demand, including licensing, temporary water use restriction, and even use of reclaimed water. Technological measures for water use and demand management uses the application of water efficient sanitary appliances, and leakage detection and repair programs and pressure reduction activities. Awareness raising and capacity building instruments seek to manage water demand by increasing the awareness of end users and raising their capacity to rationalize water demand and adopt behavioural changes towards sustainable consumption of water.

Demand management measures can be short or long term depending on the needs of the community. Many cities and countries have applied combination of these WDM tools to reduce water use. Some of the good practice are presented in respective sections below.

[78]Herbertson P.W., Tate, E.L. (2001). Tools for Water Use and Demand Management in South Africa. World Meteorological Organization Technical Reports In Hydrology and Water Resources No. 73. WMO/TD – No. 1095

[79] Global Water Partnership (2012). Water Demand Management (WDM) – The Mediter¬ranean Experience. Technical Focus Paper. http://www.gwp.org/Glo¬bal/The%20Challenge/Resource%20material/gwp_tech_focus.pdf

[80]Savenije, H., Van der Zaag, P. (2002). Water as An Economic Good and Demand Management: Paradigms with Pitfalls. Water International, 27, 98-104

[81]Brears, R. (2014). Urban Water Security in Asia-Pacific: Promoting Demand Ma¬nagement Strategies. NFG Policy Paper Series, No. 04, March 2014, NFG Research Group, Asian Perceptions of the EU" Freie Universität Berlin

4.1.1 Regulatory Instruments

Regulatory instruments involve setting allocation and water-use limits. In addition, regulatory instruments also use economic incentives for efficient water use and water conservation.

Conservation ordinances/ Water permits and licensing:

These ordinances and regulations restrict certain types of water use during specified times and/or restrict the level of water use to a specified amount. For most of the non-domestic water use reduction, license and permit for surface and ground water extraction and application is used as regulatory tools. Many Asian countries including Thailand and Japan have national laws (**Table 4.1**) to control groundwater abstraction and use, in certain critical areas.

Table 4.1: Groundwater abstraction and use regulations in selected Asian cities[82]

City (Country)	Regulations and Laws	Purpose
Bandung (Indonesia)	Government Regulation 43/2008 on Groundwater Management	Regulation for the well licensing system, registration of wells and water pricing
Bangkok (Thailand)	Groundwater Act (1977, 1992, 2003)	Regulations on groundwater abstraction to mitigate decline of groundwater levels associated with land subsidence; namely, permission for drilling, designation of no-pumping areas and set-up of the Groundwater Development Fund
Ho Chi Minh City, Viet Nam	National Technical Regulation on Underground Water Quality (QCVN 09:2008/ BTNMT) and several decisions issued by the Ministry of Natural Resources and the Environment (such as 05/2003/QD-BTNMT, 02/2004/CTBTNMT, 17/2006/QD-BTNMT, 13/2007/QD-BTNMT, 15/2008/QD-BTNMT	Regulations on drilling and licensing of exploration and exploitation of groundwater
Hyderabad (India) Andhra Pradesh	Water, Land and Trees Act (2002)	Registration and licensing of groundwater extraction wells used for industrial purposes, registration of rigs, classification of groundwater basins, etc.
Tokyo (Japan)	Industrial Water Law; Law Concerning the Regulation of Groundwater Abstraction for Use in Buildings	Regulation of industrial uses of groundwater; regulation of groundwater use in both residential and commercial buildings

[82] Shrestha, S. (2014). Towards Sustainable Groundwater Management in Asian Cities. Bangkok, Water Engineering and Management, Asian Institute of Technology. Cited in WWAP, 2015b. Facing the challenges Case studies and indicators. WWDR 2015

Water Pricing

Water pricing is a long-used economic instrument to promote sustainable water consumption and achieve urban water security by managing water demand through a variety of volume based price structures (creating disincentives for overuse). This economic theory suggests that demand for water should behave like any other goods: as price increases, water use decreases. In many cities, a flat rate is charged for water usage regardless of the volume used, where typically the size of the charge is related to the customer's property value. A volumetric rate is a charge based on the volume used at a constant rate per m^3 of water used. An increasing block tariff rate contains different prices for two or more pre-specified quantities (blocks) of water, with the price increasing with each successive block (**Figure 4.2**). A two-part tariff system involves a fixed and a variable component. In the fixed component, water users pay one amount independently of consumption and cover infrastructural and administrative costs of supplying water. Meanwhile, the variable amount is based on the quantity of water consumed and covers the costs of providing water as well as encouraging conservation[83].

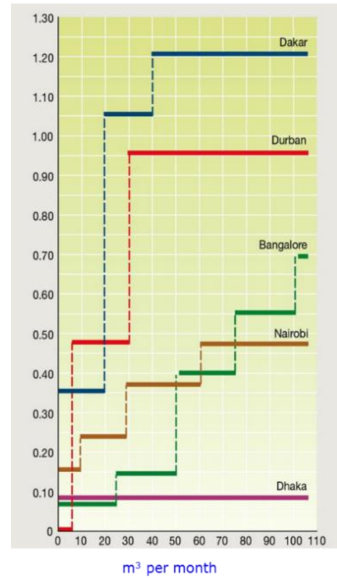


Figure 4-2: Block water tariffs, 2001-2005 (US$)[84]

Economic instruments such as subsidies, incentives, or rebates helps to modify an individual's behaviour in a predictable, cost-effective way. Nevertheless, pricing water is a complex issue and needs to address local social-economic contexts, for everyone to access water, after all drinking water is a human right.

Water Management in Singapore: Reduce, Re-price and Recycle

Water Security issue is one of the most crucial problems for Singapore's sustainability. It uses 1.73 million m^3 of water per day. Although endowed with high rainfall (2,400 mm/year), Singapore is considered to be a water-scarce country because of the limited amount of land area where rainfall can be stored. Currently, Singapore is dependent on 40% imported water while increasing local catchment, using desalination and recycling water technologies, and by adopting various water pricing and wastewater recycling mechanisms, it aims for water self-sufficiency by 2060.

In Singapore, the Public Utilities Bureau (PUB), the water authority succeeded in reducing the water consumption by implementing water pricing. Water pricing in Singapore has the following components: Water conservation tax (WCT), and Sanitary appliance fee and waterborne fee (WBF). WCT was introduced to encourage water conservation efforts by users. Revenue generated from WCT is basically used for governmental water conservation programmes, i.e., research & development to identify innovative and more efficient ways of water treatment and distribution and construction of new water supply sources to meet future water demand. WCT is channelled into the government consolidated fund managed by the Ministry of Finance, while the water tariff is allocated to PUB for operations. Water tariff and water conservation tax (WCT) are subject to governmental tax.

Besides water prices, Singapore government also adopted instalment of water saving devices such as mandatory flow regulators for non-domestic sector as well as all private residential apartments. Penalty is imposed on violators who exceed the maximum flow rate (as designated for different water uses). PUB staff occasionally conduct inspections of water saving devices and metering.

[83] Brears, R. (2014). Urban Water Security in Asia-Pacific: Promoting Demand Management Strategies. NFG Policy Paper Series, No. 04, March 2014, NFG Research Group, Asian Perceptions of the EU" Freie Universität Berlin

[84] http://www.unep.org/dewa/vitalwater/article138.html

Table 4.2: Water tariff structure between 1997 and 2000

Tariff categories	Consumption block(m³/month)	Before July 1997			July 2000		
		Water tariff(S$/m³)	% of WCT	WBF (S$/m³)	Water tariff(S$/m³)	% of WCT	WBF(S$/m³)
Domestic	1-20	0.56	0	0.1	1.17	30	0.3
	20-40	0.8	15	0.1	1.17	30	0.3
	Above 40	1.17	15	0.1	1.40	45	0.3
Non Domestic	All	1.17	20	0.22	1.17	30	0.6
Shipping	All	2.07	20	-	1.92	30	-

Because of these efforts, there was reduction in per capita water use from 172 L/day in 1995 to 155 L/day in 2012. It further aims at lowering the per capital water usage to 140 L/day in 2030.

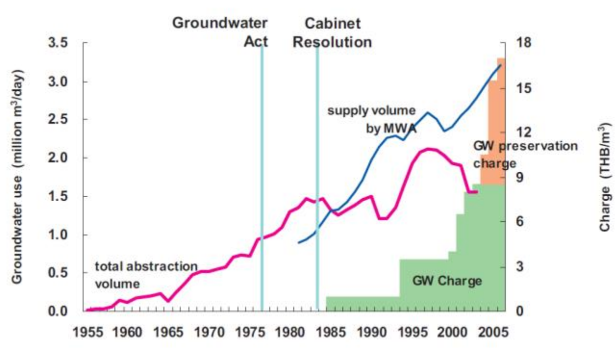
Compiled from:

http://www.pub.gov.sg/general/Pages/WaterTariff.aspx

Some Asian cities like Bangkok, Ho Chi Minh City, and Bangdung levy a user charge or a tax as a tool to disincentivize unsustainable abstraction of groundwater[85]. Nevertheless, lack of strict enforcement and cheap per unit charge (than piped water supply) have not been able to discourage over extraction of ground water. In some places, illegal groundwater abstractions are putting pressure on the aquifers.

Regulating groundwater use in Bangkok

A charge for groundwater was introduced in 1985 in 6 provinces in the Bangkok metropolitan region, at the rate of 1 Baht/m³. However, the charge was lower than piped water supply and did not lead to a remarkable decrease in ground water abstraction. Realizing this, the pricing was revised gradually till 2003, as shown in figure below. Groundwater tariff in 1994 increased up to 3.5 Baht/m³, and the tariff was levied throughout the country. An additional charge for groundwater preservation was introduced in 2004 (Shrestha, 2014). By introduction of the preservation charge, groundwater users with access to the public water supply should pay more for groundwater than for the piped water supply. With this additional charge, the tariff for groundwater extraction in critical zone reached up to 8.5 Baht/m³.



Groundwater Use Charge and Groundwater Abstraction in Bangkok (IGES, 2007)

The change in groundwater charges was expected to promote the shift from groundwater use to the public water supply. At present, the land subsidence rate has stabilized. Nevertheless, the drought episodes in 2015 have caused incidences of land subsidence and salt water intrusion in city's piped water.

[85]WWAP. (2015b). Facing the Challenges. Case Studies and Indicators. Paris, United Nations World Water Assessment

Compiled from:

IGES. (2007). Sustainable Groundwater Management in Asian Cities - A Final Report of Research on Sustainable Water Management in Asia. Chapter 1 Comparative Study of Groundwater Management- based on the case studies in Asian Cities. Kanagawa, Japan, Freshwater Resources Management Project, Institute for Global Environmental Strategies. ISBN 4-88788-039-9

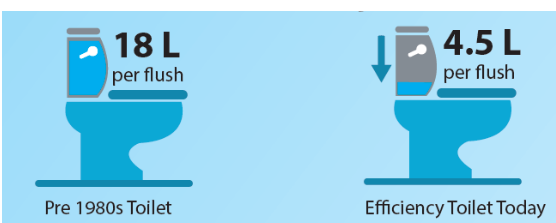
Shrestha, S. (2014). Towards Sustainable Groundwater Management in Asian Cities. Bangkok, Water Engineering and Management, Asian Institute of Technology. Cited in WWAP, 2015b. Facing the challenges Case studies and indicators. WWDR 2015

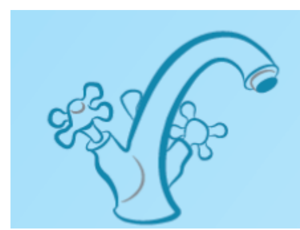
Retrofit Programs for Water Efficient Appliances/Devices

Use of low-flow sanitary equipment as retrofit programs physically reduce water consumption. Such residential rebate programs for low-flow water devices have become increasingly popular as a means of reducing urban water demand. The most common retrofits are toilet retrofits, involving customers having their older toilets replaced with newer low-/dual-flush toilets, and the distributing of showerheads and faucet aerators (devices that when inserted into taps reduce the flow of water) to households and offices. However, care must be given to monitor any possible 'rebound' effects of using water efficient devices.

Many countries have such programs on a voluntary basis, but the government of Singapore has made the instalment of water saving devices mandatory, such as installations of flow regulators for non-domestic sector as well as all private residential apartments. Penalty is imposed on violators who exceed the maximum flow rate (as designated for different water uses).

Design innovations in water saving appliances





Water saving faucets and fixtures

Sink Toilets

The sink toilet device features a toilet on the bottom and a sink mounted on the top, which immediately reclaims grey water for toilet flush. Fresh water coming from the tap after hand-washing trickles into the sink basin, bypassing the tank and directly refilling the toilet bowl. Such practice of water saving toilets are in use in Japan.

Compiled from

http://www.stufftoblowyourmind.com/blog/sink-toilets-help-you-to-wash-and-go/
http://www.zdnet.com/article/the-toilet-re-imagined-four-water-saving-designs/

WASUP- washing machine integrated with toilet flush

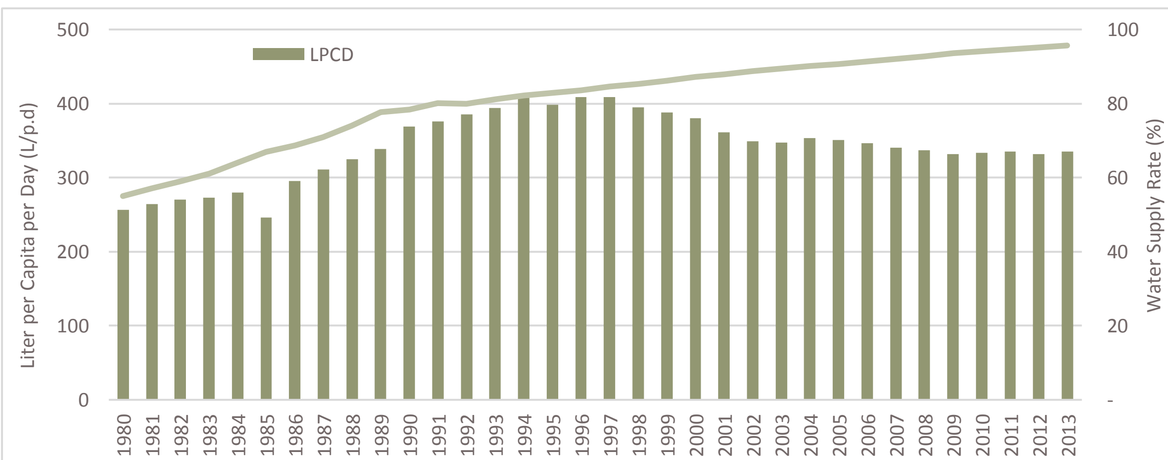
"Wasup" is a conceptual design integrating washing machine with toilette-flush. The wall-mounted Wasup stores water used in the washer in the toilet, to be reused for flushing. Along with water reuse, this machine also solves the issue of locating washing machine in small bathrooms.

Compiled from

http://icantseeyou.typepad.com/my_weblog/2008/03/washup-toilet-a.html
http://www.treehugger.com/clean-water/integrated-washing-machine-toilet.html

Successful Case of Water Supply and Waterworks Installation Act in South Korea

An average Korean uses 45% of her/his water consumption for toilet bowl flushing. Water Supply and Waterworks Installation Act was enacted in 2001 with regulation framed for accommodating businesses and public bathhouse to install water saving toilet bowls and urinals. The regulation suggested the installation of toilet bowl of 9L capacity from 13L in-use toilet bowls, and urinals with less than 4L per flushing. The regulation was further strengthened in 2012 requiring public institution sites, schools, and sport facilities to install toilet bowl of 6L per washing and less than 2 L per washing urinals. As a result, the Litres per Capita per Day (LPCD) in South Korea has gradually decreased since the late-1990s.



Compiled from
Yearly Waterworks Statistics Books published by Ministry of Environment in Korea
http://www.moleg.go.kr/english/korLawEng?pstSeq=47545

Domestic and business retrofit project - Sydney, Australia

In response to long-term drought, Sydney Water launched the 'Every Drop Counts' initiative. The project is a key element of WaterPlan 21, a long-term strategy for sustainable water and wastewater management. The initiative aims to encourage residents of Sydney to consume less domestic water. Later on, this initiative was expanded to incorporate schools, and businesses, helping them to reduce their water consumption and benefit from reduced costs. The success of this initiative was recognized widely, and it received the prestigious Stockholm Industry Water Award in 2006- the first time for an Australian organization to receive the award.

