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Sustainable Sanitation Systems: Health, Environment and Governance Challenges

The Case of Human Rights-Based Policy Reform in Alternative Wastewater Management Strategies

Florian Thevenon

WaterLex

WaterLex is an international public interest development organization based in Geneva, Switzerland. It is a UN-Water Partner with UN ECOSOC special consultative status. Its mission is to develop sustainable solutions based on human rights to improve water governance worldwide, particularly in regard to consistent water law and policy frameworks. It works with an alliance of interested parties to improve water-governance frameworks, bringing them in line with country obligations under international human rights law. It is an official member of the UN Environment Global Wastewater Initiative.

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The Global Wastewater Initiative

The Global Wastewater Initiative is a voluntary multi-stakeholders platform aiming to provide the foundations (including information, tools and policy mechanisms) for partnerships to initiate comprehensive, effective and sustained programmes addressing wastewater management. The Initiative intends to bring a paradigm shift in world water politics; to prevent further pollution and damage and emphasize that wastewater is a valuable resource for future water security. The Secretariat for the Global Wastewater Initiative is provided by the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities, a UN Environment-administered intergovernmental mechanism.

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Highlights

Context: About 2.5 billion people do not use an improved sanitation facility, and about 1 billion people practise open defaecation which is one of the main causes of drinking water pollution and diarrhoea incidences. There is an urgent need to increase the access to safely managed sanitation services, and a need for a paradigm shift towards affordable technological alternatives; tailored to local and specific environmental, political and socio-economic contexts.

Solutions: An option for low income countries and rural areas, is to promote wastewater treatment in artificial ponds and lagoons, as well as the utilisation of the treated effluents for crop irrigation and aquaculture. The improvement of sanitation systems is therefore not only important for public health, but also for climate change mitigation and adaptation. Moreover, the valuation of faecal sludge-derived products can offset treatment cost and act as an incentive to create sustainable wastewater treatment and services. Developing market-based approaches with business models can also provide long-term social benefit and profit in a sustainable manner.

Limits: Field awareness campaigns and advocacy actions are encouraged to improve and monitor water quality and hygiene practices; because wastewater, even when treated, is highly enriched in hazardous pollutants. Wastewater recycling, safe water reclamation and reuse must therefore be regulated and aligned with national quality standards or international guidelines; for example, FAO guidelines for the safe reuse of wastewater in agriculture.

Method: SDG 6 and the human rights framework. The Sustainable Development Agenda stresses the importance of "leaving no one behind", which is grounded in the human rights framework. SDG 6 for drinking water, sanitation and hygiene furthermore addresses some normative criteria and principles of the Human Rights to Water and Sanitation. In fact, ensuring that everyone has access to adequate sanitation facilities is not only fundamental for human dignity and privacy, but also for protecting the quality of drinking water sources; with significant benefits for human health and economic development, as well as for the protection of water-related ecosystems (services).

Policy reform: Integrating the Human Rights to Water and Sanitation into policies and regulations, including for service providers and regulators, could therefore be used to increase the access to safely managed sanitation services and achievement of SDG 6. Local and national governments therefore need to integrate their national and international commitments for improving access to sanitation into policies, action plans and budgets.

Strategy: Governments need to ensure that no-one is left behind, in particular, the most vulnerable and marginalised communities. States also need to assess environmental impacts on human rights and to make environmental information public, to facilitate participation in environmental decision-making, and to provide access to remedies for environmental harm. Sustainable sanitation services should therefore be part of a holistic approach to Integrated Water Resource Management. Safe wastewater reuse, and the consideration of minimum water quantity needed for domestic uses and subsistence agriculture, should all be encouraged at watershed level and from a long-term perspective.

List of abbreviations

BOOT	Build–Own–Operate–Transfer
BOT	Build–Operate–Transfer
CFU	Colony Forming Units
CLTS	Community Led Total Sanitation
CO_2	Carbon Dioxide
CSO	Civil Society Organisation
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
ECOSAN	Ecological Sanitation
EU	European Union
FAO	Food and Agriculture Organization
GEMI	Global Enhanced Monitoring Initiative on water
GLASS	UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
GW2I	Global Wastewater Initiative
HCES	Household-Centred Environmental Sanitation
HRWS	Human Rights to Water and Sanitation
IWQGES	International Water Quality Guidelines for Ecosystems
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IWRM	Integrated Water Resources Management
JMP	WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation
MDG	Millennium Development Goal
NHRI	National Human Rights Institutions
OHCHR	Office of the United Nations High Commissioner for Human Rights
PPP	Private Public Partnership
SDG	Sustainable Development Goal
UDDT	Urine Diverting Dry Toilet
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-HABITAT	United Nations Human Settlements Programme
UNICEF	United Nations Children's Fund
VIP	Ventilated Improved Pit (VIP)
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WMO	World Meteorological Organization
WSSCC	Water Supply and Sanitation Collaborative Council

Foreword


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In 2015, WaterLex published with United Nations Environment Programme (UNEP) Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), a report providing information about the good practices for regulating wastewater treatment (UNEP, 2015a). Many reports have been published by international agencies with regard to the new 2030 Agenda; and some technical reports exist on low-cost technological alternatives to centralised sewers and wastewater treatment. However, to date, there is a crucial lack of international guidelines and public knowledge concerning (i) the technological alternatives to conventional sewer-based sanitation systems that require lots of water and are expensive to build, operate and maintain; and about (ii) the impacts of (partially treated) wastewater effluents on public health, environments and ecosystems functioning. Comprehensive and standardized monitoring methodologies are therefore urgently needed to better evaluate the quality of water and wastewater; as well as for understanding the complex and dynamic responses of (aquatic) ecosystems to climate change and environmental degradation.

The 2030 Agenda which was one of the outcomes from the Rio +20 conference of 2012, and the adoption of Sustainable Development Goals (SDGs) by all member states of the United Nations in 2015, dedicated a goal to water and sanitation (SDG 6: Ensure availability and sustainable management of water and sanitation for all) with eight targets, not only focusing on drinking water, sanitation and hygiene; but also on integrated water resources management, water and wastewater quality, and ecosystems protection. However, the successful realisation of SDG 6 requires some major and urgent improvements in wastewater and sanitation (and solid waste) management in many countries, including in institutional capacity and effectiveness. There is an imperative need for a paradigm shift towards consideration of technological alternatives which have to be tailored to local and specific environmental, political and socio-economic contexts. The operation and maintenance approaches need to ensure the management of sanitation infrastructures and services; whereas municipalities should facilitate private sanitation suppliers and installation. The underlying vision of the 2030 Agenda on eliminating inequalities ("Leave no one behind") features the realisation of human rights to safe water and sanitation, with special consideration for the poorest and marginalised communities such as the residents of informal settlements, women and children. There is therefore a crucial need of (1) information campaigns to raise sanitation and hygiene awareness, (2) training programs on water and sanitation governance, (3) business solutions for managing faecal waste, and for (4) incorporating the human rights to water and sanitation into policies, regulations and institutional framework, including for service providers and regulators.

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A man collects drinking water from a street hose leaking over polluted sewage in a slum area of Titagarh, West Bengal, India (Source: Pranab Basak with courtesy of Photoshare).

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Table of contents

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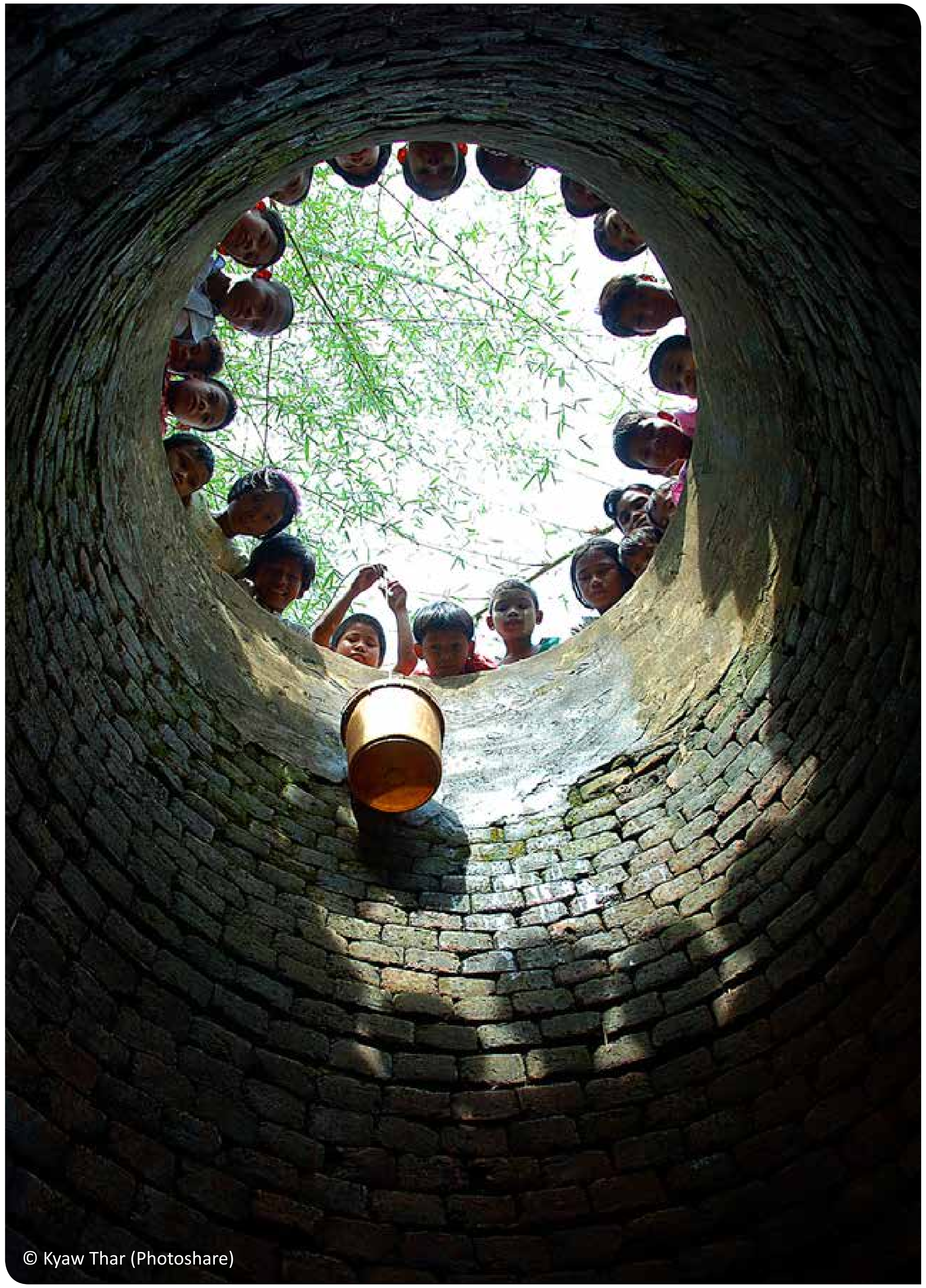
Executive summary