The key elements of this initiative were: promoting the use of water efficient devices (such as low flow showerheads, taps, toilets), and inspection of mains infrastructure for leakage detection and repair, and conducting water audit. The project reached out to people and businesses to identify technical solutions to water management problems, and educate and encourage citizens to reduce water consumption. Projects implemented by Sydney Water since 2001 have helped to reduce the per capita water use from 411 L/day in 2001 to 297 L/day in 2012.

Compiled from:
Managing Water Use in Scarce Environments, A Catalogue of Case Studies, 2030 Water Resources Group

The N-Park Condominium Water Saving Project, Penang, Malaysia

The N-Park Condominium with 965 units is the first condominium in Malaysia to pilot a water-saving project. Carried out between August 2009 and December 2010, this smart partnership initiative engaged relevant government, non-government, private sector and community stakeholders. Funded by the Malaysian Government and jointly implemented by the Department of Irrigation and Drainage (DID), Water Watch Penang (WWP) and N-Park Management Corporation (NPMC), with support from Perbadanan Bekalan Air Pulau Pinang Sdn Bhd, the project involved three main components:

1. Installation of a rainwater harvesting system comprised of six 10,000 L capacity tanks, on the roof of a parking block- for non-drinking purposes such as gardening, washing floors and toilets, washing cars and flushing toilets.
2. Fitting all the common area toilets with water-saving dual-flush cisterns, push-flush urinals, and automatic push-taps
3. Engagement of residents from 100 apartments in a water-saving competition reduce their own water use

Between these project implementation, water usage was reduced in the condominium's common areas by 37.38% in May, 36.51% in July and 12% in September of 2011, resulting in an average monthly water savings of 28.63%, and US$ 387 in savings per month. Over a six-month period, the condominium saved 8.4 million L of water, i.e., equivalent of US$ 2,324 saving.

Compiled from:

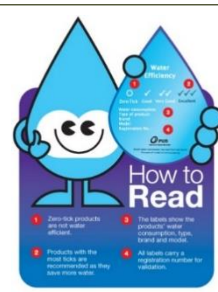
UNESCAP/K-Water (2015). Case Studies on Water and Green Growth in Asia and the Pacific. United Nations Economic and Social Commission for Asia and the Pacific and K-water

4.1.2 Communication and Information Instruments

Communication and information tools have the likelihood of changing consumers' behaviour towards conserving water resources. Community awareness campaigns, public workshops, advertisements in radio, television, newspaper, internet, and social media may persuade people to opt for water efficient behaviour. Water conservation tips and information can also be included in water utility bills.

Product labelling of household appliances according to their degree of water efficiency helps eliminate unsustainable products from the market, and give consumers the choice to reduce water consumption and their water bills.

Water Efficiency Labelling Scheme (WELS), Singapore



Singapore started a mandatory WELS since 2009. WELS is a grading system of 0/1/2/3 ticks to reflect the water efficiency level of a product. The more ticks a product has, the more water-efficient it is. With this scheme, consumers can make informed choices when making purchases. There are still two categories of products, one of which falls under mandatory WELS, and the other under Voluntary WELS.

Products Under Mandatory WELS: These products are required by PUB to comply with the WELS efficiency standards and requirements. They must be accompanied by labels for the specified supply, sale, and use in Singapore. Ex. shower taps & mixes, basin taps & mixes, low capacity flushing cisterns, urinal flush valves & waterless urinals, clothes washing machines etc.

Products Under Voluntary WELS: Vendors of these products may voluntarily apply for their products to be labelled by demonstrating that their products meet the Public Utility Board's WELS efficiency standards and requirements. Ex. Showerheads

Since 1 October 2011, washing machines sold in Singapore have to carry a mandatory Water Efficiency label. In a typical 7 kg washing machine, one-tick products help consumers save 81 L of water per wash, while two-tick products can save 102 L, and three-tick products can save as much as 112 L of water.

Compiled from: http://www.pub.gov.sg/wels/Pages/default.aspx

4.1.3 Conservation of Water Resources and Pollution Control

Pollution from cities, untreated industrial and municipal wastewater is also a challenge to the security of the water environment. Protection of water sources, catchments and river basin, groundwater aquifer recharge, and rainwater harvesting are some of the water resource conservation approach. Measures of improved water resource management have shown considerable economic gains. A US$ 15 to US$ 30 billion investment in improved water resources management in developing countries can have direct annual income returns in the range of US$ 60 billion. Every US$ 1 invested in watershed protection can save anywhere from US$ 7.5 to nearly US$ 200 in costs for new water treatment and filtration facility[86].

Clean Ganga Programs

- The Ganga Action Plan (GAP) - launched in 1986, aims to clean the Ganga in Varanasi. Under this plan sewage treatment plants were set up, raw sewage was cut off and diverted, electric and wood crematoria was set up and low-cost sanitation facilities were provided. The Ganga Action Plan which was part of the Ministry of Environment and Forests (MoEF) has now been shifted under Water Resources Ministry.
- The National Ganga River Basin Authority (NRBA) – established through the Gazette notification of the Government of India (Extraordinary) No. 328 dated February 20, 2009 issued at New Delhi with the objectives of (a) ensuring effective abatement of pollution and conservation of the river Ganga by adopting a river basin approach to promote inter-sectoral co-ordination for comprehensive planning and management; and (b) maintaining environmental flows in the river Ganga with the aim of ensuring water quality and environmentally sustainable development. NRBA was supported by the National Ganga River Basin Project.
- Namami Gange Programme - an Integrated Ganga Conservation Mission -Namami Gange approaches Ganga Rejuvenation by consolidating the existing ongoing efforts and planning for a concrete action plan for future. The interventions at Ghats and River fronts will facilitate better citizen connect and set the tone for river centric urban planning process.
- Supreme Court of India also passed many judgments on the closure and relocation of industrial plants along the Ganges. Stretch of the river between Gaumukh and Uttarkashi has been termed as 'eco-sensitive zone' in 2010.
- Save Ganga Movement- Gandhian non-violent movement with saints and social science activist as its supporters.
- Ganga Calling – Save Ganga - A campaign supported by Indian Council for Enviro-Legal Action (ICELA).

Compiled from:
https://nmcg.nic.in/gangaactionplan1.aspx

Cleaning up Indonesia's Citarum Basin

Government and community working together for clean, healthy, and productive catchment areas and rivers, bringing sustainable benefit to all people of Citarum river basin. In 2008, ADB provide Indonesia with a US$ 500 million, multiyear loan to finance a wide-ranging clean-up and rehabilitation plan for the Citarum River basin. The money is being used to clean the Citarum River and the West Tarum Canal, which connects it to Indonesia's capital, Jakarta. The city gets 80% of its water supply from the river. In Bekasi, a city on the eastern border of Jakarta, ADB has helped finance a major engineering project to keep the canal water clean on its journey to the capital by running it beneath the Bekasi River, one of the most polluted in the Citarum region. The Bekasi Siphon cost US$ 1.8 million, of which ADB contributed 80%. ADB has partnered with local government and the Ministry of Health to support a community initiative for cash for trash- recycling schemes. Some recyclers are doing more than just selling trash fished from the rivers. With these efforts Citarum River's condition has improved. However, a lot is yet to be done for the restoration of the river.

Compiled from:
http://www.adb.org/features/cleaning-indonesias-citarum-basin
Soenarto soendjaja, 2012. Citarum River Basin Restoration Investment Program. PIO Specialist / CDIET - NUFFIC-NICHE Project at IHE Indonesia. http://www.slideshare.net/soenarto/citarum-river-basin-restoration-investment-program

[86] SIWI. (2005). Making Water a Part of Economic Development: The Economic Benefits of Improved Water Management and Services. Stockholm, Stockholm International Water Institute

Water Pollution Control in Taihu Lake Basin

In order to protect the water environment of Taihu Lake in PR China, the central government took pollution prevention in Taihu Lake as a top priority work in its 9th and 10th Five Year Plans. In the 9th Five Year Plan period, the central government and the local authorities invested 10 billion Yuan. Therefore, 41.7% of the centralized water source areas in the lake basin, 57.1% of the cross-sections in and out of the lake, and 28% of the sections in border areas have attained the water quality target as identified in the Plan for 2005. Of the 255 projects in the Plan, 136 have been completed. The average reduction of the total discharge of the major pollutants in the lake basin is 50.7%. Despite the significant achievements in water pollution prevention in Taihu Lake basin, it still requires continuous long-term efforts.

Compiled from:

SEPA, 2005. Water Pollution Prevention and Control: Successful Cases in PR China. State Environmental Protection Administration. Nairobi, Kenya. www.unep.org/gc/gc23/documents/PR China-water-pollution.pdf

4.1.4 Efficient Use of Water in Agriculture Sector

Food production is the largest user of water globally. It is responsible for 80–90% of consumptive water use from surface water and ground water. Irrigation of crops is the main user of freshwater resources. Due to the growing population and the growing demand for world's food production, water consumption in Agricultural sector is predicted to rise. In 2050, with a population forecast 9.2 billion people, it is expected that there will be a 70 % increase in demand for food[87]. In Asia, it is estimated that by 2025, 17 million ha of the irrigated rice area may experience "physical-water scarcity," and 22 million ha, maybe subject to "economic-water scarcity[88]."

However, there are ways to reduce water use in agricultural sector by; improving water-use efficiency, enhancing on-farm water retention, reducing on-farm demand, growing crops that require less water, restoring habitat, protecting open space, increasing soil organic matter and soil moisture, managing and reducing impacts from water use, such as salinity and run-off and transport of agro-chemicals sequestering carbon, and generating on-farm renewable energy from sources such as livestock waste, smart/efficient irrigation systems, energy efficient pumping systems, treatment and re-use of urban wastewater for agricultural production etc.

Reducing agricultural water use through irrigation technology, scheduling and regulated deficit irrigation

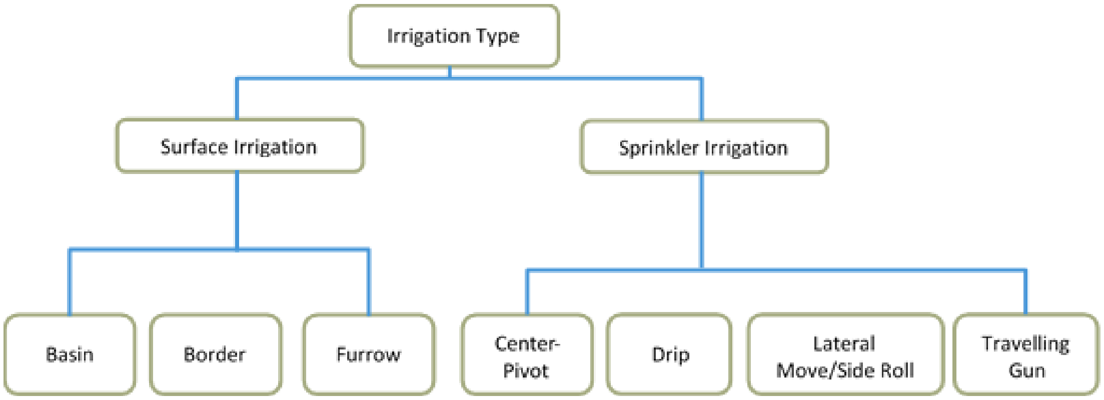
Irrigation is the top most water consumption factor in agriculture. Efficient irrigation thus means reducing the agricultural water footprint to a large extent. Choosing right *irrigation technology* (such as sprinkler and drip irrigation), application of *irrigation scheduling* (is the decision of when and how much water to apply to a field by taking into consideration of local climate and soil information to determine crop water requirements), and *regulated deficit irrigation* (i.e., imposing water stress on certain crops that have drought-tolerant life stages by taking care of the plant growth pattern) are some of the irrigation water management strategies. One example of regulated deficit irrigation is, trees are given ample irrigation during the time of rapid growth of fruit, but irrigation is reduced when fruit growth is slow or after harvest. Here the irrigation decision takes care of the growth patterns of the shoots and fruit. If RDI is properly managed, there is no reduction in the size of fruit or yield.

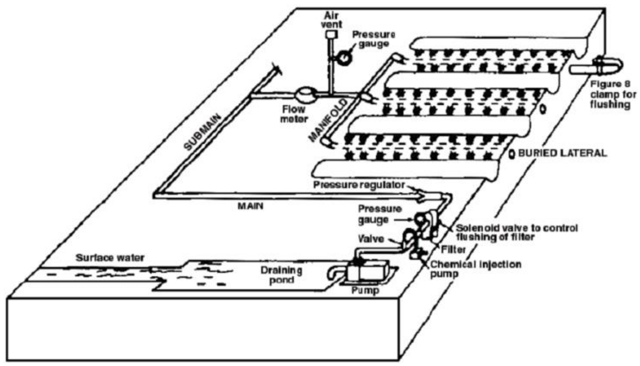
Irrigation Technologies

The figure below shows two major types of irrigation; i.e., surface/flood irrigation and sprinkler irrigation practices. Drip and sprinkler irrigation techniques are much more efficient than flooding (also known as surface) irrigation methods. Drip irrigation/trickle irrigation involves dripping water onto the soil at very low rates (2-20 L/h). This system uses a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied close to plants so that only part of the soil in which the roots grow. Surface and sprinkler irrigation, on the other hand involves wetting the whole soil profile. But , the water enclosed in the pipes of sprinkler systems is much less prone to evaporation than surface/flooding irrigation system

[87] Hoff, H. (2011). Understanding the Nexus: Background Paper for Bonn 2011 Conference: The Water, Energy and Food Security Nexus. Stockholm: Stockholm Environment Institute Report

[88] Tuong, T.P., Bouman, B. (2001). Rice Production in Water-Scarce Environments. Paper presented at the Water Productivity Workshop, International Water Management Institute. Colombo, Sri Lanka, 12–14 November





Drip irrigation

Sprinkler irrigation

Compiled from:

http://12.000.scripts.mit.edu/mission2017/irrigation/

http://www.depi.vic.gov.au/agriculture-and-food/farm-management/soil-and-water/irrigation/irrigation-scheduling-for-regulated-deficit-irrigation-rdi

Some of the arguments also suggest trade of 'virtual water' can be used as a policy option for food and water security. Some countries indirectly consume more freshwater resources than they have access to within their boundaries by relying on food imports from other nations. Virtual water basically is the trade of (food) products with higher water content.

4.1.5 Efficient Use of Water in Industries

The United Nations has proposed a set of potential targets and indicators for a global goal for water sustainability. A core indicator is the change in industrial GDP per industrial withdrawals. With regard to industry, the main elements within the target are reduction in untreated industrial wastewater and increase in safe reuse of wastewater[89].

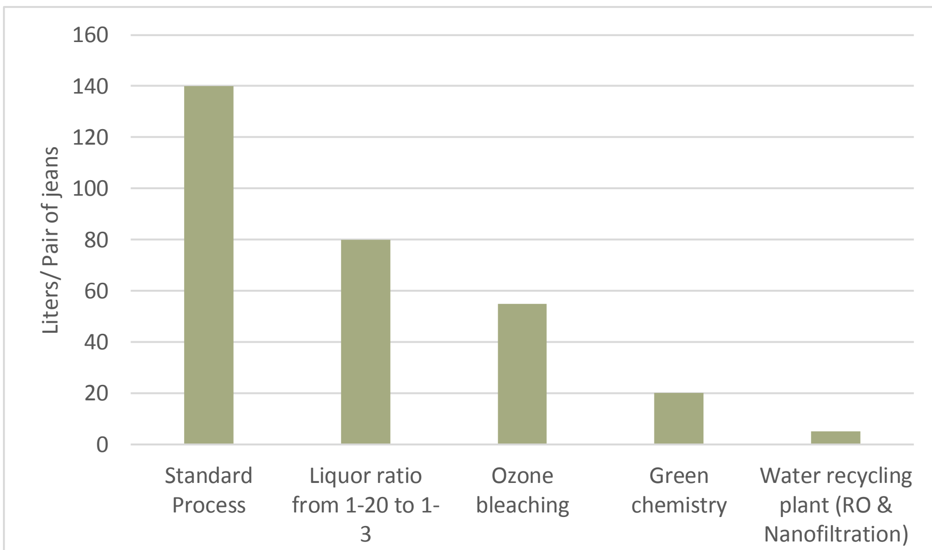
Decreasing availability of freshwater resource and higher cost of raw water have forced industries to rapidly adapt to the situation by implementing water conservation and recycling technologies. Many industries are now

[89] UN-Water. (2014). A Post-2015 Global Goal for Water: Synthesis of Key Findings and Recommendations from UN-Water. New York, UN-Water. http://www.un.org/waterforlifedecade/pdf/27_01_2014_un-water_paper_on_a_post2015_global_goal_for_water.pdf

concentrating on methods to reduce potable water intake and to promote zero discharge, which eliminates the need for an environmental permit but can be costly. The move towards water reuse is often associated with implementation of cleaner production techniques which may also include internal water recycling, reuse of treated industrial or municipal wastewater, use of treated wastewater for other activities[90]. Industrial facilities have a good potential for raising their water efficiency rates. Cleaner production (improved production planning and sequencing, good housekeeping, process/equipment modifications, product/material changes or technology changes, closed loop reuse and recycling, counter-current rinsing, reuse of wash water etc.), is one of the tools for reducing industrial water consumption.

Water Efficiency at Saitex International Vietnam Co., Ltd, Ho Chi Minh City

Saitex International, a Vietnamese denim manufacturer, also known as one of the most environmental friendly denim manufacturer in the world has achieved a remarkable success in reducing its water consumption from laundry activity. By adopting Jet washing and Jet dying machine, the factory is able to reduce from 140 to 6 L of water per pair of jeans washing. Saitex saves 266,400 m^3, with 167,832 US$ annually. These measures have lead the Saitex International to achieve total water reduction of 92.5%.



The industry recycles the water, hence closing the loop. It applies the advanced Reverse Osmosis, desalination, and nano-filtration technologies to recycle 96% of its wastewater treatment, which gives clean water to be reused in the production process. Sludge is also recycled into bricks. The factory premise also uses Solar panels – for heating water, saving energy. The building uses all sustainable practices, which make is certified with LEED certificate by U.S. Green Building Council, and is the only blue sign certified laundry.

Compiled from:
https://www.wewear.org/assets/1/7/051712SanjeevBahlENG.pdf
https://www.youtube.com/watch?v=TwXQS9NCVbI

Experience from around the world shows that adopting a systematic approach to water efficiency often results in reduced water consumption by 20-50%and up to 90%[91]. Eco-industrial parks ensure effective management of water and effluents together with liquid and solid materials recovery, through collective water supply, effluent collection, and treatment. The eco-industrial parks can benefit from specialized design, pooling best available technology, and risk reduction and risk sharing. Even at individual scale, some progressive industries are showing water stewardship as part of green industry initiative, showing their reactiveness in conservation, restoration, and management of

[90]Visvanathan, C., Asano, T. (2001). Industries and water recycling and reuse. 2001 Founders Seminar, Stockholm City Conference Center, Norra Latin. 15 August 2001
[91]AFED. (2010). Water Efficiency Handbook. Chapter 3- Water use efficiency in industry. Arab Forum for Environment and Development. ISBN: 978-9953-437-33-0

water resources, reducing their water footprint at every successive steps in their value chain of the processes and products, and reusing the reclaimed wastewater.

Innovating pollution control and industrial symbiosis to realize PR China's "circular economy"

To reduce pollution in Chinese cities, new policies were introduced mandating that the most polluting industries be concentrated within specialized industrial parks. Shanghai Chemical Industrial Park (SCIP) was created in 1999 with the aim of becoming one of the world's top ten petrochemical platforms. As a municipal industrial park, SCIP was the target of large quantities of investment to produce ethylene cracker. The park currently covers some 30 km^2 and has an annual turnover of US$ 17 billion (2013).

For new industries looking to invest in the park, need to go through an environmental impact assessment (EIA). If the assessment determines that the pollution generated is too great or too toxic to be treated, the industry is not provided the opportunity to invest in the park. Subsequently, the bureau monitors pollution levels from industrial processes.
All liquid effluent flows are concentrated and directed to a processing plant that is jointly operated by the Park Committee. The plant provides continuous 24/7 monitoring of all individual New industrial parks allowing industries to focus on their primary activities, while leaving pollution control and monitoring to centralized and specialized facilities. Contingency procedures are in place for highly toxic discharges or accidents. In addition to monitoring within the park, ocean water quality is tested in the vicinity of the plant outlet twice each year. The Shanghai Chemical Industrial Park is also considered a model of "industrial symbiosis" where the output or waste of one process or factory becomes the input to another.

Compiled from:

UNESCAP/K-Water (2015). Case Studies on Water and Green Growth in Asia and the Pacific. United Nations Economic and Social Commission for Asia and the Pacific and K-water

Asia's cities must practice reduction in water consumption, and reusing and recycling precious water resources to manage the water demand. Demand management requires many behavioural, policy and technology measures to reduce water consumption pattern. Some of these sustainable solutions include; water saving practices and technologies and/or water conservation ordinances or installation of water meters and water-saving devices, awareness on water saving attitudes, upstream water and watershed management, rainwater harvesting and ground water recharge, improving water usage efficiency in irrigation and industrial applications etc.

4.2 Reuse of Wastewater

This section discusses various water reclamation and reuse opportunities with different social, economic, and environmental values, and as a tool to achieve water security. Many of the water insecurity issues can be reduced to some extent by reclaiming wastewater. The technology, policy options, and existing cases of wastewater reclaim and reuse in agricultural use, non-potable urban uses, drinking water augmentation and aquifer recharge, restoration of water bodies and wetlands, and industrial applications are also mentioned.

4.2.1 Wastewater as a Resource

Some 80-90% of wastewater in developing countries is discharged into the waterways without proper treatment, thereby polluting water supplies of downstream users. Undoubtedly, the unmanaged wastewater is responsible for human and ecosystem health hazard, with consequences of social, economic, and environmental dimensions. Untreated wastewater is a source of many disastrous waterborne diseases, causing health challenges restricting development and increasing poverty through costs to health care and lost labour productivity[92]. Wastewater pollutants affect aquatic ecosystems leading to algal bloom with excessive nutrients, and affect food system with infested chemicals in the system. Polluted water used for irrigation affects crop productivity as well as farmers' health due to contamination. But, wastewater need not always be a problem and a drain on resources. In the

[92]Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

situation where one-fifth of the world's population is already living in water scarcity and these numbers are set to rise further, reducing unregulated discharge of wastewater and reclaiming and reusing treated water can become a solution. Given such potential, innovative wastewater management is an opportunity not to be wasted. Reclaim and reuse of wastewater is almost virtually creating a new water cycle, as shown in **Figure 4.3.** The future tendency of integrated urban water cycle plan should therefore integrate water supply, wastewater collection and treatment, and reclaim and reuse of treated wastewater for various potable and non-potable usage.

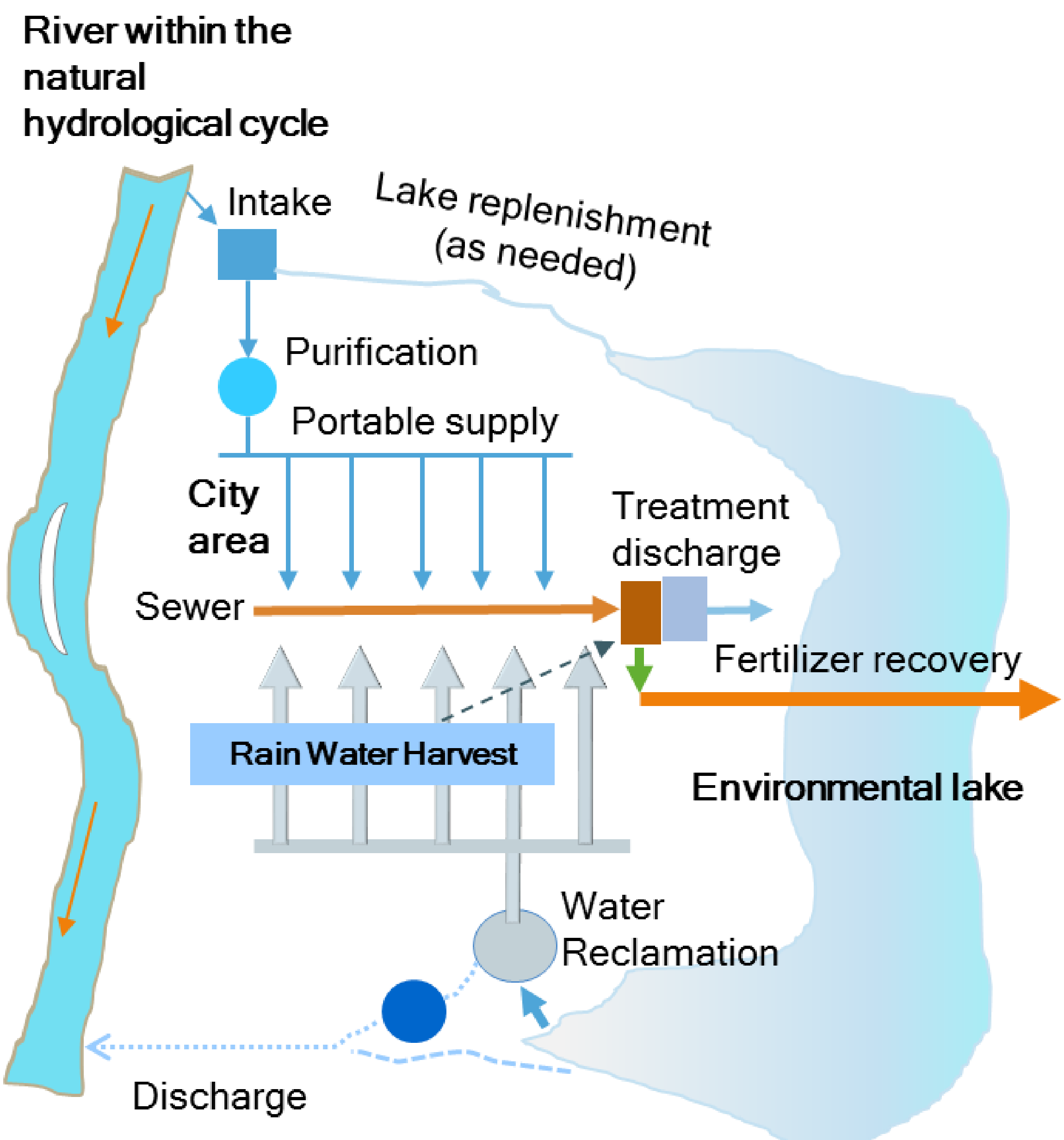


Figure 4-3: An integrated framework of urban water supply, wastewater treatment, and reuse[93]

[93] Tambo et al. (2012). Cited in Wang, X.C., Zhang, C., Ma, X., Luo, L (2015). Water Cycle Management- A New Paradigm of Wastewater Reuse and Safety Control. Springer. ISBN 978-3-662-45821-1

Municipal and industrial wastewater reclamation and storm drainage management offers many economic and environmental opportunities. Sewage, household grey water, and wastewater contain potential sources of fertilizer, nutrients, and energy, which can be recovered for secondary uses. Wastewater reclamation is the treatment or processing of wastewater to make it reusable, and water reuse is the use of treated wastewater for beneficial purposes such as irrigation and industrial cooling. Reclaimed water is a treated effluent suitable for an intended water reuse application. In addition, direct water reuse requires the existence of pipes or other conveyance facilities for delivering reclaimed water. Indirect reuse, through discharge of an effluent to receiving water for assimilation and withdrawals downstream, is recognized to be important but does not constitute planned direct water reuse.

Treated wastewater is an alternative water resource with multi-use applications in agriculture, industry, aquaculture, urban and recreational uses, groundwater recharge, and drinking water supply. Sludge from wastewater treatment can also be recovered as a nutrient resource (N & P), as well as a source of renewable energy. Water recycling and reuse has far reaching benefits, such as;

- Reduction in freshwater withdrawal and consumption
- Minimization of wastewater discharge by reclaiming wastewater, thereby reducing clean-up costs and discharge liabilities
- Recovery of valuable by-products
- Improvement of the profit margin by cost reduction
- Enhancement of corporate image, public acceptance, and environmental responsibility

If treated well, it can also replenish water courses or be reused directly for many purposes. Better management of wastewater would contribute to a solution to water scarcity as well as water pollution.

Wastewater Reuse Terminology

Alternative water source: municipal and industrial wastewater, storm water, rainwater

Wastewater reclamation: involves the treatment or processing of wastewater to make it reusable

Wastewater reuse/water reuse: is the beneficial use of the treated water

Wastewater recycling: usually captures the wastewater (especially from industries) and is redirected back into that same scheme

Direct reuse: the use of reclaimed wastewater where there is a direct link from the treatment system to the reuse application. Examples include; landscape and agricultural applications, urban applications, and dual water systems.

Indirect reuse: includes mixing, dilution, and dispersion of reclaimed wastewater by discharge into impoundments, receiving water, or groundwater aquifer prior to reuse such as groundwater recharge

Potable water reuse: refers to the use of highly treated reclaimed water for drinking purposes

Non-potable water reuse: includes all uses of water other than drinking water supplies

Compiled from
Asana, T. (1998). Wastewater Reclamation and Reuse. Water Quality Management Library, Vol. 10. Technomic Publishing Company Inc, USA. ISBN 1566766206

Wastewater reclamation and reuse supports the closed-loop systems for the realization of circular economy. Investing in water and sanitation and wastewater management will lead to increased levels of human health, reduced levels of poverty and indigence, and increased opportunities for education and employment, resulting in overall national economic development[94]. The proposed Goal 6 of the Sustainable Development Goal also includes

[94]UNU. (2013). Water Security & the Global Water Agenda. A UN-Water Analytical Brief. United Nations University. ISBN 978-92-808-6038-2

wastewater management as part of sustainable water management, with the target of halving the proportion of untreated wastewater and increasing recycling and safe reuse by 2030. Closing the water cycle requires source separation and management of wastewater. Currently, many cities lack wastewater infrastructures. Inadequate attention is being given to the collection, treatment, and disposal/reuse of wastewater. As wastewater production will rise, investments to replace under-dimensioned and aged wastewater infrastructure, and primitive technologies are required to handle the increasing, domestic, industrial, and agricultural wastewater. However, the wastewater treatment market in the region has substantially expanded in recent years. The industry research publication titled 'Asia Pacific Wastewater Treatment and Management Industry Outlook to 2018 – Increasing Government & Private Investments to Drive the Future Growth' says that the wastewater treatment market increasing in the region. The countries in the region are trying to reduce their environmental footprint by opting for superior and novel wastewater technologies or equipment. Japan, owing to its latest technologies and wide coverage of wastewater treatment plants, was the largest contributor to the market revenues. The Wastewater Treatment market in PR China is the second largest in Central and Asia Pacific region. India held the next leading position in the market[95].

Wise investments in wastewater management systems and technological innovations will generate significant returns in terms of reducing poverty and sustaining ecosystem services. Valuation of these benefits should be made to justify suitable investment policies and financing mechanisms[96].

Smart Wastewater Treatment Project is not a Liability but a Revenue Generator!

Unplanned development damaged the coastal waters surrounding Xiamen City. All domestic and industrial wastewater was also discharged untreated into coastal waters. There was a history of oil and chemical spilling too. The situation was especially bad in Yuandang. In 1980, the Bay had been cut off from sea by a causeway. Water body shrank to 1/5 of its original surface area. Foul smell from the area repulsed would-be investors in the city, residents began to flee the area.