In 2016, the experts of the World Economic Forum ranked water crises, from drought in the world's most productive farmlands, to the hundreds of millions of people without access to safe drinking water, as the top global risk to industry and society over the next decade (Source: Global Risks Perception Survey 2015, World Economic Forum). Even though in 2010, the United Nations (UN) General Assembly recognised safe drinking water and sanitation as a human right, the contamination of water supplies and the lack of sanitation is still a major and unsolved problem in many parts of the world; especially in low and middle income countries. According to UN-Water, in 2015, every 20 seconds a child died as a result of poor sanitation management and about 80% of diseases in developing countries are caused by unsafe water and poor sanitation.

Faecal contamination of water bodies is a worldwide problem which is not only concerning developing countries that lack wastewater treatment, but also industrialised societies where highly populated centres draw their supply of drinking water and urgently need to improve their sewage, excreta, and sludge management practices (e.g. Thevenon et al., 2011a and 2012a). However, the problem is generally worst in low and middle income countries as these often lack appropriate sanitation systems and functional wastewater treatment plants. In fact, agricultural and urban runoff, the discharge of uncontrolled landfill leachate, as well as industrial, hospital, and domestic effluents, result in detrimental environmental impacts and significant public health hazard. Low-level of access and poor quality of basic water supply and sanitation services are particularly important in rural areas and in informal settlements and poor unplanned urban areas. As a consequence of the predominant lack of adequate infrastructure and public environmental awareness, rivers are commonly receiving untreated wastewaters from domestic, industrial and hospital effluents; while at the same being used as source of drinking water supply, for bathing and for irrigation of agriculture lands. Disease-causing organisms (e.g. bacteria, virus and worms) are hence spread into the environment, making water unsafe for human consumption and recreation, in many parts of the world. On the other hand, black water (excreta, urine, faecal sludge, flushing water and cleansing water) could produce a significant source of renewable energy and a valuable source of water and fertiliser for food production, if properly managed.

This report aims to highlight some existing sanitation system alternatives (e.g. ecological sanitation) to conventional (centralised) sewer-based sanitation systems; but also to point out the necessity to consider (international) water quality guidelines, environmental and health protection, as well as human rights-based legislation and policies when addressing domestic water and sanitation issues. The objective of this report is therefore to stress the multi-faceted aspects of what is needed for achieving sustainable development in water and sanitation. In fact, providing affordable and sustainable water and sanitation services in large cities (including informal settlements) and remote rural areas of low and middle income countries is a massive challenge that does not only require technical skills and financing investments in new activities or technologies; but also strong national and local governance institutions. The present report highlights that there are several factors that need to be appropriately addressed when setting up a model of sustainable sanitation; such as (i) the capacity of local communities, individuals and institutions to manage sanitation systems and services, and (ii) the coordination between the different sectors (health, environment, land planning), partners (public, ministers and private companies) and stakeholders. Strategic and flexible sanitation plans need (1) to solve local problems using local or national institutional and financial responses, (2) to develop innovative business models for the whole sanitation services chain, (3) to promote the safe reuse of water and nutrients present in wastewater, and (4) to incorporate and monitor the human rights to water and sanitation in the legal and institutional framework of wastewater management.



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1. Introduction: Setting the scene

The required improvement of wastewater management and governance must be adapted to local environmental specificities and to human needs and activities (e.g. water uses and pollution), but also considered at the basin-scale in order to protect surface and groundwater resources (i.e. rivers, aquifers and lakes) and ecosystems (services) and human livelihoods. The response to the present (water and) sanitation crisis is complex and can be intrinsically limited (i) by economic criteria such as the financial resources available for both initial investment costs and to guarantee long-term operation and maintenance, or (ii) by unfavourable political conditions in the region (weak political structures and high rates of corruption), as well as (iii) by a relative lack of data and knowledge related to wastewater management and water dynamics (e.g. the separation of storm water runoff and sanitary sewerage systems). Another challenge is that the implementation of wastewater management strategies, action plans and policies to reduce the contamination of water resources by human excreta need to involve a broad range of stakeholders such as the water and sanitation operators (from public, private or cooperative network providers), public institutions (including human rights institutions and judicial courts), policy makers (including national and local legislative and administrative authorities), civil society organisations (such as non-governmental organisations and media), academic institutions, the research community, industrial and agricultural users, tourism industry and international organisations. The involvement of this broad variety of stakeholders in policy design is an inherent component and requirement of the human rights legal framework which is necessary to provide a specific legal-based leverage opportunity to drive sustainable changes in the field, and to successfully address socio-economic and water pollution issues from environmental conservation and human rights points of view.

The most effective measures to reduce sanitation vulnerability are holistic approaches that implement robust water and sanitation infrastructures, but also which further stretch the disaster response capacities at the watershed scales and take into account the views and needs of the populations concerned, including poor communities and people living in informal settlements. The improvement of sanitation systems is particularly important in the context of climate change because extreme weather events which may become more frequent and intense may damage sanitation infrastructures and threaten freshwater resources. On the other hand, domestic wastewater management can provide the required quantities of water and of major plant nutrients for crop cultivation; ensuring sustainable food supply and reducing the pressure on available freshwater resources. Finally, faecal sludge end-products can generate revenues that could offset treatment cost and act as an incentive to sustain wastewater and faecal sludge management services, while saving fossil fuel combustion and therefore reducing carbon dioxide (CO_2) emission. It is noteworthy to understand that improving wastewater management is of public interest because of the resulting significant benefits for other water users (human health and economic development) as well as for the protection of water ecosystem (services). This requires the implementation of basic but efficient monitoring programs to evaluate the quality of wastewater effluents and their impact on scarce water resources and aquatic ecosystems, which can be additionally threatened by other pollution sources and climate change effects.

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2. Key water challenges

2.1. General context

According to the latest estimates of the WHO/ United Nations Children's Fund (UNICEF) Joint Monitoring Programme for Water Supply and Sanitation (JMP), around 32% of the world's population – 2.4 billion people – still lack improved sanitation facilities, and 663 million people still use unimproved drinking water sources (WHO/ UNICEF 2014). Inadequate access to safe water and sanitation services, coupled with poor hygiene practices, kills and sickens thousands of children every day. The Millennium Development Goal (MDG) sanitation target aimed to reduce the proportion of the population without access to improved sanitation from 51% in 1990 to 25% in 2015 (but only reached 33%). Between 1990 and 2012, almost 2 billion people gained access to an improved sanitation facility, and open defaecation decreased from 24% to 14% (from 1.3 to 1 billion). Although the world met the MDG drinking water target, 748 million people (mostly the poor and marginalised) still lack access to an improved drinking water source. Of these, almost a quarter (173 million) relies on untreated surface water supply, and over 90% live in rural areas (WHO/UNICEF 2014). However, other estimations suggest that 1.8 billion people (28% of the global population) used unsafe water in 2010 – whereas the 2010 JMP estimate is that 783 million people (11%) use unimproved sources.

Despite major efforts by the international community over the last decade, the water and sanitation crisis continues to affect the health and livelihoods of many of citizens, and to hamper the economic development of many developing countries. In fact, the economic benefits of improved access to water and sanitation do not only include a reduction of health costs, but also increase productivity among adults and children, including higher school attendance rates. It is generally accepted that for every 1 USD dollar (USD) invested in sanitation, there is a significant socioeconomic benefit gained, yielding an average return of USD 5 to 46 depending on the Water, Sanitation and Hygiene (WASH) intervention (Haller et al., 2007); because business opportunities and job creation exist on several levels (e.g. construction workers, sanitation services and safe reuse practices). According to the 2016 United Nations World Water Development Report, three out of four of the jobs worldwide are water-dependent, and water shortages and lack of access may limit economic growth in the years to come (WWAP 2016).

Although the percentage of population with access to improved sanitation facilities increased since 1990 in all regions (**Figure 1**), the number of people living without access to sanitation has sometimes increased due to slow progress and population growth. The population with access to improved sanitation facilities is particularly low in Sub-Saharan Africa with 31%, but the largest share of population without access is in South Asia (**Figure 1**; WHO/UNICEF 2010).

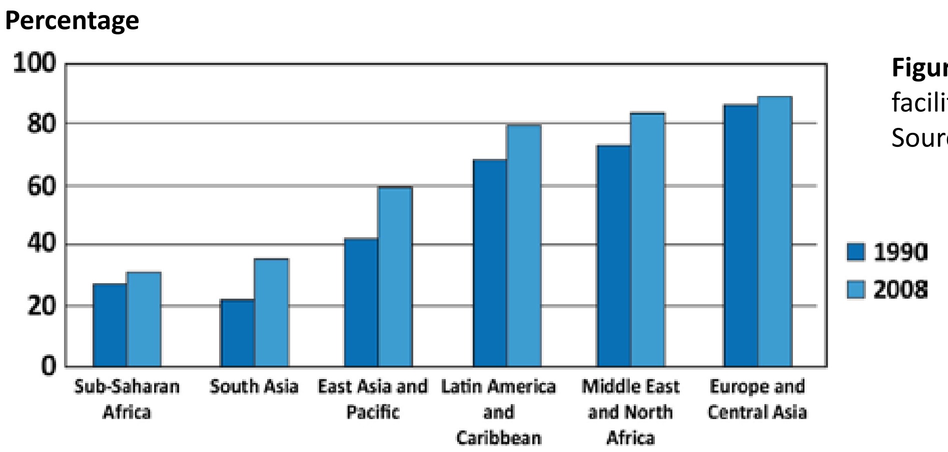

Figure 1. Access to improved sanitation facilities (percentage of population; Source: WHO/UNICEF 2010).

2.2. Sanitation impact on drinking water quality

During the 2012 conference of the United Nations Convention on Sustainable Development (Rio + 20), the UN stressed that 2.5 billion people (roughly 37% of the world's population) still did not use an improved sanitation facility (toilets or latrines), and a little over 1 billion people were practising open defaecation which is one of the main causes of drinking water pollution and diarrhoea incidences; resulting in the deaths of more than 750,000 children under 5 years of age per year (UN 2012). With 67% of the population having access to improved sanitation in 2015, the world is thereby far from meeting the agreed target of 75%. About 1.5 million children die each year (5,000 every day) from diseases which are largely preventable through proper sanitation and improved hygiene (UN 2012; Montgomery and Elimelech, 2007). With only 47% of the rural population using improved sanitation, rural areas lag far behind urban areas where the rate is about 80%. Seven out of ten people without improved sanitation live in rural areas. Countries that still have less than 50% coverage in water supply are almost all in sub-Saharan Africa, while several populous countries in Southern Asia also have low rates of improved sanitation (**Figures 2** and **3**).

It is meaningful to note that the countries which do not have a general access to improved sanitation (i.e. less than 75% of the population) are (i) almost the same as the ones which do not have access to improved water source (**Figure 2**) and are (ii) mainly located in sub-Saharan Africa and Southern Asia (**Figure 3**). In fact, microbial contamination of freshwater resources is particularly significant in developing countries which lack adequate sanitation facilities and where the proportion of households that practice open defaecation is still high (e.g. Democratic Republic of Congo; Mwanamoki et al., 2014). The discharge of untreated wastewater and excreta into the open environment leads to the contamination of the surface waters by human faecal bacteria; increasing the potential risks of human infections either by direct uptake through drinking water, recreational activities, or through food via bacterial contamination of raw vegetables. Such bacterial contamination also threatens the biodiversity and the ecological functions of the rivers, streams and lakes, ecosystems that are vital for human wellbeing and livelihoods. Major efforts are therefore necessary to prevent contamination of water resources by excreta, and with that, disease-causing microorganisms such as viruses, bacteria and worms. The majority of urban slum dwellers from developing countries lack access to improved sanitation or rely on badly managed non-sewered sanitation systems resulting in negative public health outcomes and significant environmental risks. Faecal sludge is frequently allowed to accumulate and overflow from poorly designed pits directly into storm drains or open water. When pits are emptied, the faecal sludge is often dumped into waterways, wasteland or unsanitary dumping sites (WSP, 2014); thereby polluting the environment, including water bodies and groundwater. Leaking sewers or septic tanks, and open defaecation along river banks also contribute to a large-scale diffuse contamination by faecal bacteria. Faecal sludge management is often unsystematic and unplanned; with poorly regulated faecal sludge collection and inappropriate or lacking treatment and disposal facilities (Strande et al., 2014). Finally, besides the treatment of microbial contaminated domestic wastewater, the treatment of industrial and hospital wastewaters as well as solid waste, typically showing toxic and hazardous properties, must be pursued so that all the population can be protected from the exposure to harmful inorganic toxic substances (e.g. heavy metals, pharmaceuticals and endocrine disruptors).

In 2015, 29% of the global population lacked safely managed drinking water services - i.e. water at home, available, and safe; 61% of the global population lacked safely managed sanitation services - i.e. use of a toilet or latrine that leads to treatment or safe disposal of excreta. In sub-Saharan Africa, 15% of the population had access to handwashing facility (WHO/UNICEF 2017).

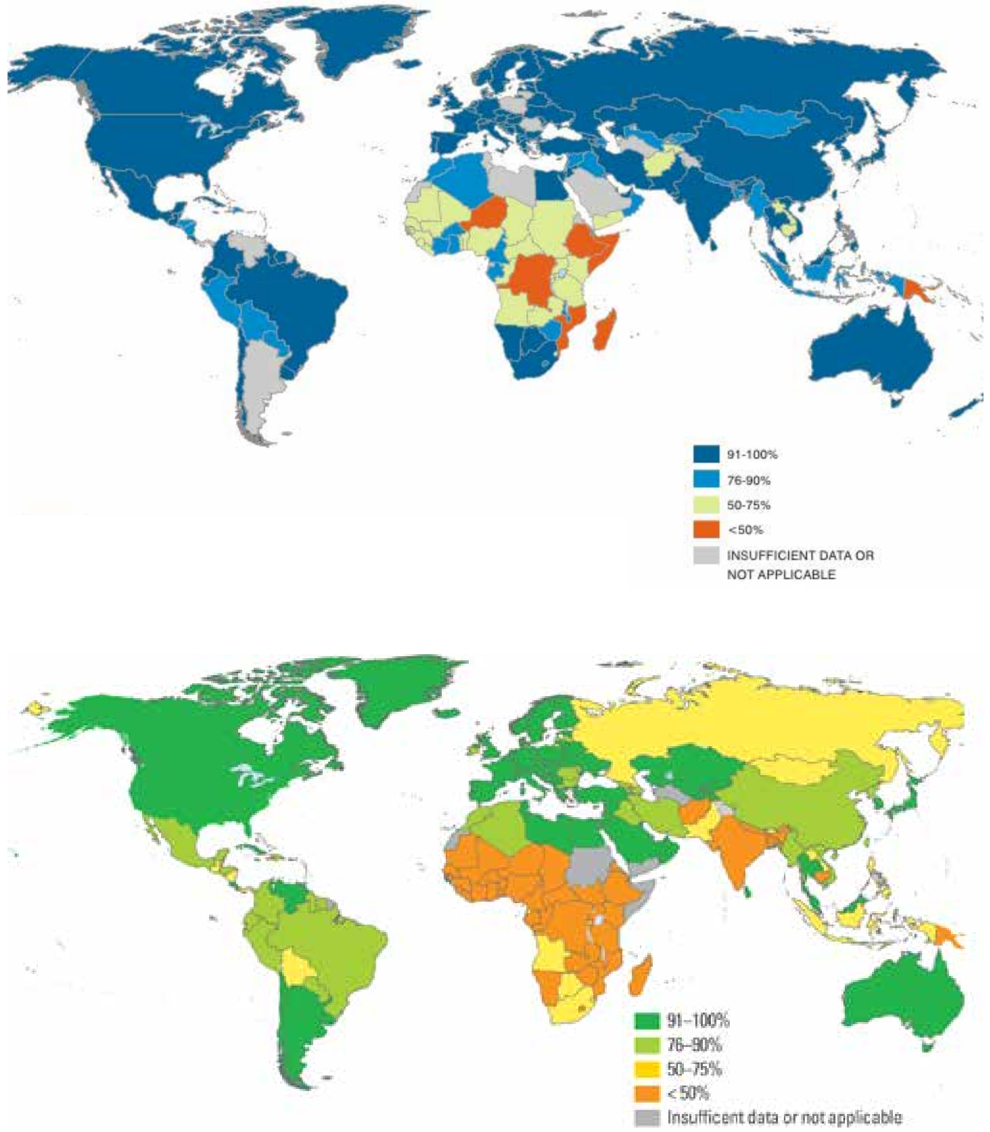

Figure 2. (Top) World map showing the proportion of the population using improved drinking water sources in 2012. (Bottom) World map showing the proportion of the population using improved sanitation in 2012 (Source: WHO/UNICEF, 2014).

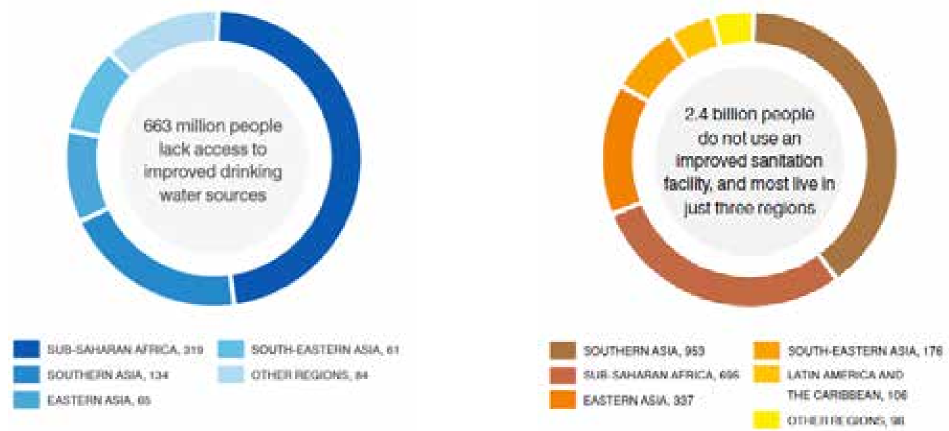

Figure 3. (Left) Population without improved sources of drinking water in 2015, by region. (Right) Population without improved sanitation in 2015, by region (Source: WHO/UNICEF, 2015).