In 1988, Xiamen began, Yuandang rehabilitation project. The project invested in infrastructures to capture and treat the polluted waters. The almost dead water with Dissolved Oxygen at 0 mg/L improved to 5.2 mg/L, and met the national standards. With the change in surrounding water quality, the area regained its charm and high-rise buildings rapidly increased in number attracting big business. Of the 173 investors, 53% cited good environment as a reason for relocation. The city government generated funds by levying fees for use of sea areas, waste disposal, and exceeding waste standards. Thus, collected funds were used for marine management. Xiamen has invested a total of US$2 billion in sewage treatment over the last 20 years (XOFB, 2009). Treatment of industrial sewage increased from 20% in 1994 to nearly 100% in 2000, while treatment of domestic sewage rose from 28% in 1995 to 85% in 2007 (PEMSEA, 2006). Xiamen has not only become more sustainable, its beauty has also attracted immigrants, tourists, and real-estate development. A sense of pride in the beauty of their city has also grown in Xiamen's people.

Compiled from:
PEMSEA (Partnerships in Environmental Management for the Seas of East Asia). 2006. A perspective on the environmental and socioeconomic benefits and costs of ICM: the case of Xiamen, PR China. PEMSEA Technical Report. No. 17, 132 p. Quezon City, Philippines: GEF/UNDP/IMO PEMSEA
XOFB (Xiamen Ocean and Fisheries Bureau). 2009. Bulletin of marine environmental quality in Xiamen 2008.

95 http://www.reportlinker.com/p02088300-summary/Asia-Pacific-Wastewater-Treatment-and-Management-Industry-Outlook-to-Increasing-Government-Private-Investments-to-Drive-the-Future-Growth.html

96 Hernández-Sancho, F., Molinos-Senantea, M., Sala-Garrido, R. (2010). Economic Valuation of Environmental Benefits from Wastewater Treatment Processes: An Empirical Approach for Spain. Science of The Total Environment. 408 (4), pp 953-957

Beira Lake Restoration, Sri Lanka

Beira Lake was originally built before the colonization of the country and connected to many intricate canals providing easy way of transporting goods within the city and suburban areas. The lake was one of the most polluted water body with unpleasant odour and regular outbreaks of algal blooms. The source of pollution was nitrate rich wastewater discharge from motor repair garages, as well as wastewater from hospitals. A survey carried out in 1985 by the National Aquatic Resources Research and Development Agency (NARA) revealed that over 2000 waste outlets were open to the Beira Lake. Garbage and sewer tanks, squatters' latrines also directly open to the lake. Reduced DO level in the water caused fish deaths.

However, with the Beira Lake restoration project, in coordination with Sri Lanka Navy, Urban Development Authority, and the Colombo Municipal Council, the lake is becoming cleaner. The project aimed to develop the areas surrounding the lake under the City Beautification Project.

- Improve water quality in the Beira Lake – diversion of sewerage network from the lake, relocation of unauthorized houses
- Conserve the existing aquatic fauna to maintain the sustainability of the lake.
- Improve the scenic and beauty of Beira Lake and Colombo City as a commercial hub.
- Generate potential for different commercial benefits such as water transport and sports
- Enhance commercial investment opportunities in the surrounding area.

One of the economic benefit of the clean-up program is the completely transformed look of the Beira Lake. The Urban Development Authority rehabilitated the south west side of the lake into tourist attraction. Beira Lake is in the heart of the city of Colombo, Sri Lanka, and is now surrounded by many large businesses in the city. Once polluted lake is now a popular urban water recreational spot with boating and fishing activities.

Compiled from:

http://srilog.com/project-to-develop-beira-lake-in-colombo-as-a-tourist-attraction_3315.html

4.2.2 Wastewater Reclaim and Reuse in Various Sectors

Agriculture, urban and industrial water uses produce equally large proportion of wastewater, but at the same time these are the potential sectors for wastewater reclaim and reuse. Wastewater from urban water use usually is from sewage. Lack of adequate sewerage connection and wastewater treatment infrastructure causes further pollution of water ways and groundwater. Industry generates a substantial proportion of toxic wastewater, with complex organic compounds and heavy metals released into the environment causing both human health and environmental disasters. In many developing countries more than 70 % of industrial wastes are dumped untreated into waters where they pollute the usable water supply[97]. Current practice of food production and livestock rearing uses 70–90% of the available fresh water, returning much of this water to the system with additional nutrients and contaminants; originating from dissolved contents of fertilizers, chemical runoff (such as pesticides), human waste, livestock manure and nutrients. Nitrogen and Phosphorous are two major anthropogenic addition to waterways. Agricultural practices, primarily the cultivation of nitrogen fixing crops and the manufacture of fertilizer convert about 120 million tonnes of nitrogen from the atmosphere per year into reactive nitrogen containing compounds. Up to two-thirds of the total nitrogen makes its way into inland waterways and the coastal zone. Similarly, approximately 20 million tonnes of phosphorus a year is used mainly as fertilizer, but almost half of this finds its way back into the ocean[98]. Together, the excess nitrogen and phosphorus cause algal blooms, including toxic red tides affects fish stocks or human health.

The acceptability of the reclaimed water for the specific reuse depends on the physical, chemical, and microbiological quality of the treated water, as depicted in **Figure 4.4**.

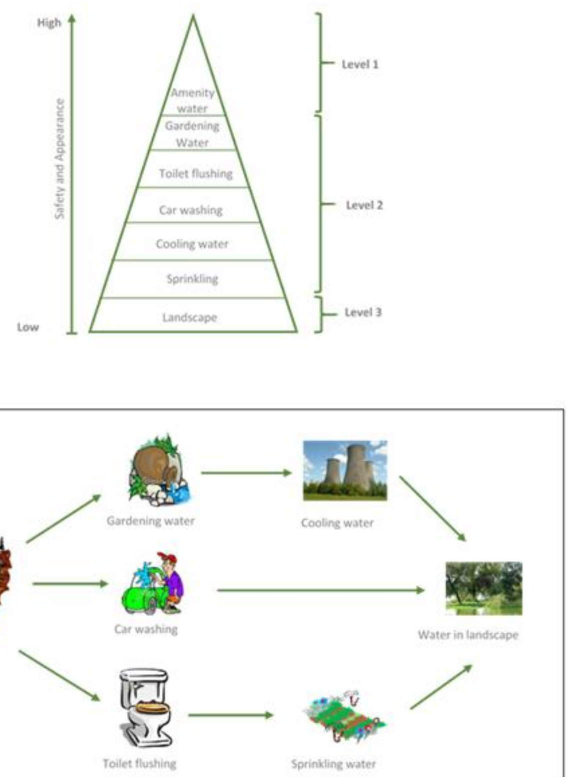


Figure 4-4: Water quality levels for different water reuse applications

[97]WWAP. (2009). The United Nations World Water Development Report 3: Water in a Changing World. Paris, UNESCO, and London, Earthscan. World Water Assessment Programme http://unesdoc.unesco.org/images/0018/001819/181993e.pdf

[98]Rockström, J., Steffen, W. Noone, K., Persson, Å., Chapin, F.S. et al. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. Ecology and Society 14(2), p32. Available at: http://www.ecologyandsociety.org/vol14/iss2/art32/

4.2.2.1 Wastewater Reclaim and Reuse in Agriculture

Agriculture is one of the water intensive sectors, and at the same time is the largest potential sector for the reuse of treated wastewater. On a world-wide basis wastewater is the most widely used low-quality water, particularly for agriculture and aquaculture[99]. Reuse of reclaimed water for irrigation enhances agricultural productivity: it provides water and nutrients, and improves crop yields[100]. Wastewater treatment and reuse in agriculture can provide benefits to farmers in conserving fresh water resources, improving soil integrity, preventing discharge to surface and groundwater waters, and economic benefits in fertilizer savings. Wastewater has been reused in irrigation since historic times. Currently, 10% of world's population relies on food grown with contaminated wastewater[101]. In Pakistan, 26% of national vegetable production originates from urban and peri-urban agriculture irrigated with wastewater[102]. In Hanoi peri-urban agriculture, using diluted wastewater, provides 60–80 %of the perishable food for local markets[103].

Chinese Wastewater Reuse Systems

PR China has a long tradition of reuse of garbage and human excreta in agriculture and aquaculture. The classical night soil system was reported to reuse as much as 90% in agriculture. Reuse of wastewater from large cities in aquaculture started in 1951 in Wuhan, reaching a peak of 20,000 ha by the 1980s (Edwards, 1992). Of the total amount of wastewater in PR China, which reached almost 80 billion tons annually around year 2000, 75% was of industrial origin. Wastewater treatment has fallen behind with only 24% treatment of industrial wastewater and 4% of domestic sewage being treated. Irrigation with municipal wastewater began in large scale in the late 1950s, and it reached about 1.5 million ha in 1995 covering around 1% of the total cultivated land of PR China (Ou and Sun, 1996). The reuse of wastewater in aquaculture systems has been linked to traditional concepts of "Integrated Farming" and "Fish Polycultures."

Compiled from:
Edwards P. 1992. Reuse of human wastes in aquaculture, a technical review. UNDP-World Bank, Water and Sanitation Program, 350 pp.
Ou Z.Q. and T.H. Sun. 1996. From sewage irrigation to ecological engineering treatment for wastewater in PR China.

Whilst considering the reuse of wastewater, utmost care has to be given in promoting appropriate and innovative technologies that are socially and culturally acceptable, economically viable, and environmentally suitable. However, before using wastewater into irrigation and food production, care must be taken to treat it to acceptable level of reuse. Considering the potential of toxic metals and chemicals entering into the food chain, greater care must be given to monitor the presence of highly toxic elements such as Cadmium, Copper and Molybdenum. Untreated wastewater can kill the plant with overloaded nitrogen, phosphorus and potassium (NPK) (algal bloom in water bodies), but the treated effluent can supplement the NPK normally required for agricultural crop production. Other risks of wastewater in irrigation is health risks to farmers who come in direct contact with wastewater affected through faecal-oral transmission pathways or contact with disease vectors in the water, such as schistosomiasis[104].

Some countries have national guidelines for the acceptable use of wastewater for irrigation, many do not. The Guidelines on the Safe Use of Wastewater, Excreta and Grey water in Agriculture and Aquaculture[105] provide a comprehensive framework for risk assessment and management that can be applied at different levels and in a

[99] Helmer, R., Hespanhol, I. (1997). Water Pollution Control - A Guide to the Use of Water Quality Management. Chapter 4- Wastewater as a Resource. WHO/UNEP. ISBN 0 419 22910 8

[100] Bahri A. (1999). Agricultural Reuse of Wastewater and Global Water Management, Wat. Sci. Tech., 40 (4-5), pp. 339-346

[101] WHO/FAO. (2006). Guidelines for the Safe Use of Wastewater, Excreta and Grey Water in Agriculture and Aquaculture, 3rd edition. Volumes 1 – 4. Geneva, World Health Organization. http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html

[102] Ensink, J., T. Mahmood, W. van der Hoek, L. Raschid-Sally, and F.P. Amerasinghe. (2004). A Nation-wide Assessment of Wastewater Use in Pakistan: An Obscure Activity or a Vitally Important One? Water Policy. Vol 6: 197-206

[103] Lai, T. (2002). Perspectives of Peri-urban Vegetable Production in Hanoi. Background Paper Prepared for the Action Planning Workshop for the CGIAR Strategic Initiative for Urban and Peri-urban Agriculture (SIUPA), Hanoi, 6-9 June 2002, convened by the International Potato Centre, Lima, Peru
van den Berg L.M., van Wijk, M.S., Van Hoi. P. (2003). The Transformation of Agriculture and Rural Life Downstream of Hanoi. Environment and Urbanization 15, pp 35-52

[104] Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

[105] WHO/FAO. (2006). Guidelines for the Safe Use of Wastewater, Excreta and Grey Water in Agriculture and Aquaculture, 3rd edition. Volumes 1 – 4. Geneva, World Health Organization. http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html

range of socio-economic circumstances. Only a few Asian countries have experience in planned reuse and wastewater treatment plants producing a safe water.

4.2.2.2 Wastewater Reclaim and Reuse in Ecosystem Functions

Wastewater reuse can also have other reuse potential for environmental water enhancement, to facilitate ecosystem recovery such as restoration of rivers, augmentation of natural/artificial streams and groundwater aquifers recharge, and for recreation and landscape enhancement. This way the wastewater ultimately helps to restore and replenish freshwater resources.

India – Calcutta Wetlands

In the 1980s, the wetlands east of Calcutta were restored in the context of the Ganga Action Plan (GAP), using an ecosystem approach for solving the problems of municipal sanitation. The Calcutta Wetlands using wastewater both in agriculture and in aquaculture covered an area of about 12,000 ha, known as the Waste Recycling Region (Ghosh, 1996). The social-economic and environmental benefits were; employment for about 17,000 poor people and production of about 20 tonnes of fish per day for the urban poor (Edwards, 2000), and reducing environmental impacts of contamination from heavy metals from the tanneries in Calcutta.

Compiled from:
Edwards P. 2000. Wastewater-fed aquaculture: state of the art. In: B.B. Jana, R.D. Banerjee, B. Guterstam, J. Heeb (Eds.) Waste recycling and resource management in the developing world. University of Kalyani, India and International Ecological Engineering Society, Switzerland. pp. 37-49.
Ghosh D. 1996. Turning around for a community based technology, towards a wetland option for wastewater treatment and resource recovery that is less expensive, farmer centered and ecologically balanced. Calcutta Metropolitan Water and Sanitation Authority, 21pp.

Reviving of flora and fauna by restoration of river flow

The Meguro River, which flows through a residential area in Tokyo, had been abandoned by residents due to the decreasing flow of water and pollution with an unpleasant odour. To solve this issue, the Tokyo Metropolitan Government released water treated with UV radiation into the river. With the drastic improvement in water volume and quality, aquatic biodiversity and environmental amenities have thus been restored effectively with wastewater reuse.

Compiled from:
Tokyo Metropolitan Government (2001), Sewage in Tokyo - Advanced Technology [online] Available from
<http://www.gesui.metro.tokyo.jp/english/technology.htm>. In UNEP/GEC, 2005. Water and wastewater reuse- An Environmentally Sound Approach for Sustainable Urban Water Management. Booklet.

Reuse of wastewater for groundwater recharge: Montebello Forebay Groundwater Recharge Project, Los Angeles County, California

Reclaimed municipal wastewater has been successfully applied to recharge a potable ground water aquifer in south-central Los Angeles County in California for over 50 years. This is the oldest planned groundwater recharge project using recycled water in California. To date, over 1.6 million ac-ft (1,970 MCM) of recycled water has been recharged at the MFGRP to replenish the Central Groundwater Basin, which provides 40% of the total water supply for Los Angeles County.

Water is percolated into the groundwater using two sets of spreading grounds: the Rio Hondo Coastal Spreading Grounds, which consist of 235 ha with 20 individual basins, and the San Gabriel Coastal Spreading Grounds which consists of 52 ha with 3 individual basins. Recycled water is conveyed to spreading grounds by gravity through existing waterways and operated under a wetting/drying cycle designed to optimize inflow and discourage development of vectors.

This project provides a new water supply roughly to a quarter of a million people. In addition, the use of recycled water has saved tens of millions of dollars a year in water purchases for replenishing the groundwater.

Compiled from:
Monica Gasca, P.E. and Earle Hartling (2012). Montebello Forebay Groundwater Recharge Project using Recycled Water, Los Angeles County, California. USEPA (2012). Guidelines for Water Reuse.

4.2.2.3 Wastewater Reclaim and Reuse in Industries

Industrial reuse of the reclaimed wastewater is the second major reuse after irrigation. Various types of industrial water reuse is presented in **Table 4.3** below[106]. Water reuse and recycling in the industrial process can be achieved by implementing cleaner production good operating practices, changing to technologies that require less process water, and on-site reuse and recycling. Wastewater reuse for industry can be implemented through the reuse of municipal wastewater in industrial processes and internal close-loop recycling (Zero Liquid Discharge-ZLD), hence realizing the circular economic utilization of wastewater. The three major uses of water within industry are for heat dissipation, power generation, and processing. Often 50 % or more of the water intake in industry may be used for the purpose of process cooling alone, a need that can often be met with lesser quality water saving the potable water for truly potable needs. **Table 4.4** below shows the water saving potential in Industries.