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3. Definitions and sanitation solutions

Wastewater is a combination of one or more predominately liquid waste substances: Domestic effluent consists of black water (i.e. a mix of excreta, urine, flushing water and anal cleansing water) and greywater (water from personal hygiene, kitchen and laundry). Together with storm water entering the drainage system (combined sewers), this is the dominant composition of wastewater. Other wastewater sources include: Wastewater from commercial establishments and institutions (including hospitals), industrial effluent, other urban runoff, and wastewater from other specific production facilities or extractive industries such as agriculture, horticulture, aquaculture or mining. Centralised sewer systems transport the solid and liquid fractions of wastewater using water (Annex 3.2). Sewer systems are typical of industrialised countries, but are not necessarily appropriate in low income settlements characterised by weak governance structures and capabilities, low water access and consumption, and low capacity and financial resources to secure regular and appropriate maintenance so that correct operation can be ensured. The feasibility of conventional sewage treatment plants for most people living in developing countries is often not realistic. Other sanitation alternatives are better suited, as they can be better integrated into the local specific context. These can be developed by the local community and be embedded in a system of local ownership. They utilise predominately local resources, can be locally managed, need less water, and can facilitate possible (local) reuse of nutrients (Jenssen et al., 2004).

Toilets flushed with clean drinking water which use about one third of the water consumed in cities of rich countries are not sustainable for many parts of the world: In the European Union (EU), toilet wastewater (urine, faeces and flushing water) amounts to between 10,000 and 25,000 litres per person per year; and greywater ranges between 25,000 to 100,000 litres per person per year (Wendland and Albold, 2010). Flush toilets and subterranean gravity sewers (Annex 3.2) have significantly improved human health and wellbeing by removing wastewater from the settlements. However, the discharge of large volumes of treated effluents and urban storm water overflow into the environment contributes to the burden on drinking water resources and aquatic ecosystems. In fact, treated effluents released by wastewater treatment of industrial, hospital and domestic wastewater generally contain high amounts of toxic pollutants which can eventually contaminate drinking water resources and water-related ecosystems on a long-term perspective (Thevenon et al., 2011a and 2012a). Solid particles smaller than screens or sieves (e.g. micro and macro-plastics) and dissolved inorganic pollutants (e.g. heavy metals plus pharmaceuticals and endocrine disruptors) do not degrade in the environment; whereas faecal bacteria (e.g. multiple antibiotic-resistant indicator bacteria) persist and grow in the water column and in organic-rich sediments (Poté et al., 2009; Thevenon et al., 2012b). These pollutants therefore represent a potential risk for human health, because their re-suspension can affect the quality of the water which could be ingested; for instance, during recreational activities (Thevenon et al., 2011b). It is worth to note that apparently clean effluents which are discharged into the environment can be also highly enriched in microbiological contaminants, toxic chemicals (e.g. heavy metals and pesticides), and organic matter such as nitrogen and phosphorus which can cause eutrophication problems.

To meet the need of sanitation for all and to achieve the SDGs, but also to minimize environmental degradation and invest efficiently, new approaches to wastewater management are needed. Consideration should be given to low resource consumption (financial affordability), limited use of water, recycling of nutrients or organic matter, and/or recovering energy. Following the principles of ecological sanitation offers new opportunities for the poor but also for countries of high income (Jenssen et al., 2004). There are many documents presenting alternatives for sanitation and cost-effective wastewater management (see Annexes 1 and 2). This chapter is not intended to exhaustively present all existing technologies but rather gives an overview of some key characteristics and selected best practices for toilet and wastewater management systems.

3.1. Appropriate sanitation options

Although the importance of access to improved sanitation options has been pointed out by the international community as a priority for over 30 years (starting with the first International Decade of Water and Sanitation in the 1980s), the MDG target of halving by 2015 the proportion of people living without sustainable sanitation access was not achieved. One main reason is that the necessary change from a conventional (high technology and high cost) approach to a new, more appropriate technology at lower cost approach, was not adequately and broadly implemented (Mara and Alabaster, 2008). A new approach would imply an urgently needed major shift in the vision of water and sanitation management, and a new paradigm to address the water related sanitation challenges. Such a global change of perspective can only occur by encouraging existing technological alternatives over conventional sanitation systems, in order to (i) save freshwater resources, (ii) limit the volume of flushing water discharged in the environment, and (iii) promote the separation and reuse of resources in wastewater such as water, human excreta and urine (**Figure 4**). Selected low-cost sanitation technologies that can meet sustainable development criteria for excreta management are briefly described in **Box 1** and presented in Annex 3.1 using the illustrations of Tilley (2014). Such sanitation technologies may include on-site solutions such as ventilated improved pit (VIP) latrines, pour-flush toilets, urine diverting dry toilet (UDDT such as ecological sanitation (EcoSan) toilets) or also off-site simplified small grid systems such as condominial sewers for grouped individual sanitation. Different sanitation facilities have been classified as improved or unimproved by JMP (WHO, 2006) (**Table 1**). To further ensure public health, the indicator SDG 6.2.1 (Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water) (i) excludes shared facilities, (ii) includes safely abandoned pit latrines, and

Figure 4. Bio-toilets installed by the government in a slum of Kolkata, India (Photo credit: Ashim Kumar Mukhopadhyay with courtesy of Photoshare).

(iii) incorporates the safe management of faecal waste along the entire sanitation chain (i.e. from containment to final treatment and safe disposal); in addition to the MDG categorisation of facilities between improved/unimproved based on the hygienic separation of excreta from human contact. Recent estimates indicate that 39% of the global population (2.9 billion people) used a safely managed sanitation service. Two out of five people using safely managed sanitation services (1.2 billion) lived in rural areas (WHO/UNICEF 2017).

A basic pit latrine can be improved to a "Ventilated Improved Pit (VIP)" toilet by addition of a ventilation pipe. Air flows from the pit through the ventilation pipe into the open decrease the smell inside the toilet. The airflow through the pipes also captures and moves flies through the pipe and when the top of the pipe is covered by a fly screen the flies cannot exit the pipe and die. A further improvement is the construction of a second pit which is alternately used when the first one is full. While the second pit is in use, the excreta in the first pit is degraded by bacteria, worms and other organisms and some degree of pathogen reduction occurs. So, when the first pit is emptied, the transformed waste can be more safely reused as fertiliser in agriculture or

Improved sanitation services or methods	Unimproved methods are all those that do not ensure there is no human contact with human excreta
WC or flush toilet uses a cistern or holding tank for flushing water, and a U-shaped seal pipe that prevents the passage of flies and odours.	A **hanging toilet/latrine** is a non-flush toilet built over a water body into which excreta drops directly.
Flush/pour-flush **pit latrine** is a system that flushes excreta into an underground hole with water. The hole is protected and covered.	A **flush/pour-flush toilet** refers to excreta being flush and discharged in or nearby the household or into the environment.
A **piped sewer system** (or sewer) is a network of pipes designed to collect human excreta and wastewater and remove them from the household environment.	A **pit latrine without slab** is a non-flush pit for collection of excreta, where the pit is not covered or protected by a safe slab but rather by a haphazard construction posing a risk to the user.
A **septic tank** is a water-tight tank located underground, into which excreta and wastewater is flushed and where excreta can settle.	**Bucket latrine** refers to the use of a bucket or other container for temporary collection of faeces (and urine). The bucket or container is then periodically removed and emptied.
Pit latrine with slab is a non-flush pit. The pit is covered by a hygienic and safe squatting slab or platform (i.e. easy to clean, above the ground level, with a squatting hole or a seat). The pit collects excreta and wastewater.	**Open defaecation,** no facilities includes defaecation in the open, on a field, in a ditch or behind a bush. Excreta is deposited on the ground, into surface water (drainage channel, beach, river, stream or sea) or wrapped in a bag and thrown into the garbage. On the ground it can be covered with a layer of soil.
Ventilated Improved Pit (VIP) toilet is a non-flush pit latrine with an appropriate ventilation pipe that avoids smell and flies.	
A **composting toilet** (with or without urine separation device) is a non-flush toilet into which material (vegetable wastes, straw, sawdust, ash) are added to produce absorb odours and moisture and generate compost.	

Table 1. Improved and unimproved sanitation definition by the JMP (Source: WHO, 2006).

aquaculture. The main advantage of pit latrines is their relatively low cost. The superstructure (housing above the pit) can be built with locally available materials (e.g. bamboo, mud or bricks). One main challenge is that when faecal sludge is removed from the pit, safe emptying, transport and treatment practices are lacking. Faecal sludge is often removed from pits manually by dwellers, frequently, without adequate protective equipment (**Figure 5**). After emptying, faecal sludge is often dumped without treatment into the surrounding environment thus causing public health risks as well as environmental pollution (especially drinking water sources contamination).

Wet sanitation methods utilise water to flush the

BOX 1: DRY OR WET PIT SYSTEMS AND VAULT SYSTEMS (see illustrations in Annex 3.1).

- A pit latrine is a type of toilet collecting human faeces in an underground hole (i.e. a pit dug in the ground) and represents the lowest cost method for collecting excreta and removing faeces away from people. In the pit, the wastewater infiltrates into the ground. Once full, the pit is either covered and closed with soil (a tree can be eventually planted in the covered pit) or it may be emptied by a mechanical (vacuum truck) or manual emptying device and transport away for treatment and discharge. Construction of an underground pit is not advisable for unstable or hard (rocky) soils which complicates construction or conditions with high groundwater table, else contamination of the groundwater may occur. Situations where typical rainfall pattern causes frequent flooding are not favourable for pits. It is noteworthy that a pit that is not covered completely with a safe and hygienic slab is not considered improved sanitation (Table 1) as it may endanger the user (falling into the pit) attract flies and other disease carrying vectors. Excreta deposited in the pit will degraded partly by anaerobic process (i.e. in the absence of oxygen) in the bottom layers and aerobically in the top layers and stabilize to a soil-like product (Herron, 2011).
- Dry vault sanitation technologies are defined as those that avoid the use of water for flushing excreta and are not designed to received large amounts of wastewater (except anal cleansing water). These include systems that separate faeces and urine (e.g. urine-diverting dry toilet, UDDT). Urine is diverted into a closed tank or infiltrated into the ground by a soak field while a watertight vault (above ground) receives and stores the faeces. Often after defaecation the faeces are covered with ash, shredded leaves, or sawdust to absorb excess of moisture and reduce odour emissions. Vault and dehydration systems allow better groundwater protection as the storage is above ground and only controlled infiltration into the soil (urine in soak pit) is allowed. Most common problems are to keep the dehydration chambers dry (especially critical in cases of high precipitation) which is the main difficulty of use of urine diverting systems (especially for young children) (Herron, 2011).

waste and thus require access to and affordability of water. One of the most widely used technologies is the pour-flush latrine with 1-3 litres of water per flush and with a subsequent septic tank. Typically, the toilet bowl has a U-bend water seal and significantly reduce the odours. Flush toilets with pans are more expensive than dry toilet slabs and there is the risk that the pipes may clog. The flushing water transports the excreta into a septic tank (e.g. aqua-privy), which can be located outside the house, and can also receive greywater. Septic tanks have two connected chambers (Annex 3.1). The first acts as solid matter settling chamber where the solids undergo anaerobic degradation. This settled sludge must be regularly removed. The construction of septic tanks is more expensive than pit systems as the tank needs to be constructed to avoid leakage. Wastewater effluent from a septic tank needs further management, either by a soak field (i.e. the percolation of the effluent through the soil) or discharge into a wastewater drain that leads to a wastewater treatment facility. This step is required as the effluent is potentially harmful for humans and water-related ecosystems (see part 4). Soak fields also may present health risks for the environment when the groundwater table is close to the surface. On the other hand, if enough unsaturated soil is available, soak fields or subsurface irrigation can be used to achieve low-cost natural treatment of wastewater. Planting semi-aquatic plants and flower or vegetables enhances this effect. Effluent from a septic tank is still nutrient rich and can be further used as a source of nutrient (and water) for aquaculture (and agriculture) if appropriate measure to avoid health risks are applied (see part 4.2).

Figure 5. A sewer worker cleans the drainage system of the metropolitan city of Kolkata, India, without proper protective Equipment (Photo credit: Sujan Sarkar with courtesy of Photoshare).

3.2. Wastewater treatment in ponds and lagoons

Although there is a willingness to pay for drinking water provision and services, the willingness to pay for wastewater collection and treatment is generally low (or even absent) while wastewater management is more expensive than water supply. Moreover, treated wastewater is not easily recognised as a valuable product, unlike water treatment for drinking water supply. These observations point out some of the difficulties facing sustainable wastewater collection and maintenance of wastewater treatment systems in low and middle income countries (Gijzen, 2001).

Management of wastewater beyond the sanitation facility is crucial to ensure public health benefits and environmental sustainability. The separating of the solids and liquids (which make up faecal sludge) has historically been achieved through sedimentation and thickening in ponds or tanks, or filtration and drying in sludge drying beds. The resulting solid fraction may require post treatment, mainly to meet hygiene requirements for reuse in agriculture as a soil-conditioner and fertiliser (e.g. additional dewatering/drying for landfilling). Post treatment is also necessary for the liquid fraction, to satisfy criteria for water reuse or for discharge into surface waters to avoid long-term impacts on water bodies and groundwater quality (Strauss and Montangero, 2002). Water can be treated through natural biological processes (i.e. degradation of organic matter and nutrients by aerobic/anaerobic bacteria, algae, or macro-organisms), or by physical processes such as settling by gravity (i.e. sedimentation of the solids suspended in wastewater) or filtration (e.g. reverse osmosis and nanofiltration membrane processes).

Nutrients in wastewater or faecal sludge, when properly managed, can be converted to fish protein (i.e. as feed for fish in aquaculture) or crop protein (through irrigation agriculture). Their use therefore constitutes a recycling process that is applicable under a wide variety of rural and urban conditions, is energy efficient, cost effective and has possible significant economic returns (see part 3.3) (Gijzen, 2001). However, as wastewater and faecal sludge contains pathogens, measures must be applied to avoid endangering human health and the environment by this application.

Wastewater treatment in lagoon or pond systems is one of the most cost-effective wastewater treatment options (Annex 3.3). Although it has a high land requirement, it is easy and cheap to construct, operate and maintain; as compared to more technical and energy intensive approaches. It is also used in industrialised countries for rural and small communities or for seasonal rental properties and recreational areas with intermittent periods of both light and heavy use (PIPELINE, 1997). Here, wastewater is treated with a combination of physical, biological and chemical processes; for example, anaerobic, aerobic, aerated and facultative lagoons which can be used in series, in parallel or both. However, lagoon systems must be individually designed on a case-to-case basis depending on many factors such as the type of soil, the amount of land area available, the climate (precipitation, sunlight and wind), the quantity of wastewater to be treated and the level of treatment required by local regulations and reuse options (PIPELINE, 1997).

Treatment of faecal sludge can also be achieved by a series of specifically designed anaerobic and aerobic ponds. However, it is important to understand the properties of the faecal sludge; which is highly variable, depending on factors such as storage type and duration, tank emptying technology and patterns, other materials added, temperature, or intrusion of ground or surface waters (Montangero and Strauss 2004). Fresh excreta (e.g. from latrines or public toilets) do not settle easily and will require long retention times where sludge can undergo further stabilisation. Conversely, partially digested sludge with little organic matter and easily settable solids (e.g. from septic tanks or anaerobic digesters) will require short retention times, and the sludge will settle and dewater quicker. Short retention-time thickening ponds are often called settling tanks, while long-retention and stabilisation-thickening ponds are called sedimentation or anaerobic ponds (Tilley et al., 2014; Annex 3.3).

Wastewater ponds and lagoons can be constructed and lined with clay or artificial liner to avoid infiltration and thus protect the groundwater from contamination. Additional treatment using aquatic macrophytes such as hyacinth, lettuce or duckweed can remove nutrients from wastewater before the effluent is discharged into the environment. These macrophytes can then be harvested and further used as animal feed (e.g. duckweed) (PIPELINE, 1997) or biomass energy. The major limitations for such applications is the requirement of land space at reasonable cost. Furthermore, anaerobic ponds may generate undesirable odours and insects, especially when inadequately maintained. Finally, lagoons are not very effective at removing chemical contaminants (e.g. heavy metals) and the effluents of the lagoons may even be enriched in organic biologic material due to the proliferation of blue-green algae inside the lagoons. Although simple, ponds and lagoons require good long-term management and some regular maintenance (e.g. for desludging or for repairing fences to prevent entry by children and animals); otherwise the lagoons also provide a breading area for mosquitoes and other insects. Finally, wastewater ponds can provide a relatively pleasant ecological appearance and can even be used for recreational purposes (e.g. boating and ornamental lakes). The effluent can be used for crop irrigation or commercial aquaculture activities (Gijzen, 2001).

For good technology selection, it is essential to conduct a detailed analysis of costs for investment (land and equipment), operation (staff, electricity and other inputs) and maintenance required for normal operation (e.g. frequency of repairs and required staff). The environmental context (geology and climate), input quality and output requirements set by the regional authorities should also be taken in account (Nikiema et al., 2014).

In addition to technical and scientific aspects, there are several other factors that need to be appropriately addressed when pursuing a model of sustainable sanitation. These include the capacity of communities and institutions to manage systems, as well as the coordination between the different sectors (health, environment, land planning) and partners (national and local authorities and private sector) (see part 4.3).

It is worth noting the Wastewater Treatment Technology Matrix developed by UNEP and the International Water Association (IWA), to support decision making for wastewater treatment technology options in low and middle income countries. The technology matrix was developed for the entire sanitation chain from containment to reuse and/or disposal, to provide a guidance document for decision makers and donors for selecting wastewater treatment technologies (e.g. the vehicular access to households; **Figure 6**). The matrix which was created to take into account environmental performance, economic factors, and social sustainability, has strong links with the Compendium of Sanitation Systems and Technologies (Tilley et al., 2014). The latter category encompasses the local population's acceptance of the technology and responsibility for its maintenance and operation. Life cycle analysis and consideration of waste reduction and recycling methods was used as a backdrop for technology considerations.

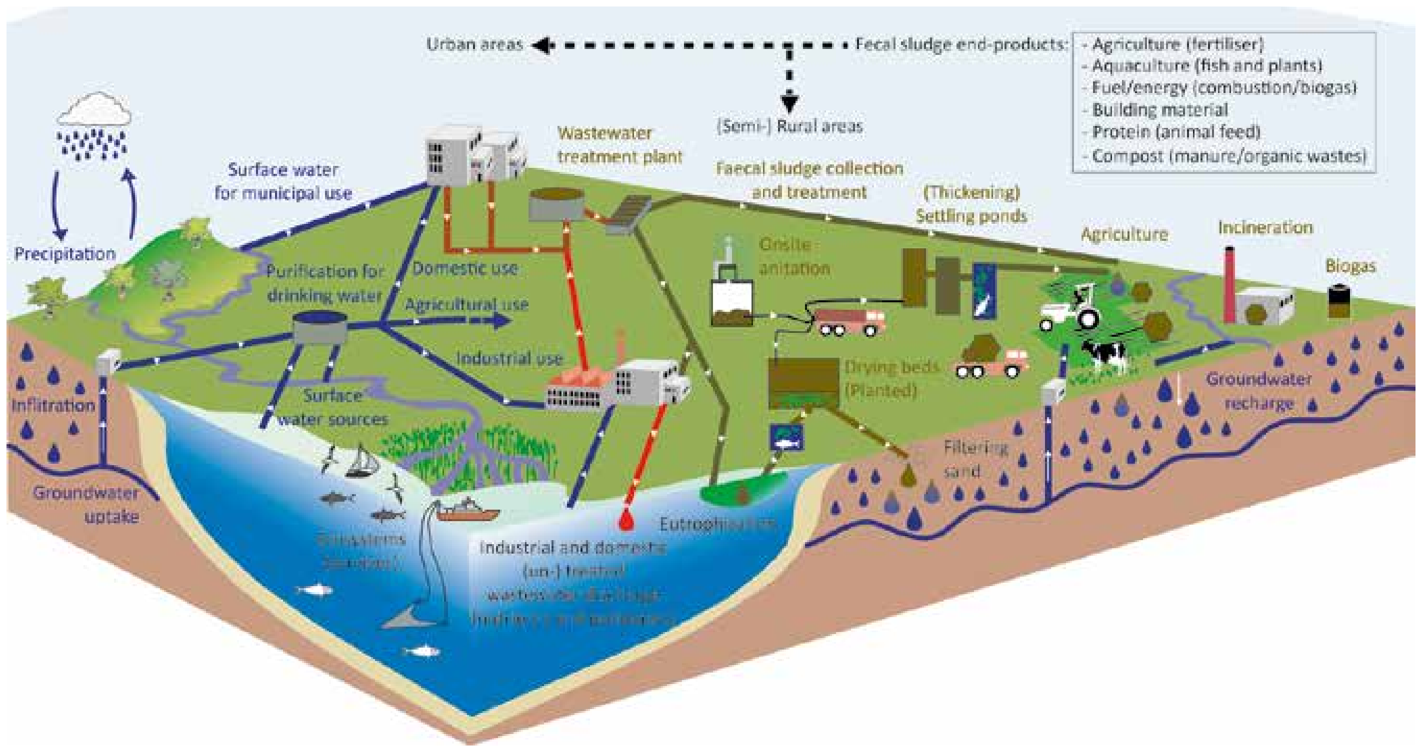
Figure 6. A wastewater treatment facility in Accra Ghana (Photo credit: PATH/R. Wilmouth).