Table 4.3: Water-saving potential in industry

Efficiency Measures	Potential saving (%)
Closed loop reuse	90
Closed loop recycling with treatment	60
Automatic shut-off valves	15
Counter-current rinsing	40
High-pressure, low-volume upgrades	20
Reuse of wash water	50

The potential use of reclaimed water for industrial processes depends on the water quality requirement. For example, the electroplating industry requires almost distilled water for washing circuit boards and electronic components whereas tanneries can use relatively low quality water for washing hides. The scope of water recycling and reuse varies according to the type of industry, the requirement of the process, the type of wastewater produced and the treatment technology used. Simple physico-chemical treatment may be sufficient for wastewater produced from some activities like floor washing, while wastewater containing such contaminants as heavy metals, toxic chemicals, and refractory inorganics may need advanced treatment or may be considered for products recovery. **Table 4.4** below shows the types of wastewater reuse in various industrial process[107].

Table 4.4: 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 application
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 premises
Non-industrial use of effluent	Heating water for pools and spas Agricultural applications

[106]Asano, T., Levine, A. (1998). Wastewater Reclamation, Recycling and Reuse: Introduction. In: Asano, T. (ed.), Wastewater Reclamation and Reuse, CRC Press, Boca Raton, Florida, USA, pp.1-55

[107]Visvanathan, C., Asano, T. (2001). Industries and water recycling and reuse. 2001 Founders Seminar, Stockholm City Conference Center, Norra Latin. 15 August 2001.

Potential water saving in Indian thermal power plants through water recycling

Energy production is water intensive process. In India, thermal power plants accounted approximately 88% of industrial water usage as of 2012. About 40% of freshwater intake is used in the process of wet ash handling, during which a slurry is created from ash and water, and transported to nearby dykes for disposal. High levels of water loss (50-80%) are experienced during this process. 25% of thermal power plants in India continue to use "once-through" systems in cooling towers to dissipate heat from condensers. These systems require a continuous flow of water, and demand is 30-50 times higher than in "closed-cycle" systems where water is re-circulated and treated with clarified water to compensate for evaporation.

Effective recycling of wastewater could reduce freshwater intakes by 18 to 26%. Furthermore, water audits revealed that power plants of 3,000 MW capacity could potentially save 17.9 million m^3/year of water and approximately 72 million rupees annually through the recycling of drain wastewater. Implementing the recycle/reuse system is considered cost effective, with the payback period for implementing the system being less than 3 years. Implementing the interventions identified above, the potential volume of water savings equals 81,000 m^3 per day, over 65.2 million m^3 per year, and a total reduction of 61% of total water usage.

Compiled from:

UNESCAP (2015). Case Studies on Water and Green Growth in Asia and the Pacific. United Nations Economic and Social Commission for Asia and the Pacific and K-water

Many Electric Utilities companies are successfully utilizing municipal wastewater. Power-generating stations have a huge cooling water requirement, they provide potential reuse locations for reclaimed sewage. The impending freshwater shortages and increasing electricity demand have encouraged the reuse of municipal wastewater in electric utilities companies. Reclaimed water from municipal wastewater treatment plants can safely meet the needs of the power producing process while conserving freshwater for other uses[108].

Reuse of municipal waste water at Eraring power station, New South Wales Australia

Eraring Power Station located near Lake Macquarie in the Hunter Region of New South Wales is Australia's largest power station, with the total capacity of 2,880MW. It is a successful example for reuse of domestic wastewater for industrial cooling. It has been accepting recycled water, in the form secondary treated recycled water from the Dora Creek Wastewater Treatment works, the onsite sewerage treatment plant and the Myuna Bay Sport and Recreational Club since 1995. Eraring treat the water onsite using microfiltration (coupled with sodium hypochlorite disinfection) and reverse osmosis to generate a high quality recycled water primarily for boiler feed, and recirculating evaporative cooling systems. In FY 2014, the reliance on potable water decreased as the volume of reclaimed water generated on site increased by 80% from 1.4 ML per day to 2.4 ML per day.

Compiled from:
Milne et. Al., 2009, and , http://www.originenergy.com.au/sustainability/material-aspects/protecting-water-resources)

Many industries are moving further towards zero liquid discharge (ZLD) by investing on closing the water-loop within the industry by using various advanced water treatment technologies. ZLD describes a process that completely eliminates liquid discharge from a system. The goal of any well-designed ZLD system is to minimize the volume of wastewater that requires treatment, process wastewater in an economically feasible manner, while also producing a clean stream suitable for reuse elsewhere in the facility.

Along with the regulatory requirements to safe disposal of industrial wastewater, one of the strongest driving force for reuse of the treated wastewater in industries is the ever-growing water scarcity. Hence, industries first inclination is to recover and recycle rather than discharge the wastewater. Other drivers include the potential savings the industries can make as compared to extraction of freshwater and wastewater and sludge disposal cost.

[108] ASME/WEF (2012). Municipal Wastewater Reuse by Electric Utilities: Best Practices and Future Directions. Workshop Report, 12 September 2012. Water Environment Federation

4.2.2.4 Municipal Wastewater Recycling and Reuse for Urban Applications

Reuse of wastewater can supplement existing water sources, especially in water hungry urban clusters. If treated using advanced technologies, recycled wastewater can also have potable reuse. However, one of the key concerns for wastewater reuse in urban applications is the protection of public health, hence, care must be taken to avoid contamination of drinking water by misconnection (cross connection) between potable water pipes and reclaimed water pipes, and also to disinfect reclaimed wastewater properly.

Wastewater may be reused for non-potable municipal purposes mainly for domestic uses in toilet flushing, car washing, gardening etc. In some developed countries, such reclaimed water for non-potable use is distributed through a dual distribution systems/dual reticulation (one for drinking water and the other for reclaimed water) as shown in **Figure 4.5** below. A purple pipe is used to supply this alternate water so as to reduce the risk of inappropriate use. Countries like Singapore, the United States of America, the United Arab Emirates and Israel use recycled water as a component of their water supply system. Each house is provided with two pipelines, one at for drinking water and the purple pipeline for recycled water. Recycled water is usually limited to the use in garden watering, toilet flushing. However, depending on the level of treatment and quality of the recycled water the usage can be extended to car washing, irrigation in open space, and fire hydrant etc.

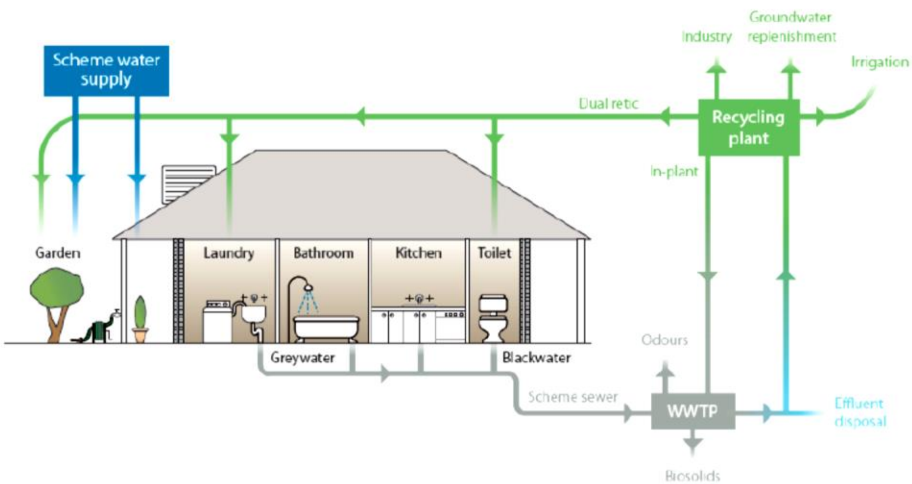
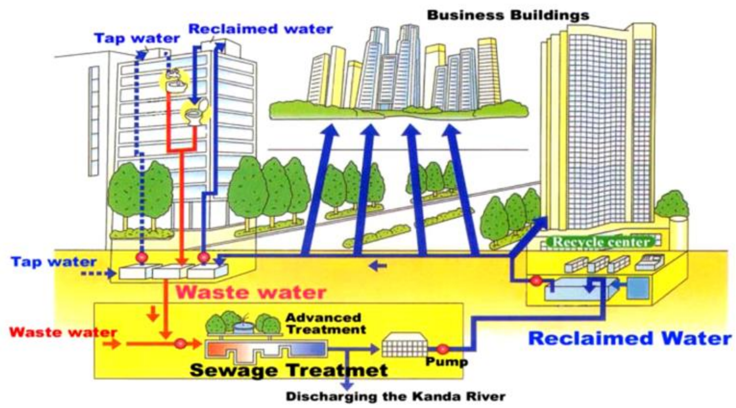


Figure 4-5: Source of wastewater and recycling opportunities[109]

[109]Government of Western Australia, Department of Water (2013). Information Sheet – July 2013. Dual Reticulation (Non-drinking water) Schemes. ISBN: 1 74043 7535

Wastewater reuse in Japan through dual distribution systems

Tokyo is one of the leading cities successfully implementing dual distribution systems for wastewater reuse. In Shinjuku area of Tokyo, a dual distribution system has been adopted for reusing treated water from Ochiai Municipal Wastewater Treatment Plant. Reclaimed water is chlorinated and used as toilet-flushing water in 25 high-rise business premises, and as well as for stream augmentation. The system, which has been successfully operated since 1984, is supplying treated wastewater up to a maximum 8,000 m^3/day (Tokyo Metropolitan Government, 2001). There is also a small-scale on-site system where the grey water is recycled as an in-building water resource, with a dual distribution system.



Scheme of area recycling system in Shinjuku, Tokyo, Japan

Compiled from:

Tokyo Metropolitan Government (2001), Sewage in Tokyo - Advanced Technology [online] Available from <http://www.gesui.metro.tokyo.jp/english/technology.htm>. In UNEP/GEC, 2005. Water and wastewater reuse- An Environmentally Sound Approach for Sustainable Urban Water Management. Booklet.

Water supplies are being enhanced in many countries through innovative wastewater treatment and reuse techniques, going beyond non-potable use to direct potable consumption as drinking water.

Chief Minister Drinks "Toilet-to-tap" water, New Delhi, India

Keshopur sewage treatment plant in Delhi has recently started "toilet-to-tap" project. A joint venture between the Delhi Jal Board (DJB) and an NGO - Social Awareness Newer Alternatives produces drinking water from raw sewage. Such decentralized small treatment plant is a smart solution amid increasing demand for water and depletion of groundwater resources in the city for its 16 million people. Delhi's chief minister Mr. Arvind Kejriwal inaugurated the treatment plant by drinking the treated water himself.

'Sujala Dhara- the treatment system' is expected to generate 4,000 L of water per hour. The plant uses advanced bio-filtration nano membrane filtration technology. After screening, raw sewage is pumped into the five-layered biofilter — comprising earthworms, cotton extracts, bacteria, organic sand, pebbles, stones etc. This treated sewage is then pumped into the membrane system, measuring 0.001 micron, where it is chlorinated and made available for drinking purposes. The whole procedure uses solar energy, making it eco-friendly. This project is an example of how potable water can be produced from waste water flows and used for all domestic purposes, including drinking. Built at a cost of Rs 55 lakh, the plant can generate approximately 25 million litres of water per year.

Compiled from:
http://indianexpress.com/article/cities/delhi/kejriwals-advocates-toilet-to-tap-by-drinking-water-after-sewage-treatment/
http://www.asianage.com/delhi/cm-kejriwal-drinks-treated-raw-sewage-water-824

Wastewater reclaim and reuse need to be economically and financially viable, and socially and culturally acceptable. Immediate, targeted, and sustained investments in multiple forms for wastewater management can:

- Reduce the volume and extent of water pollution through preventative practices
- Capture water once it has been polluted
- Treat polluted water using appropriate technologies and techniques for return to environment
- Where feasible safely reuse and recycle wastewater thereby conserving water and nutrients
- Provide a platform for development of new and innovative technologies and management practices

Along with financing and technologies, local capacity, including human resources, policy and legal framework, and institutions is very important in achieving sustainable targets of wastewater reuse plans. This following section further discusses the Policy Levers, Technological Innovations, Institutional responses to water security (especially roles of municipalities for urban water and wastewater management), Innovative Financing wastewater management, and Effective communication and participation in water conservation activities etc.

4.3 Recycling Technologies

All the above stated reuse applications of wastewater is only possible when there is availability and innovations in wastewater treatment and recycling technologies. The decision on the selection of treatment technology type and scale of operation mainly depends factors such as quality of the wastewater influents, the intended reuse options, and the wastewater generation. It also depends to large extent on its cost (investments and operation and maintenance) and as well as the capacity of the qualified human resources (more advanced the technology more skilled personnel required). A typical wastewater technology is successful if the wastewater collection system is well in place. The ultimate twin goals of any wastewater treatment technology should be to prevent environmental pollution and circular economic utilization through resource (nutrient, water, and energy) recovery. Along with the choice of appropriate technology, an enabling policy environment and adjustment of the existing structures (especially municipalities and local authorities) or establishing new institutional framework is critical for successful recycling and reuse of wastewater.

Wastewater treatment technologies have come a long way. The first generation wastewater recycling technologies relied on simple physical settling to chemical treatment of sewerage discharge, whereas, today this sector is well equipped with advanced technologies such as use of biological filters, activated sludge treatment, complex nutrient removal, advanced oxidation processes, and membrane based technologies. The primary treatment involves physical separation, including mechanical screening and solids separation through sedimentation tanks or clarifiers to separate sewage solids and sludge. Chemical separation uses many coagulants and flocculants. The secondary treatment handles removal of BOD, COD, Nitrogen and Phosphorous by activated sludge or fixed bed technology, while tertiary treatment involves advanced treatment processes for removal of nutrients and salts or suspended solids, filtrations (surface, micro, ultra, nano), flocculation/precipitation, ion exchange, reverse osmosis; and Disinfection by ozone, chlorine dioxide, chlorine gas, and UV radiation. **Figure 4.6** summarizes the level of wastewater treatment technologies that are currently in use. For effective treatment, it is advisable to segregate the wastewater source. For example wastewater stream consisting of high total dissolved solids (TDS) and heavy metals need to be avoided at initial stage.

USEPA (2013) in its report 'Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Management' discusses a long list of wastewater treatment technology, categorizing them into three types; research, innovative and emerging technologies. The objective of all these wastewater treatment technologies is to reduce water consumption in various sectors and fight the freshwater crisis by closing the water loop. Nevertheless, there are some wastewater treatment processes that have been established for many years, and are used even now. The chosen technology is considered appropriate if it serves the desired quality for designated water reuse purposes, is simple to use, maintain, and repair, is replicable and affordable, and can be adapted to local conditions. Based on the advanced technology used, wastewater can also be treated to be used for drinking purposes too, however, technological failure risks and human perception ('yuck factor') interferes with the possibility of the direct reuse as potable water.