3.3. Valuation of sanitation products

Anthropogenic excessive input of nitrogen and phosphorus into aquatic ecosystems is the primary cause of eutrophication and algal bloom problems. This is primarily a result of phosphorus runoff (diffuse from agricultural land uses and direct fertiliser) during rainfall events into surface waters, or due to untreated domestic wastewater discharge. It is worth noting that most of the inorganic (i.e. mineral) phosphorus used in fertiliser comes from mining fossil phosphate rock deposits; which are a non-renewable resource, generally containing some environmentally hazardous chemical elements (e.g. trace metals) which accumulate in the cultivated soils on a long-term basis. In addition, the demand for mining fossil phosphate rock is rising, due to the increasing food demand of a growing world population, and in the context of declining soil fertility due to intensive cultivation. Consequently, cheap and high-quality reserves of phosphate fertiliser are rapidly becoming increasingly scarce; possibly threatening the world's ability to produce food in the future if concerted efforts are not encouraged by policy makers, scientists, industry and the community.

When analysing the value contained in human waste, it is relevant to mention that urine contains important quantities of phosphorus and nitrogen while faeces contains mostly organic matter (e.g. carbon and potassium). Together, excreta (a renewable resource) thus contains the primary nutrients that are essential for the growth and survival of plants and animals. Urine and faeces together have a general nutrient value of 4550 g of nitrogen and 548 g of phosphorus per person per year; based on the production of human waste ranging from 182 to 601 kg per person per year (Richert et al., 2010). Recovering the organic matter and nutrients in excreta should therefore be given more attention in the forthcoming years. Such a practice would improve soil health and fertility (i.e. water holding capacity and microbial activity). Although technical and social challenges remain concerning the treatment and safe reuse of human waste, this appears to be an appropriate sustainable solution to enhance agricultural and aquaculture productivity worldwide (**Boxes 2 and 3** and **Figure 7**).

Figure 7. Hydrologic and drinking water cycle, wastewater and faecal sludge collection, treatment and reuse (Source: This report).



BOX 2: BENEFITS OF HISTORICAL WASTEWATER USE FOR AQUACULTURE – CALCUTTA (INDIA).

The largest wastewater-fed system for fish production has developed over the last century due to the discharge of wastewater and urban runoff from Calcutta (population metropolitan of more than 13 million of inhabitants; **Figure 8**), receiving about 600 million litres of sewage per day. The main sewers of Calcutta began functioning in 1875 and sewage-fed farming started in the 1930s in the extensive pond system used for wastewater treatment. In 1945, the area of sewage-fed fish ponds was about 4628 ha, in a wetlands area of about 8000 ha, but the fish pond area has been reduced to about 3000 ha by 1987; due to urban reclamation and conversion of fish ponds to rice paddies (Pescod 1992). Wastewater flows through fishponds where physical, biological and chemical processes are likely to improve the quality of the water. These wastewater stabilization ponds also create thousands of jobs and provide low-cost protein to the local population, with the fisheries supplying the city markets with 10-20 tonnes of fish per day and providing 10-20% of the total fish demand. However, because of increasing pressure of urbanisation, change in the quality and quantity of solid waste and sewer, this Ramsar site (i.e. recognized as a Wetland of International Importance) is under major threat (Kundu et al., 2008). Indeed, without any treatment of the wastewater before being discharged in the Calcutta aquaculture ponds, and considering that this wastewater-fed fishpond system receives as much as 70% of industrial wastewater, the quality of the water does not comply with the WHO criteria for microbiological quality for aquaculture (i.e. zero nematodes and less than 1000 faecal coliforms per 100 ml) (Gijzen, 2001). The safe recovery and reuse of water and nutrients from wastewater effluents is a major challenge faced by the future increases in water irrigation demand, and in the context of human systems adaptation to climate change and growing urbanisation. Indeed, despite direct benefices, it is important to apply international water quality criteria to preserve the environment and public health, including when using wastewater for agriculture and aquaculture practices (see part 4.2 for further details on health concerns and **Box 7**).

Figure 8. Kolkata Wetlands near Calcutta (India) consists of 12,500 hectares of sewage fed fisheries, small agricultural plots and solid waste farms (Kundu et al., 2008) (Image credit: Google Earth view).

Recently, attention has been drawn to the potential sources of energy from human waste with the production of biogas, mainly methane and carbon dioxide, generated through anaerobic digestion of faecal sludge and wastewater. Dried and charred faecal sludge (which can be crushed and used as a fuel) has similar energy content to charcoal or coal. It thereby represents a significant economic, social, and environmental opportunity, when compared to conventional charcoal production which leads to deforestation, soil and land degradation as well as declining water quality. A recent report from UN University's Canadian-based Institute for Water, Environment and Health estimates that biogas, potentially available from human waste worldwide, has a value of up to USD 9.5 billion in natural gas equivalent; theoretically representing a potential fuel source great enough to generate electricity for up to 138 million households (equivalent to the number of households in Indonesia, Brazil, and Ethiopia combined) (Schuster-Wallace et al., 2015). If the biogas were to be digested, dried and charred, it could produce about 2 million tonnes of charcoal-equivalent fuel. This large energy value is nevertheless small relative to the global health and environmental benefits that would accrue from the proper universal treatment of human waste.

Treatment, recovery and recycling of faecal sludge starts with a pre-treatment step to remove inorganic and solid macro-waste such as plastics. For this purpose, a grid (manually or automatically cleaned) is generally used. This is followed by faecal sludge dewatering which separates the fluid from the solids. This can be achieved by drying using mechanical or non-mechanical units. For community-scale facilities in low-income countries, non-mechanical processes are often recommended given the lower cost implied (Nikiema et al., 2014). One of the possible options is the use of faecal sludge settling ponds followed by faecal sludge drying beds (**Figure 9**). These are especially appropriate when the faecal sludge is much diluted or not yet stabilised. Indeed, a longer

Figure 9. (Above) Settling ponds and drying beds in Uganda (Photo credit: Franz Hollhuber). (Left) Paved sludge drying beds from the Wadi Shueib located in the Salt Valley of Jordan (Photo credit: Calvin College website), (Right) Co-processing of faecal sludge and other urban waste streams to produce fuel pellets, briquettes and crushed fuel in Kampala (Uganda) (Photo credit: Studer et al., 2016).

residence time in the settling ponds increases faecal sludge dewater ability. The drying beds (paved or sand beds with a gravel layer) or in some cases planted drying beds, are appropriate to dry the faecal sludge. Drying beds require space, thus when available space is limited and the treatment capacity must be increased, mechanical processes (e.g. belt or recessed plate filter presses, centrifuge or thermal drying) might be considered. Despite the higher operating cost (resulting from their high-energy consumption) and higher complexity (requiring skilled staff for operation and maintenance) the increased capacity may justify such a choice (Nikiema et al., 2014).

Although faecal sludge management in low-income countries frequently fails due to a lack of sufficient financial (and institutional) resources, faecal sludge treatment end-products (e.g. fuel, protein as animal feed, building materials and soil conditioner) can generate revenues and thereby offset faecal sludge management costs (Bassan et al., 2015; Gold et al., 2014). Pilot projects and studies carried out in Accra (Ghana), Kampala (Uganda) and Dakar (Senegal) demonstrate (i) that soil amendment (and faecal sludge for protein in animal feed) potentially does not generate as much revenue as energy production (**Figure 10**) and (ii) that local solutions need to be first determined because the demands vary significantly among locations (Diener et al., 2014). Co-composting of faecal sludge with municipal organic wastes could also be a pioneering way to develop business models and to increase the potential of resource recovery, while simultaneously contributing to solid waste management (EAWAG and IWMI, 2003; Gold et al., 2015).