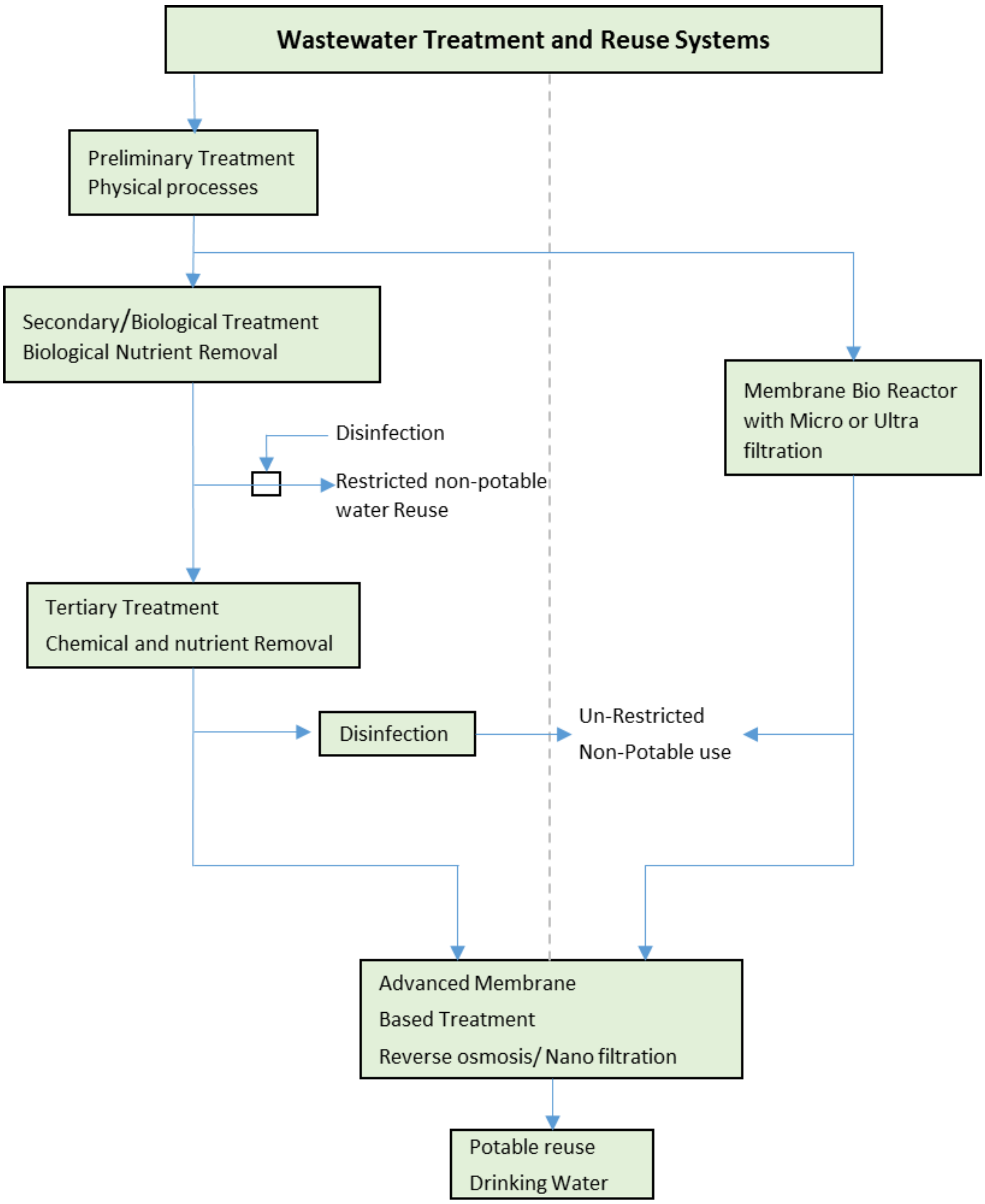


Figure 4-6: Wastewater treatment technology and reuse systems

Among these treatment technologies, membrane separation is the most advanced technology in use for water wastewater treatment, which results in the high quality treated effluent. New designs for membranes systems with reduced capital costs and improved efficiencies are now being introduced to the market. A detailed historical timeline of membrane based wastewater treatment technologies are further showcased in **Figure 4.7**.

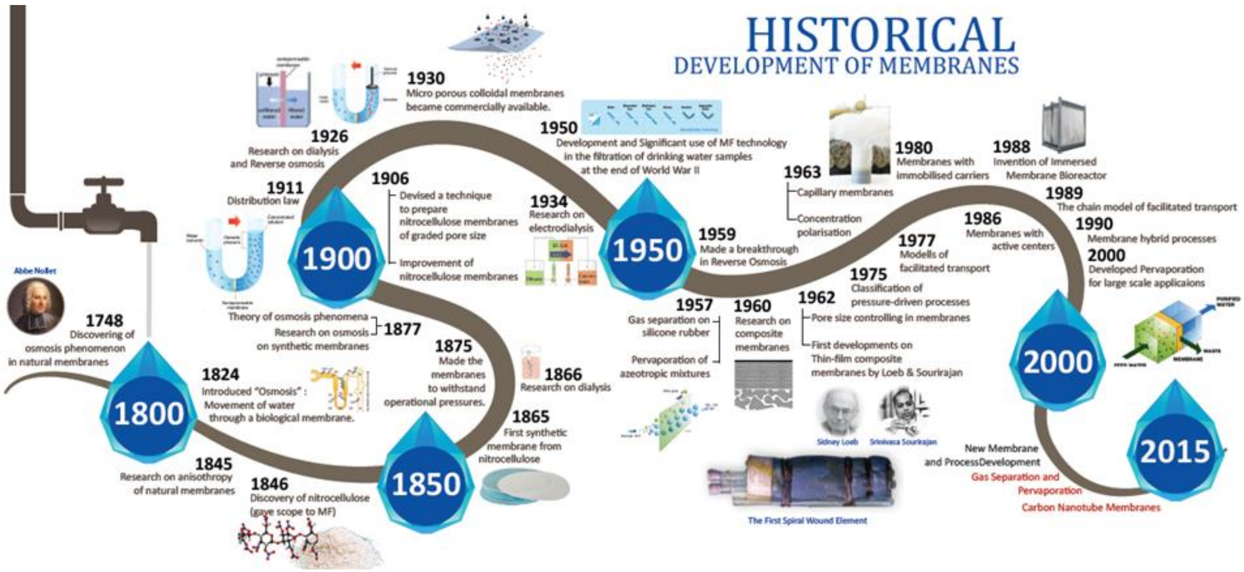


Figure 4-7: Timeline of advancement in membrane technologies for wastewater treatment

In parallel to municipal wastewater treatment for water reuse, there has been significant progress in the collection, treatment, and reuse of rainwater too. In some progressive cities, rainwater harvesting is an integral part of the urban water management plant. Some green building designs also include rain water harvest infrastructure in the building plumbing code. **Figure 4.8** below shows a typical rainwater harvesting facility with membrane based technologies. Membrane based technologies coupled with rain water harvesting projects lead to direct potable use of rainwater rather than indirect non-potable use such as gardening or car washing or groundwater augmentation.

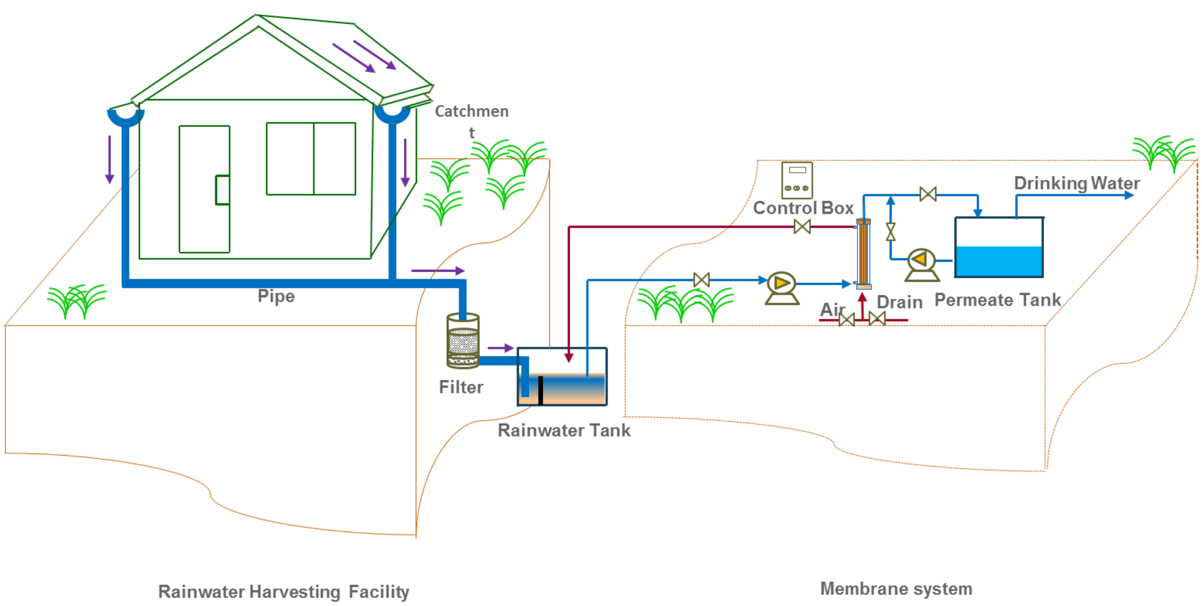


Figure 4-8: Typical rainwater harvest facility with membrane based technology

With proven technologies and emerging advanced treatment technologies, wastewater, rainwater and storm water are gaining popularity as an alternative water sources to quench the thirst of water hungry urban centres.

5. The Way Forward: Use of 3R for Making Wastewater a Favourable Solution to Water Security

This section is a consolidated list of factors that drive water security through wastewater recycling and reuse. For the potential realization of successful water security status through 3Rs, we require enabling policy and regulatory framework, effective institutional arrangements, diverse and sufficient financial mechanisms, all of which will then lead to the circular economy realization potential of water and wastewater management.

Reclaiming wastewater for potential reuse in Asia and the Pacific at this stage is limited to few developed countries and has not materialized at a sufficient pace. At large, wastewater reuse projects suffer from inadequate infrastructure, technology, policy and finance, as well as social and cultural reluctance. However, looking at the water scarcity and depletion of freshwater resources in Asia and the Pacific, it seems the region will be unable to keep up with the estimated water demand from the unprecedented urban population growth. Wastewater has been described as both "a resource and a problem[110]," as such the challenges relate to maximizing the resource potential and minimizing the problems. **Figure 5.1** clearly shows the scope for wastewater reuse to address and alter the freshwater demand.

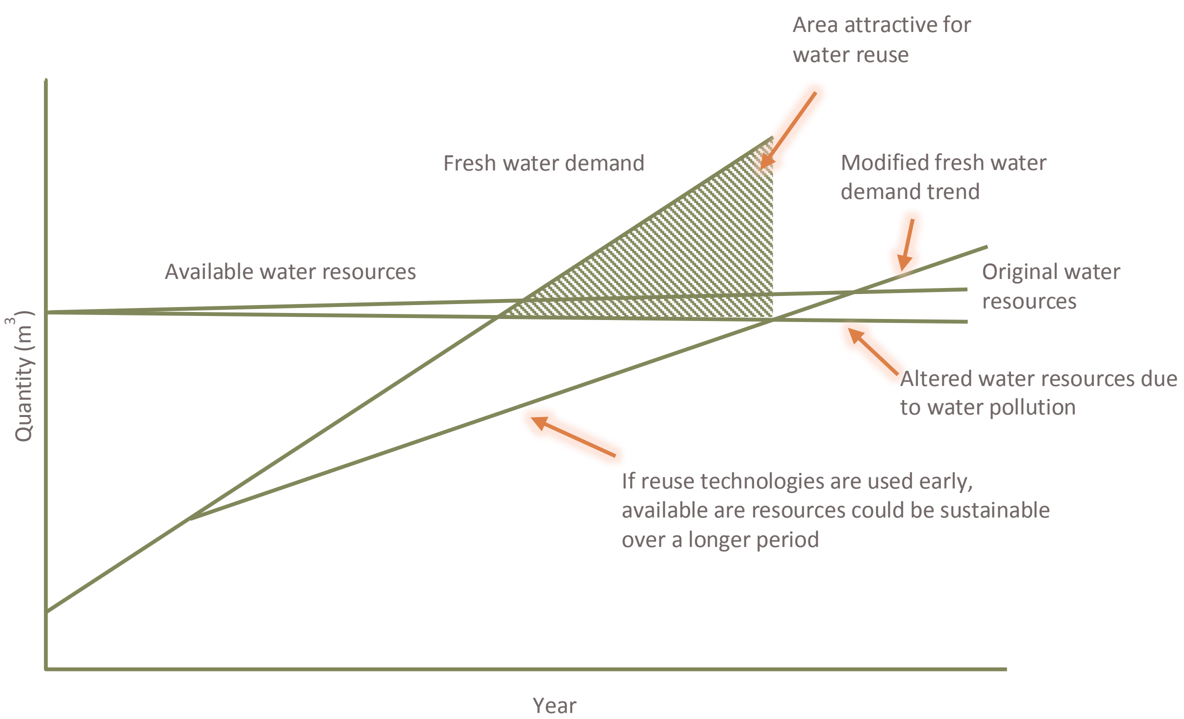


Figure 5-1: Water recycling and reuse domain

Therefore, wastewater reuse can be a solution to improve urban water management through various water demand management, and pollution control and water reuse in an integrated way. Such wastewater reclaim and reuse is not only able to manage the water demand by supplying alternative sources of water (treated wastewater in this case), such processes are equally economical. However, promoting wastewater management as a part of solution to water

[110]Hanjra, M. A., Blackwell, J., Carr, G., Zhang, F., Jackson, T.M. (2012). Wastewater Irrigation and Environmental Health: Implications for Water Governance and Public Policy. International Journal of Hygiene and Environmental Health 215, pp 255-269

security needs a number of things (such as governance, financial support and controls, appropriate technologies, infrastructure, institutional framework) in place to break the existing barriers into opportunities. Implementing 3Rs in water sector requires all stakeholders, including policy makers (governments), investors (governments/private sector companies), managers (public and private sectors) and users (communities/community organizations) within a coordinated system that establishes clear responsibility and authority.

Circular Water Economy

One of the driving factors for water resource management and wastewater reclaim and reuse is its central role in the economic growth and overall human development. In fact, the sectors that drive economy (food-energy-transport- manufacturing/production-as well as service sector like tourism) are dependent on water. Investments in water resource management infrastructure therefore contribute significantly to an increased economic productivity within these economic sectors and also contribute in poverty alleviation. The Water Innovation Europe 2014 event report mentions that "all economic activities in the world that depend on water have a combined market value of US$70.2 trillion - including US$2.8 trillion for the water-handling economy that involves direct management of water, US$720 billion for water-related equipment and services, and US$557.8 billion for water treatment and distribution. The total global wastewater treatment market has a value of US$388 billion for the period of 2010-2016 with a European market share of 27.3%, preceded only by the East-Asia Pacific region, with a market share of 37.6%[111]."

Many businesses are giving preference to areas where water risks are lowest. Because of such intense role of water in the economic growth and development, it also becomes a vehicle for circular economy. The shift to a circular water economy holds much promise, which will transform the linear economy (take-make-use-dispose) model into 'take-make-reuse-repair-refurbish-and-recycle' model by encouraging industries to include water component into a value chain and life cycle of a design/production/product distribution and use/service/recycle and a reuse cycle. Reduce, reuse and recycle of water resource is what address the principle of 'circular economy', which calls in for closing the resource loop for better economic growth. Since water is the resource used across all supply chains, and wastewater is the largest untapped waste category in industries, treating water as a 'product' is the starting point for the circular revolution. Circular economy perspective calls for efficient water use and promotes water and wastewater as a product and hence discourages inefficient water use and the discharging of the treated wastewater without reusing in its production processes. Hence, accelerating the technological innovation and financial investments in wastewater (energy, nutrient, and water) reclaim and reuse before the water crisis hits the economy is a way forward. PR China's Circular Economy Promotion Plan for 2015[112] details the actions and targets to use resources (water, metals, land and coal) more efficiently and to better manage resources & waste in industry, agriculture and cities.

Near Zero Liquid Discharge at Coca-Cola Plant in Asia

Zero Liquid Discharge (ZLD) describes a process that completely eliminates liquid discharge from a system. The goal of any well-designed ZLD system is to minimize the volume of wastewater that requires treatment, process wastewater in an economically feasible manner, while also producing a clean stream suitable for reuse elsewhere in the facility.

Water for soft drinks is typically purified using reverse osmosis, but this process rejects more than two thirds of the influent water in the form of brine reject. Coca-Cola bottling plant in Asia adopted GE's Aquarelle system to treat the existing primary Reverse Osmosis (RO) concentrate. The AquaSel system had a capacity of 36,000 gal/d (5.7 m3/h) when commissioned in December 2011. In over 1,000 hours of operation, Coca Cola's plant was able to capture and convert 1.5 million gallons (5,678 m3) of what was previously considered a waste stream, into water suitable for reuse in its operations . The AquaSel process enables Coca-Cola to use 99% of the water it withdraws as ingredient water.

Compiled from:
http://www.globalwaterawards.com/2013-winners)

[111] WssTP The European Water Platform, 2014. Water Innovation Europe 2014- 'Water in Europe: Green tape or Blue Gold?' Event Report – Key messages. wsstp.eu/files/2014/07/Final-Report_WIE2014.pdf

[112] http://chinawaterrisk.org/notices/chinas-circular-economy-plans-for-2015/

PHA bioplastics production from industrial wastewater

Circular economy opens new innovation in technolgies that tranforms wastes and by-prodcuts into new useful prodcuts. The PHA bioplastics production from industrial wastewater is one such example. Veolia has pioneered the production of bioplastics from sludge. Veolia used technology such as bacteria that eat sludge and neutralize it into carbon. This 'wastewater carbon' was then converted into biomass rich in PHA, which has mechanical properties equivalent to polypropylene and is thus valuable in making consumer plastics and chemicals. Veolia produced the first biopolymers from municipal waste in 2011, and is now refining the process to meet end-customer specifications at full-scale wastewater treatment sites in Belgium and Sweden.

Compiled from:
Ellen MacArthur Foundation (2013). Towards the Opportunities for the Consumer Goods Sector.

Water scarcity is the main driver for water recycling and reuse, and bringing water into the circular economy discussion, however, some regulatory and pricing mechanisms combined with other measures can encourage industries to work towards reducing their 'water footprinting' as much as their carbon footprints and hence opt for water or embedded water stewardships.

Policy levers

Reflecting the diverse nature and roles of water, the scope of 'water policy' has to be extended to national development frameworks. Generally city's water management plan considers only water supply, but an integrated framework for sustainable water management need to include wastewater reuse in a holistic manner. Appropriate legal and institutional frameworks are required in order to achieve sustainable use and management of freshwater resources. Some fundamental elements that create a holistic legislative wastewater management regime include: Management of urban waste, integrated water resources management by addressing water use and wastewater management by industry type, protection of waters against nutrient pollution caused by agricultural sources by defining good agricultural practices, and governing the use of pesticides in agriculture, construction and operation of wastewater treatment plants, and guidelines and codes of practice for the use of recycled water.

Singapore's Active, Beautiful and Clean (ABC) Waters Programme

The PUB had launched the Active, Beautiful, Clean Waters (ABC Waters) Programme in 2006. By integrating the drains, canals and reservoirs with the surrounding environment in a holistic way, the ABC Waters Programme aims to create beautiful and clean streams, rivers, and lakes and create urban recreational opportunities. Over the years, Singapore has gradually developed a pervasive network of about 8,000 Km of waterways and 17 reservoirs for water supply. This programme is a remarkable re-orientation of policy and thinking. In 2009, ABC water design guidelines were issued to provide reference to developers and industry professionals on how to integrate environmentally sustainable green features or ABC Waters features in their developments.

WHAMPOA PARK CONNECTOR

PUB
Water for All: Conserve, Value, Enjoy

ABC
Active, Beautiful, Clean Waters for All

Compiled from:

http://www.pub.gov.sg/abcwaters/Pages/default.aspx

Existing water resource management policy and legal frameworks can be aligned to facilitate wastewater reuse programmes. These policy should address technology, financial, infrastructure needs that enable wastewater reuse application opportunities. Some of the necessary regulations for wastewater reuse may include; technical specifications on wastewater treatment, reclaimed water quality standards for various applications, and regulations on disposal of waste (sludge, brine, etc.) from treatment. The policy also should focus on the quality of the reclaimed wastewater, i.e., guidelines for reuse of reclaimed wastewater in various potential sectors without public health risks. A clear legal framework is essential for any reuse of wastewater. The World Health Organisation (WHO) and the Food and Agriculture Organisation (FAO) of the United Nations have prepared guideline on the safe use of wastewater. Along with these broad guidelines, some of the progressive countries have already introduced legislation on reuse of wastewater. It is also important to note while countries in the Asia and Pacific region do have a well-defined drinking water quality and wastewater effluent discharge standards, and also the formal institutional set up to handle these, most of the countries do not have standards and institutional arrangements and mandates for wastewater reuse applications. Such lack of standards often act as a barrier to establish large scale wastewater reuse projects. Public health aspects of reuse of treated wastewater is phenomenally the important aspect. Presence of toxic chemicals such as heavy metals, organochlorine, pharmaceutical compounds, and endocrine disruptors need to be evaluated and corresponding standards need to be developed and monitored. Similarly, the reuse of treated wastewater in agriculture needs to monitor the impacts on plants and soil, where factors like soil salinity, solidification of soil (SAR), excess Boron, Nitrogen & Phosphorous need to be maintained at the healthy level.

Promotion and support for Water Reuse Act in Korea

With the growing awareness of water reuse "Promotion of and Support for Water Reuse Act" was established in 2010. The Act enabled the management of rainwater-using facilities, grey water systems, and the reuse facilities of treated effluents from wastewater treatment plants (WWTPs) under a single umbrella while they were previously regulated by individual laws. For the enforcement of this Act, the "Water Reuse Master Plan (2011-2020)" was formulated in September 2011. It is expected to secure 25.4 tons of alternative water resources by 2020 and to replace 1.1 billion tons of tap water annually.

Compiled from
http://eng.me.go.kr/eng/web/index.do?menuId=307&findDepth=1

New Zealand: Code of Practice for Management of Domestic Wastewater

Under the Environment Protection Act 1970, New Zealand has prescribed a Code of Practice (COP) for the management of domestic wastewater. This COP applies to all types of on-site systems treating up to 5,000 L of wastewater per day and covers various design elements for on-site wastewater management for residential complexes, hotels, food businesses, community recreation facilities, and sporting facilities, public halls and amenities, shopping centres and commercial and industrial sites.

The Code identifies the four stages in treatment of domestic wastewater:
1. Discharge sewage offsite to a reticulated sewerage system
2. Partially treat sewage onsite, then discharge the primary or secondary treated effluent offsite via a reticulated sewerage system for further treatment and/or recycling
3. Treat and dispose off or recycle sewage onsite
4. Treat and recycle grey water on-site and discharge backwater as well as any excess grey water offsite to a reticulated sewerage system (or, if in an unsewered area, to an onsite wastewater treatment system)

Compiled from:
Emanuel, E (2002). International Best Practice – International Overview of Best Practices in Wastewater Management. Sustainability Managers

Usually the limitations posed by current regulations that focus more on the "end-of-the-pipe" solutions, often put constraints on the selection of different scenario and technologies for reducing water use and wastewater production as well as reusing wastewater. Water security policies therefore should promote investing and incentivizing the "reduce, reuse, recycle" systems, and has to cover the holistic urban water cycle inclusive of water supply, treatment, reuse application. Policies for reducing water can use water withdrawals, or volume based water tariff structures by municipalities to lower domestic water consumption etc., and use of technological fixtures for water saving by cities in homes, offices, and public buildings. Policies should also address public awareness and communication for public acceptance of reclaimed wastewater.

Incentives, such as grants and low-interest loans, flexible permits and priority access to infrastructure, may also be effective in increasing interest in wastewater reuse.

Institutional responses to water security

The water sector crisis and water security solution are very much linked to institutional changes both within and outside the water sector. Therefore, institutional reorientation involving water law, water policy, and water administration dimensions of water institutions is crucial for progressing toward water security[113]. Water Institutions are responsible for service delivery, planning, and management. The responsibility for water, sanitation, and wastewater management on a national level is shared between different ministries. **Table 5.1** below is a typical institutional arrangements for wastewater and sanitation management in India.

Table 5.1 Typical mandate for wastewater and sanitation management institution in India[114]

	Regulation	Integrated Planning	Construction	Operation and Cost recovery
Rural and Peri-urban	-	-	State Water Corporation/Board	State Water Corporation/Board; Local government
Urban	State Pollution Control Board (SPCB); Central Pollution Control Board (CPCB)	Ministry of Urban Construction; Ministry of Water Resources; State Water Corporation/Board	State Water Corporation/Board	Local government
Industrial	(SPCB); (CPCB)	-	Industry	Industry

The formal institutions involved in water supply and wastewater reuse are, the ministries (national governments), which are responsible for the overall policy and necessary legislation regulations and standards formulation, and local authorities and agencies, such as municipalities, private water utility service providers, wastewater treatment plant operators, which are responsible for the execution, monitoring and supervision of those regulations, and establishments of water and wastewater treatment infrastructures. Besides these formal institutions, research and development institutions, knowledge management organizations, community-based semi-formal or informal water user organizations, community based wastewater treatment projects also play important role.

Japan Sanitation Consortium (JSC)

Japan Sanitation Consortium (JSC) was established in 2009 as part of the Asia-Pacific Water Forum (APWF)'s Knowledge Hub for sanitation in the Asia-Pacific region. JSC brings together Japan's know-how and years of accumulated knowledge and experiences in wastewater, sludge and night soil management.

To increase access to sanitation and promote sustainable sanitation improvement, JSC's expertise covers a wide range of sanitation systems in the following fields:

- Basic sanitation (toilets)
- On-site sanitation (decentralized wastewater treatment systems such as the Packaged Aerated Wastewater Treatment Plant (PAWTP) or Johkasou, night soil/sludge collection and treatment systems)
- Sludge recycling, wastewater reuse and energy recovery.

Compiled from:

http://www.apwf-knowledgehubs.net/jsc.html

[113] Saleth, R. M., and Dinar, A. (1999). Water Challenge and Institutional Response: A Cross-country Perspective. World Bank.
[114] www.who.int/water_sanitation_health/resourcesquality/wpcchap8.pdf

In the context of water supply and wastewater management, gaps between these formal institutions and their rules and existing informal practices need to be identified and addressed through better inter-sectoral coordination at all levels of water resources planning and management. Similarly, there has to be coordination with wastewater collection and treatment sector and the potential reuse sectors (such as agriculture, industries, and the municipalities) so that the desired level of treatment and required infrastructure for redistribution of reclaimed wastewater can be planned accordingly. To create successful and sustainable implementation of wastewater reuse schemes, changes and reforms in these water utilities/establishments are needed. Along with clear roles and responsibilities, these institutions need funds to cover operating costs and capacity development of the staffs, technical assistance and organizational development.

In many countries, municipalities are generally responsible for water supply, wastewater collection, treatment, and disposal. Regulations are clearly vital for promoting wastewater management. Brown and Farrelly (2009) [115], reviewed 53 studies of innovation processes in water and wastewater management and found that the primary barrier is socio-institutional rather than technological challenges. It is therefore necessary to examine relevant existing institutions and strengthen them, or to create new ones and assign adequate mandates and responsibilities in order to undertake wastewater reclamation and reuse projects. Installation of a recycling and reuse infrastructure (for example, construction of new wastewater treatment plant, dual pipe system for distributing recycled wastewater in houses, retrofitting of water saving appliances, etc.) may also be promoted via these institutions.

Water and Wastewater Master Plan Gwinnett County, Australia

Gwinnett County as a joint effort of the Department of Water Resources and Planning and Development has developed the 2030 Water and Wastewater Master Plan. This Master Plan identifies and details the water and wastewater investments, policies, and projects for the next 20 years. This first of its kind master plan provides a path for the future of water and wastewater infrastructure upgrades. The Master Plan intends to address new state and regional water policies, unresolved water rights disputes, and future system demands, as well as identify the infrastructure that need to be in place to support growth far past the 2030 planning period. Of the several planning issues identified in the Master Plan, one of the priority issue is the return of reclaimed wastewater to recharge natural freshwater resources to supplement the supply for water withdrawal needs in the County.

Compiled from:
https://www.gwinnettcounty.com/static/departments/planning/pdf/2030_water_and_wastewater_master_plan.pdf

Rainwater Harvesting in Chennai, India

The success of rainwater harvesting in Chennai India is an example of an institutional level efforts in water conservation and reuse. The Chennai Metropolitan Waste and Sewerage Service Board (CMWSSB), now called as Chennai Metro water- began to promote rainwater harvesting and wastewater reuse to alleviate water shortage in industry and households in the mid-1990s. In 1994, the CMWSSB and other regulatory authorities made the installation of suitable rainwater harvesting facilities mandatory for property developers of multi-storey and special buildings. Recently, this requirement has been extended to individual households for which planning permits are to be submitted. The CMWSSB ensures the installation of such devices by inspection before water/sewer connections are made.

Compiled from:
UNEP/GEC, 2005, and http://chennaimetrowater.gov.in/campaign/campaign.htm)

Sometimes, not only the government institutions but community based organizations play an important role for local water governance in managing water supply and sanitation services. It also needs to involve the community and the local institutions in the process of designing different scenarios for wastewater recycling and reuse. Thus, there is a need for combined effort and understanding of all relevant stakeholders for bringing the desired changes in the overall institutional set-up for successful wastewater reclaim and reuse for addressing water insecurity issues.

[115] Brown, R.R., Farrelly, M.A. (2009). Delivering Sustainable Urban Water Management – A Review of the Hurdles We Face. Water Science and Technology—WST, 59 (5), pp 839-846

Financing wastewater management

Increased investment and financial support for water development is essential. However, the relatively high costs associated with sewage collection and treatment systems often acts as a barrier for wastewater treatment and reuse. Many regulations can be planned for wastewater treatment cost; one of which could be the application of 'polluter pays' principle. Similarly, revenue collected as freshwater use tariff and other sanitation tariffs can be partly reinvested into wastewater collection and recycling. Costs incurred in actual recycling and redistribution of the recycled water can be covered by the reclaimed wastewater users. However, the trickiest part is the appropriate pricing for reclaimed water reuse. In one hand, a very low price for wastewater may give an impression that wastewater reuse is a cheap and limited option, but in reality, treating the wastewater up to the quality of reuse may turn out to be expensive than processing freshwater for consumption. But on the other hand, if the price is set too close to the price of potable water, people might prefer potable water instead of treated wastewater. Pricing wastewater is challenging and may vary from region to region depending on the regional variability. For a fair pricing policy, some further questions that need to be researched as per Kularatne et al. (2005: 16)[116] are:

- How can the cost of treatment and distribution infrastructure of recycled water schemes be structured to promote uptake?
- Would private sector involvement in recycle schemes improve the commercial viability of recycle schemes?
- What incentives can improve commercial viability of large-scale recycle projects?
- What incentives should the government and water authorities adopt to improve the demand signals for recycled water schemes?

Apart from conventional tariffs, other innovative sources of funds may be from grant finance, loans from Government and Multilateral agencies, commercial bank loans, revolving funds, and other income (reuse of waste water) can be opted for.

Innovative Financing for Wastewater Management- Caribbean Regional Fund for Wastewater Management (CreW)

The United Nations Environment Programme Caribbean Environment Programme has partnered with the Inter-American Development Bank (IADB) and the Global Environmental Facility (GEF) to develop a prototype regional revolving fund which will provide sustainable financing for environmentally sound and cost-effective wastewater management projects in the Wider Caribbean Region. The fund is being piloted as a possible modality for providing sustainable financing for wastewater management projects in the region while also addressing key capacity constraints within existing legal, institutional, policy frameworks for wastewater management.

Compiled from:
Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

Reuse of water, Recovery of valuables and Resource efficiency in urban wastewater treatment (R3Water)

Funded by the European Commission (7.8 M€) under the Framework Programme 7, the R3Water project is a consortium of 12 technological partners from seven European countries, and is coordinated by IVL Swedish Environmental Research Institute. The project was initiated in January 2014 and will run 42 months. The main objective of the project is to demonstrate solutions that support the transition from a treatment plant for urban wastewater to a production unit of different valuables (such as nutrients, energy, water). Furthermore the project aims to facilitate the market uptake of the innovative technologies for the European and global market by demonstrating the solutions in Spain, Belgium and Sweden.

Compiled from:
http://r3water.eu/

[116] Kularatne, D.; Ridley, D.; Cameron, C. 2005. Assumptions Associated with using Recycled Water for Primary Industries. Discussion Paper. Department of Primary Industries. Pp. 1-31. Cited In Mekala, G.D, Davidson, B., Samad, M., and Boland, A.M ().A Framework for Efficient Wastewater Treatment and Recycling Systems. Working Paper 129. IWMI.