An additional advantage of the co-composting of faecal sludge (i.e. mixing the faecal sludge with animal manure, vegetables or municipal organic wastes) is that its composition can be tailored

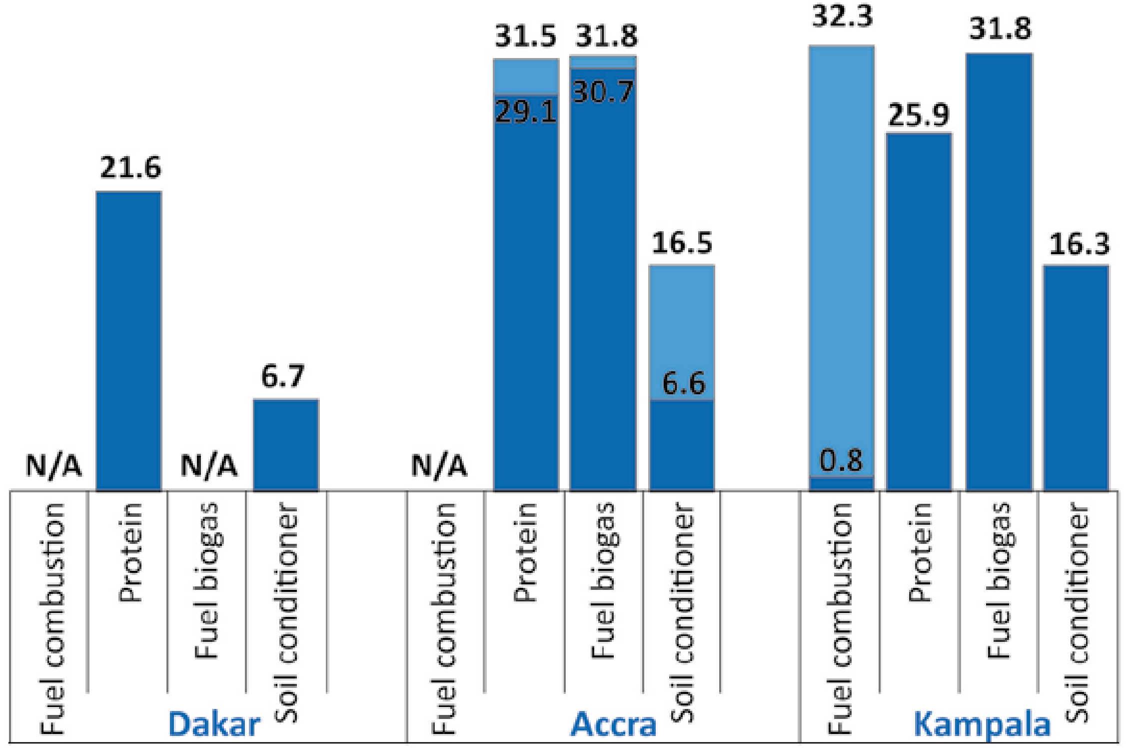


Figure 10. Potential market value (in USD) of different products derived from faecal sludge processing technologies per tonne of faecal sludge (dry weight) in three African cities (upper range in lighter shade) (Source: Diener et al., 2014).

BOX 3: BENEFITS OF HISTORICAL WASTEWATER USE IN AGRICULTURE - MEXICO.

For over a century, the Mezquital Valley of the Tula River Basin located about 60 km north of Mexico City represents the world largest area of wastewater irrigated agriculture (83,000 ha), with most of the 500,000 inhabitants involved in agricultural activities; despite the fact that rainfall is limited and poorly distributed over the year. Use of raw sewage for irrigation began in 1886 and in 1945, the Ministry of Agriculture and Water Resources established some irrigation districts to manage the distribution of wastewater and surface runoff from Mexico City for irrigation purposes (**Figure 11**). Irrigation District 03, the most significant, is comprised of 16 municipalities with a population of 300,000 in 1985. A complex network of canals serves the area, allowing intensive cultivation year round taking advantage of the supply of wastewater. According to the FAO, during the agricultural year 1983-84, 52,175 ha in Irrigation District 03 were harvested to produce 2,226,599 tonnes of food crops, with a value of more than USD33 million. It is strongly believed that fertility conditions measured based on productivity, were better than before (see details in Pescod 1992). The total production value was estimated at about USD 100 million in 1994 (Romero, 1997). It is thought that the high content of organic matter in the wastewater has increased soil organic matter and prevented the accumulation of soluble salts (Sanchez Duron, 1988). However, the sewage produced from domestic and industrial sources from the metropolitan area of Mexico City (about 1900 million m³/year for 18 million inhabitants) which is mixed with variable proportions of surface water collected in reservoirs within the basin, has not received conventional treatment. It is therefore containing high levels of faecal coliform and toxic chemicals that constitute a health risk for both farmers and consumers (see part 4.2 and **Box 8**) and contaminate groundwater. Due to the recent implementation of the world's largest wastewater treatment plant (Atotonilco), most of the wastewater generated by the inhabitants of Mexico City is now treated. Treated wastewater is used for agricultural irrigation and methane is produced during the digestion process, making the plant electrically self-sufficient.

Figure 11. In the Mezquital Valley, Mexico, crops have been irrigated with untreated municipal wastewater for more than a century (Photo credit: Ariel Ojeda for El Universal).

to the specific needs of soils on which it will be applied; in addition to its possible conversion into organo-mineral fertiliser to best fit with nutrient demand by soils and plants. A study conducted by the International Water Management Institute (IWMI) has shown that pelletization could be an appropriate approach to increase the compost's market value (Nikiema et al., 2014): The benefits of pelletization include lower compost volume density, thus substantially reducing storage and transportation costs. It is also meaningful to note that pellitization which reduces faecal sludge volumes by 20 to 50% also modifies the visual aspect of faecal sludge recycling products, which could help in lowering negative perception barriers. Therefore, processing faecal sludge into fuel pellets and subsequent gasification for electricity production can provide a higher market value than the use of faecal sludge as a soil conditioner (**Figure 10**). This could offset treatment cost and act as an incentive to sustain faecal sludge treatment and management services; although toxic emissions produced during the pelletization process (e.g. dioxins and heavy metals) need to be carefully controlled during energy recovery and ash disposal (Gold et al., 2015).

Generally, the liquid effluent from the faecal sludge dewatering units should be further treated to meet the requirements for wastewater reuse or discharge into the environment. Low-cost technologies such as waste stabilization ponds or constructed wetlands could be used for this kind of effluent treatment. Traditional low-cost wetlands have historically been used as a buffer zone in effective recovery and reuse of water and nutrients from wastewater effluents, particularly in China, India, Indonesia and Vietnam. For domestic wastewater or secondary effluent treatment, small and large-scale stabilization duckweed systems have also been widely used; in some cases, yielding important economic returns via aquaculture and crop production (Gijzen, 2001) (**Boxes 2 and 3**).

Using (raw or treated) wastewater in agriculture irrigation is increasing in many countries due to growing urban and peri-urban populations and their increasing demand for food products; for example, in North Africa (e.g. Tunisia) in the Middle East (e.g. Jordan), and Europe. In Spain, wastewater reuse (and desalinisation) is highly encouraged for agriculture and golf course irrigation, because of the rapid depletion of groundwater resources due to intensively exploited aquifers for agriculture (Pedrero et al., 2010). Beneficial use of wastewater has been for instance practised in California since the 19th century, when raw sewage was applied on 'sewer farms'. By 1987, more than 0.899 Mm³/d of municipal wastewater (7-8% of the production) was being used, mainly for agricultural use. Over the past decade reclaimed wastewater has been increasingly used for landscape irrigation in urban areas and for groundwater recharge (Pescod, 1992). Although using treated wastewater in agriculture for irrigation could be a realistic solution for the shortage of freshwater in water stress countries, it is associated with environmental and health threats. Effluent quality assessment is therefore necessary before use and to evaluate the probable health and environmental impacts of wastewater reuse in agricultural irrigation; including regarding the cumulative effects of multiple toxic substances over time (Baghapour et al., 2013).

The practice of using wastewater can provide potential socio-economic benefits, lifting some farmers out of poverty or enabling them to earn a living. On the other hand, unregulated wastewater use also raises serious concerns about the health of both consumers and farmers, creating the competing need to balance health impacts against livelihood needs (Faruqui et al., 2004). There is therefore a strong need of wastewater regulation and legislation for promoting effective wastewater treatment, disposal, and reuse, and to encourage the protection of aquatic receiving ecosystems. Six successful cases in the implementation of wastewater legislation from developed and developing countries around the world have been recently reported (Argentina, Australia, Finland, Jordan, Singapore and South Africa; UNEP, 2015a). This report underlines the fact that wastewater regulation and implementation is highly context specific, and that an effective national policy is needed to promote the importance of sanitation, set priorities and mobilize resources.

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4. Strategy for sustainable sanitation

4.1. International wastewater and water quality guidelines

Effective wastewater and water quality (and quantity) monitoring is obligatory to enforce pollution regulations and provide benefits for society as a whole (CapNet 2016). Achieving water quality objectives (i.e. point and non-point pollution management) requires comparing the level of pollution in water receiving systems, with the quality standards that are enforceable by laws and regulations. Assessing the status of a water body in terms of negative impacts on aquatic organisms and biodiversity, as well as on human health and livelihoods, then allows decision-making authorities to identify and solve specific problems via corrective actions. However, an appropriate water quality monitoring plan needs to consider (i) the sampling point locations (e.g. outlet of major municipal and industrial discharges), (ii) the sampling frequency, and (iii) the water quality parameters to analyse.

Although international guidelines and quality standards are currently available for drinking water, recreational use, irrigation, livestock and wastewater reuse (see next paragraph), no comparable international water quality standards exist for ecosystems, even though the health of many ecosystems is threatened by declining water quality. For that purpose, UN Environment has developed the International Water Quality Guidelines for Ecosystems (IWQGES) project: A set of science-based policy and technical guidelines enabling regional, national and local authorities to improve their frameworks for sustainable management of their water resources and aquatic ecosystems. The IWQGES focus on freshwater ecosystems with primarily advisory guidelines for national governments. They provide a framework and relevant information required by government and management authorities, to develop water quality guidelines for ecosystems, including approaches to identify indicators and set target and threshold values (UNEP 2016).