Municipal Councils can also participate in Public-Private Partnership projects for wastewater treatment and reuse. Similarly, a wave of private start-up companies is rising up to address the growing need for wastewater treatment and monitoring solutions. The wastewater management business is part of a $600 billion industry, with multinational companies such as GE, Veolia, Siemens, and Suez in the play[117]. Half of the start-up businesses are looking into monitoring, forecasts, and process controls, and roughly the same is addressing basic wastewater treatment.

Durban Water Recycling (DWR) Plant

The Durban Water Recycling (DWR) Plant, commissioned in May 2001 is the first private water recycling project in South Africa. It is also the most successful PPP under a 20-year BOOT (build-own-operate-transfer) contract to Durban Water Recycling Ltd. Funding for the project was provided entirely by the private sector. DWR shareholder equity and loans from Societe Generale, Natexis, the French government, Rand Merchant Bank and the Development Bank of South Africa provided the necessary capital.

The plant treats 47.5 million litres of domestic and industrial wastewater daily, using the state-of-the-art water treatment processes and technologies to reclaim water of 'near potable standards.' The reclaimed water is sold back to industrial customers at a lower tariff than potable piped water. DWR is the key contractual entity and holds the 20 year concession contract with eThekwini Water Services (EWS), and has the 20 year consumer contracts with Mondi Paper and Sapref. Mondi Paper uses the recycled water directly for the production of fine paper. Other benefits include; disadvantaged peri-urban communities receiving the potable water that otherwise was used by the industrial consumers from the municipal system, and the decreased pollution load on the marine environment, as industries prior to DWR plant discharged their wastewater in the sea. The Durban Water Recycling Project demonstrates that innovative financing approach to water resource management, and how the proper management of wastewater technology and institutional arrangements can yield exceptional results.

Compiled from:

http://www.durban.gov.za/City_Services/water_sanitation/Services/Pages/durban-recyling.aspx
http://www.veoliawaterst.co.za/medias/Events/DWR_10yr_Anniversary.htm
Gisclon, A., McCarley, S., McNally, K. (2002). The Durban water recycling project- the vision becomes reality. Paper presented at the Biennial Conference of the Water Institute of Southern Africa (WISA) 19 – 23 May 2002, Durban, South Africa. ISBN Number: 1-86845-844-X

Other popular forms of wastewater treatment and reuse in rural and peri-urban areas is the community based decentralized wastewater management system (DEWATS). It can often become low cost solution to the wastewater problem in many developing countries where neither on-site sanitation systems nor large centralized sewerage systems are suitable. This can bring significant benefits to poor communities, particularly women.

Community based water supply and wastewater treatment project in Cambodia

A community based Reservoir Utilization and Community-based Sustainable Ecotourism Development project in a fishermen village in Stung Hav, Cambodia, rehabilitated a 5.9 ha water reservoir with holding capacity of 40,550 m^3 and provide water for supplemental agricultural production. The reclamation activities included; recharging of groundwater in nearby water wells, a constructed wetland to prevent water contamination, and plantation of 380 trees around the reservoir to prevent soil erosion. A wastewater garden was also created as a natural water treatment system to prevent water contamination from household wastewater discharge for irrigation. The project was initiated under the Joint Communiqué of the UNDP GEF Small Grants Programme and PEMSEA. It was a community inclusive water governance practice, where the members established monthly savings up to US$34 on water-use fees.

Compiled from:
Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli H. (eds). (2010). Sick Water? The Central Role of Wastewater Management in Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no ISBN: 978-82-7701-075-5

[117] http://www.forbes.com/sites/heatherclancy/2014/01/22/9-startups-tapping-the-600-billion-cleantech-water-sector/

Expanding a range of financial services opportunities -both public funding and private financing- is a key component for promoting water and wastewater recycling. Besides wastewater discharge fees, more innovative financing opportunities for wastewater reuse initiatives need to be explored. These new financing mechanism may include government budget, overseas development technical assistance programmes, small-scale financing mechanisms (i.e. microcredit schemes), polluter pays principles, public private participation, etc.

Technological answers

Trust in the chosen wastewater treatment technology matters a lot in terms of public acceptance of reclaimed wastewater reuse. In a study conducted by Sydney Water in 1999, lack of trust on the treatment technology was the second-most frequently stated reason among participants who opposed using reclaimed water for irrigation[118]. To address the current freshwater shortages in most cities of the developing world, innovative closed-loop system technologies for water saving and reclaiming and reuse of wastewater are being devised. Considerably there has been a great deal of technological advances in wastewater recycling and reuse, for example; membrane technology, nano technology, reverse osmosis, crystallization, distillation etc. Technological innovations have led to production of new products from wastewater.

Nonetheless, these emerging technologies are expensive and lacks large capital investments and return of investment guarantees. Depending on the local context, sometimes decentralized treatment systems would bring benefits in reducing both the capital and operational costs of wastewater recycling than conventional centralized systems. Identifying the appropriate technology, making favourable investment for technology acquirement, and the transferring the technology with knowledge/skills act as technology levers for wastewater reuse possibilities.

Raising public awareness, participation, and consumer acceptance

Stakeholder engagement is important for improving water resources management. Solutions for smart wastewater management must be socially and culturally appropriate. Water and sanitation issues are deeply linked to local practices, culture and traditions, and often to religious beliefs. Many cultural practices and religious beliefs discourages the reuse of treated wastewater terming it as ‘dirty’ and ‘unholy’, which acts as one of the greatest barrier for wastewater reclamations and reuse. In addition, socio-economic disparity in the urban population also creates a stigma that ‘rich man's excreta and poor man's water.’ It is seen very often that in cities, people with low incomes cannot afford municipal water supply and sanitation services, while the people with high income have good coverage to piped water supply and sewerage. Many wastewater treatment projects also are established in low lying areas and the water are distributed to urban poor. Such social disparity can be cured by popularizing the treated wastewater distribution equally to all city dwellers. Some positive trends can be seen in popularizing the potable direct use of the treated wastewater, where well-known people consumed the treated wastewater.

NEWater Visitor Centre, Singapore

NEWater is high-grade reclaimed water that is produced from treated waste water using advanced membrane technologies and ultra-violet disinfection, making it ultra-clean and safe to drink. Developed by the Public Utility Board (PUB) after three decades, NEWater has passed more than 130,000 scientific tests and surpasses World Health Organization requirements, assuring its high quality. As of 2014, NEWater meets up to 30% of the nation’s current water needs, and by 2060, it is targeted to meet up to 55% of water demand.

A lot of public education programme followed with the establishment of the NEWater Visitor Centre in 2003 for the public acceptance of NEWater for consumption. The Visitor Centre is a state-of-the-art water museum, with interactive tours and educational workshops demonstrating how NEWater is produced. To date (in 2014),

[118] Mekala, G.D, Davidson, B., Samad, M., and Boland, A.M ().A Framework for Efficient Wastewater Treatment and Recycling Systems. Working Paper 129. IWMI.

about 25 million bottles of NEWater have been distributed free of charge for public consumption (HISS, 2014). NEWater is primarily intended for industrial users with high standards required for their feed-water.

Compiled from:
http://www.pub.gov.sg/water/newater/Pages/default.aspx)
HISS (Horizon International Solutions Site). 2014. *Singapore's NEWater Wins UN-Water Award on World Water Day.* New Haven, CT, Horizon International. http://www.solutions-site.org/node/1302 (Accessed November 2014)

Drinkable Water from Human Sewage – Bill Gates drinks Poop Water!

On the first week of January 2015, the world gasped to see the multi-billionaire philanthropist Mr. Bill Gates drinking water reclaimed from human sewage. Omniprocessor is a distillation technology, which purifies a liquid by heating it to a vapour then condensing it. Evaporating the water vapour from waste sludge and condensing it creates the water, which is then purified. The remaining sludge is then heated in a steam engine and runs a generator to produce electricity. Run by Janicki Bioenergy, an engineering firm based in Sedro-Woolley, Washington, the Omniprocessor machine (38 feet wide and 66 feet long) is able to turn sewer sludge from 100,000 into 86,000 L of drinkable water a day and 250 kW of electricity, along with pathogen-free ash.

Compiled from:
http://techcrunch.com/2015/01/06/bill-gates-will-drink-water-made-from-poo-to-prove-new-santitation-tech-works/)

Despite a long history of wastewater reuse in many parts of the world, social acceptance of the wastewater reuse still remains a challenge. Information sharing, education, communication, and awareness raising programmes are therefore necessary in overcoming the public reluctance to consume safe reclaimed wastewater. Raising the awareness of the public about water shortages and encouraging their participation in water conservation activities is crucial. People are often confused about grey and black water reuse. The beneficiaries have to be clearly educated about the potable and non-potable uses of treated water to avoid potential health hazards. Public participation throughout the wastewater treatment project planning, inception and project implementation can overcome such confusions and public health concerns from the target beneficiaries. Involvement of local skilled manpower on wastewater treatment construction, operation, and monitoring can also disseminate the knowledge by word of mouth to the community. Continued education and visit can also lower public hesitation about reuse water. NEWater Visitor's centre is one excellent example. Similarly, the treated wastewater reuse in the houses can be put into a system by local authorities developing urban housing regulations/building codes with rainwater harvesting and dual reticulation pipeline system for distributing alternative water sources.

6. Conclusions and Recommendations

6.1 Conclusions

Rapid economic growth and accelerated urbanization in Asia and the Pacific is increasing pressure on the supply of fresh water. Along with diminishing water resources, increasing water pollution and lack of wastewater management are pushing the region further into a state of water insecurity. In general, urban wastewater treatment has received less attention compared to 'water supply and treatment'. But, alternative water resources such as integrated wastewater management through 3R is a potential solution that cannot be allowed to go untreated and untapped.

There are many bottlenecks for the large-scale reuse of treated wastewater in most countries of Asia and the Pacific. The potential and the need for the reuse of treated wastewater is still hugely underappreciated and unaddressed in national strategies and policies on water. Insufficient sanitation infrastructure, sewerage connection, lack of (tertiary) treatment facilities, and failure to project water demand and wastewater production are resulting in a water scarcity, which may be alleviated by applying 3Rs in waste water sector. Despite regulations on discharge of industrial wastewater, much of industrial wastewater and its reuse potential, is discharged into natural waterways due to weak enforcement of regulations. Though many countries in Asia and the Pacific do have drinking water and wastewater discharge standards and limits, ironically there are no standards for the use of recycled water for various purposes. The lack of regulations acts as a barrier for private companies to invest in wastewater recycling business, as well as affect the acceptance of treated water by the public. Economic constraints, in particular, the investment funding and the long-term financial viability of reuse schemes are other bottlenecks. Fragmented institutional set-up in the water and related sectors adds more problems to this. In practice, formal institutional arrangements exist for water distribution and pollution control, whereas wastewater reuse is done on an ad-hoc basis, either at individual level or through community based organizations. In addition to these bottlenecks, the lack or low acceptance of recycled wastewater by consumers due to various social, economic, cultural, and religious beliefs is also a noteworthy challenge to wastewater reuse.

Even though the challenges are overwhelming, unsustainable management of water resources cannot continue. Taking full account of these challenges and potential opportunities, national governments should take significant actions by making efficient use of water and increasing investment in not only the water supply infrastructure but also wastewater management. These bottlenecks can be removed by developing national, regional, and local master plans for the reuse of reclaimed wastewater, as part of an integrated water resources management approach. These master plans need to include transfer of appropriate technology, institutional framework rearrangement, and capacity development, considering all necessary aspects (technical, institutional, legislative, social, economic, financial, management and operations). Industries, on the other hand, can set up a decontamination fund for financing an on-site central wastewater treatment plant, or adopt Zero Liquid Discharge production processes hence prompting the closed-loop economy, saving both environment and water charges, and championing sustainability. Wastewater is to be recognized and included into the water cycle and accounted for in the water budget.

It is a good sign that nowadays, a real paradigm shift is taking place, with wastewater increasingly seen and treated as a resource. Application of 3R principles for wastewater reclaim and reuse in the integrated water management plan and policy along with water demand management is the need of the hour to address local and global urban water scarcity. The focus therefore has to shift to the sustainable water management encompassing the whole water/waste cycle including water supply, sanitation and wastewater reclamation, and reuse. Such 3R plans in water sector should envision and address potential future scenarios – both in terms of water demand, wastewater generation, as well as technological innovations in wastewater recycling. To successfully implement the strategies for wastewater reuse, it is important to break the existing institutional, policy, finance, technology, and behavioural barriers.

Given the importance of good wastewater management and the urgent need to address this on a global basis, it is recommended to include wastewater management in the post-2015 development agenda. In conclusion, in the context of sustainable development, where water is often a key driver – and a potential limiting factor – for economic growth, human well-being, and environmental health, enhancing water system security and sustainability by incorporating centralized and decentralized water reclamation and reuse should play an important part of the local and/or national water security agenda.

6.2 What Role should the 3R Forum in Asia and Pacific Play in Promoting 3Rs in Water Sector?

3Rs for sustainable water resource management in the Asia and Pacific could be the pathway for achieving SDGs in the region. The Asia and Pacific region also need to keep a track on progress of the Hanoi and Surabaya Declaration on integrating "3R Concept" in relevant policies and programmes for transitioning to a resource efficient and sustainable development society.

The application of new concepts and technologies to enhance the long-term sustainability of wastewater management can be expedited by promoting research needed to develop and demonstrate these concepts and technologies. The Forum can look into technical needs assessments such as; upgrading older WWTPs, promoting nutrient, energy, and water recovery for circular economy realization. The other issue worth discussing at the 6th 3R Forum is, "how to promote and facilitate 3R concepts in water sector as successfully as 3R interventions in solid waste management in the region?" One of the way ahead is to address solid waste and sanitation and wastewater (as well as gaseous emissions) within a 'holistic waste management' framework rather than the conventional approach of looking at each form in a 'silo'. The Forum needs to set up a clear research direction to identify the policy, institution, technology, infrastructure and financing needs, barriers, and drivers, in municipal or national level water plans, such as;

- Needs Assessment- Detailed status with quantification of wastewater production in each country (from municipal, industrial and agricultural sectors), and the existing wastewater reclaim and reuse practices (wastewater treatment facility)- and- forecasting future water and wastewater needs
- Study of existing laws, policies, and programs in Asian countries related water environment and conservation
- Scope for water recycling technology transfers across Asia and Pacific
- Exploring the economic instruments and potential market for reclaimed wastewater uses
- How to invert the end-of-pipe system to wastewater treatment practices to reduction and efficient use of water beforehand?
- How to create public awareness and acceptance to use reclaimed water for various potable and non-potable use
- Development of water reuse regulations, standard and guidelines for reclaimed water quality for various reuse applications, and the continuous monitoring (expanding learnings from countries like Japan, Korea, Singapore and Australia)
- Extending Partnership with existing water institutions, such as Water Environment Partnership in Asia (WEPA)
- Promoting design innovation research for water efficiency products, and development of products which can be operated on recycle water of non-potable quality (for example; washing machine)
- Like other successful eco-labels and energy labels, how to promote Water Labelling of products (based on the Singapore experience)

6.3 Three Policy Questions

With the potential water crisis lurking, the need for necessary reforms on water sector is inevitable. Such reforms can tap opportunities for water use reduction, reuse, and recycling (for circular water economy). This however requires overcoming of the overwhelming challenges and barriers through technology, policy, financial innovations for achieving water security. The Forum is expected to stimulate discussion around the policy questions given below, and arrive at an enabling policy environment for promoting 3R in water sector within the Asia and the Pacific countries.

1. Do existing legal and institutional framework allow wastewater reclaim and potential reuse application in Asia and the Pacific countries?

2. What are the 'Push-and-Pull' factors to promote circular water economy in Asia and Pacific Region in the following respective areas; a) Technology, b) Socio-cultural and public perception, c) Policy and Institutional Framework, and d) Financial mechanisms?

3. Private sector involvement can play an important role to perform 3R in water sector, especially for technology innovation and financing of the 3R projects. However, bringing private sector into water sector is a delicate issue, as it meets the public opposition because water is considered a basic human rights. In such case, how to attract private sector into 3R businesses for water security?