In 1989, WHO published "guidelines for the safe use of wastewater and excreta in agriculture and aquaculture, measures for public health protection", to encourage their safe use, i.e. in a manner that protects the health of the workers involved and of the public at large (Mara and Cairncross, 1989). Here, wastewater refers to domestic sewage and municipal wastewaters that do not contain substantial quantities of industrial effluent. Excreta refer to excreta-derived products such as sludge and septage. These WHO guidelines emphasise the practical approaches for reducing human health risks and for maximising the beneficial use of scarce resources (i.e. the wastewater reuse for irrigation). Nevertheless, health protection considerations generally require that some treatment should be applied to these wastewaters to remove pathogenic organisms before being discharged into the environment. Other health protection measures are also considered, including (specific) crop restriction, waste application techniques and human exposure control. For instance, in Tunisia, irrigation with treated wastewater of vegetables and of any crop that might be consumed raw is forbidden; direct grazing on land irrigated with treated wastewater is prohibited; and the precautions required to prevent contamination of workers, residential areas and consumers are detailed as a function of the crops (forage and industrial crops, cereals, trees) that might be irrigated with treated wastewater (see details in Pescod 1992). Additional case studies, lessons learned and health approaches from wastewater use in irrigated agriculture can be found in Faruqui (2004) and Drechsel (2010); as well as in the guidelines for the safe "wastewater treatment and use in agriculture" published by FAO, as a guide to the use of treated effluent for irrigation and aquaculture (Pescod, 1992). This latter document points out the health risks, the environmental hazards and the crop production potential associated with the use of treated wastewater. In 2006, the WHO published a third edition of its "guidelines for the safe use of wastewater, excreta and greywater, wastewater use in agriculture" (WHO, 2006).

WHO produced guidelines for drinking-water

	Indicator (unit)	Pollution	[1]WHO Guidelines for drinking water	[2]FAO Guidelines for irrigation Degree of restriction on use		
				None	Slight to moderate	Severe
PHYSICAL	Total Dissolved Solids (mg/l)	Inorganic salts (and organic matter)	600 mg/l	<450	450-2000	>2000
	Conductivity (dS/m)	Total salt concentration		< 0.7	0.7-0.2	< 0.2
	pH	Measure of how acidic/ basic water is	No health-based guideline value	Normal range 6.5 - 8		
CHEMICAL	Chloride (me/l)	Disinfectant residuals	5 mg/l for chlorine	<4	4-10	>10
	Copper (mg/l)	Industrial pollution	2	0.2		
	Lead (mg/l)	Industrial pollution	0.01	5		
	Mercury	Artisanal mining and Industrial pollution	0.006 mg/l	Maximum permissible concentration of in soil: 1.5 mg/kg dry solids		
	DDT and metabolites	Pesticide and malaria/ mosquitoes	0.001 mg/l	No guideline value		
	Chromium	Industrial pollution	0.05	0.1		
BIOLOGICAL	Escherichia coli	Faecal pollution	Absent in 100 ml sample	< 1000 faecal coliforms / 100 ml		
	Enterococci E. faecalis, E. faecium	Faecal pollution	Absent in 100 ml sample			
	Cyanobacteria blue-green algae	Toxins	Total microcystin-LR: 0.001 mg/l	No guideline value		
	Helminth pathogens (Absence recommended)	Intestinal parasites	Dracunculiasis (guinea worm) and Fascioliasis (liver flukes)	Ascariasis, trichuriasis, hookworm infections and strongyloidiasis		

[1]WHO 2011; [2]Pescod, 1992

Table 2. Examples of quality indicators for drinking, recreational and agricultural wastewater reuse (Sources: WHO, 2011; Pescod, 1992).

quality which are the international reference point for standards setting and drinking-water safety. In 2011, WHO published the fourth edition of the WHO guidelines for drinking water quality (WHO, 2011; **Table 2**), which has formed an authoritative basis for the setting of national regulations and standards for water safety in support of public health. It is important however to note that the WHO and FAO guidelines on drinking water quality, recycled water for agricultural use, and the guidelines for water for recreational use, are influential but are not legally binding. Moreover, these guidelines are not exhaustive since there is no guideline for many chemical pollutants, especially when there have not been sufficient studies about the effects of the substance on organisms to define a guideline limit. Finally, many pollutants cannot be measured accurately and routinely with traditional analytical techniques.

Industrial and commercial standards concerning the activities relating to drinking water and wastewater services can also follow the guidelines of the International Organization for Standardization (ISO) which is an international standard-setting body composed of representatives from various national standards organisations (e.g. ISO 24511:2007 providing guidelines for the management of wastewater utilities and for the assessment of wastewater services). The EU also drew up the Council Directive 98/83/EC on the quality of water intended for human consumption, which provides a sound basis for both the consumers throughout the EU and the suppliers of drinking water (**Box 4**). Its objective is to protect human health from adverse effects of any contamination of water intended for human consumption, by ensuring that it is wholesome and clean. More detailed information on specific aspects related to drinking water directive implementation can also be found on the websites of the EU Member States.

In addition to these international guidelines, national regulatory standards are typically established. For example, the wastewater discharged to surface waters and municipal sewage treatment plants (e.g. US Environmental Protection Agency); global quality standards for non-food crop irrigation; and recommendations on toxic elements in irrigation water (e.g. EU Water Framework Directive; **Box 4**). The primary objective of these regulatory guidelines is to ensure public health and protection from toxic chemicals and microbial contaminants which can be present in drinking water or enter the food chain. Although the lowest values should be taken as the maximum acceptable value, the criteria adopted for assessing good geochemical status should be flexible and adapted to the public health priority, but also to the local environmental conditions (geochemical background of pollutants) and to local/regional human activities (e.g. mining or agriculture).

Operational water quality monitoring can include measurement of quantitative measurable parameters (e.g. chlorine residuals) or observational activities (e.g. odour and colour). Indicator organisms are often of limited use for operational monitoring, because the time taken to process and analyse water samples does not allow operational adjustments to be made prior to supply (WHO, 2011). However, biological indicators such as aquatic plants, algae and animals (e.g. fishes, molluscs, crustaceans) can provide a convenient and sensitive tool for assessing and monitoring the ambient water quality (Ngelinkoto et al., 2014). In fact, although water quality monitoring benchmarks water quality at the time of sampling, biological monitoring can provide an integrated view of water quality over the lifetime of the selected fauna and flora (CapNet 2016). Moreover, while it is impossible to separately monitor all the chemicals present simultaneously in the environment, biological methods can provide an indication of their combined effects. For the same purpose, the chemical composition of sediments reflects ambient water quality more accurately than water samples (Thevenon et al., 2011a; **Box 5**). Consequently, biological and sediment monitoring are strongly recommended for assessing and monitoring environmental contamination in aquatic systems. This is also appropriate when there is no possibility for implementing a continuous or regular monitoring of water quality, i.e. to ensure that the frequency of the monitoring is effectively

BOX 4: EU WATER LEGISLATION AND THE WATER FRAMEWORK DIRECTIVE (WFD).

The Water Framework Directive (WFD 2000/60/EC) adopted in 2010, introduced a holistic approach for the management and protection of surface waters and groundwater based on river basins. The WFD is supplemented by international agreements and legislation relating to water quantity, quality and pollution. The WFD establishes a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater, in order to prevent and reduce pollution, promote sustainable water use, protect the aquatic environment, improve the status of aquatic ecosystems and mitigate the effects of floods and droughts.

- Concerning drinking water, the Council Directive 98/83/EC defines essential quality standards for water intended for human consumption. It requires Member States regularly to monitor the quality of water intended for human consumption by using a 'sampling points' method. Member States can include additional requirements specific to their territory but only if this leads to setting higher standards. The directive also requires the provision of regular information to consumers. Furthermore, the quality of drinking water has to be reported to the Commission every three years. The Directive laid down the essential quality standards at European Union (EU) level. A total of 48 microbiological, chemical and indicator parameters must be monitored and tested regularly. When translating the Drinking Water Directive into their own national legislation, Member States of the European Union can include additional requirements e.g. regulate additional substances that are relevant within their territory or set higher standards. Member States are not allowed, nevertheless, to set lower standards as the level of protection of human health should be the same within the whole European Union. Member States may, for a limited time depart from chemical quality standards specified in the Directive. This process is called "derogation". Derogations can be granted, provided it does not constitute a potential danger to human health and if the supply of water intended for human consumption in the area concerned cannot be maintained by any other reasonable means. The Directive also requires providing regular information to consumers (see details on EU law website, http://eur-lex.europa.eu/).
- Concerning urban wastewater treatment, the directive 97/271/EC aims to protect the environment in the EU from the adverse effects (such as eutrophication) of urban wastewater. It sets out EU-wide rules for collection, treatment and wastewater discharge. The law covers domestic wastewater and wastewater generated by industries such as the agro-food industries (like food-processing and brewing) and concerns the collection, treatment and discharge of wastewater.

reflecting the ambient water quality, and the long-term response of the ecosystem to natural or human-induced disturbances (e.g. rainfall patterns and fertilizer nutrient leaching). Finally, the evaluation of human exposure to anthropogenic pollutants (i.e. the cumulative effects of different pollutants due to consumption of contaminated drinking water) can also be performed by analysing human biomarkers (e.g. blood, urine, breast milk, hair, nails, saliva and teeth).

Water quality is controlled by a wide range of physical, chemical and biological indicators, so that water quality monitoring can be an expensive and complex process. Technical training, technology transfer and community-based water quality monitoring systems are therefore strongly encouraged (COHRE et al., 2007). When affordable, portable testing kits can allow the rapid determination in the field of key water quality parameters, such as faecal indicator bacteria count,

free residual chlorine, pH, turbidity and filterability. Nevertheless, basic laboratory analysis is usually the most appropriate way to analyse with precision many water samples. Moreover, many chemical indicators of pollution (e.g. trace elements like heavy metals or persistent organic pollutants like pesticides) can only be analysed using very sensitive (and costly) analytical procedures under clean laboratory conditions (standardised analytical and data quality assurance). It is also important to know that some precautions must be taken during the sampling procedure in the field (e.g. blank control samples), and that the transport and the storage of the samples can also require specific conditions (e.g. cold temperature for bacteria and rapid analysis). Hence, many water quality parameters can only be performed by accredited research institutes or (private) laboratories, using reproductive and standardised protocols. The obtained quantitative data must then be (i) compared to national and international guideline values, (ii) used to provide quantitative information to policymakers for protecting human and ecosystem health, and (iii) systematically stored in a database for future use, if possible in a user-friendly environment (e.g. open online access to water quality maps using Geographic Information Systems). To summarize, the choice of the monitoring systems (e.g. the indicators measured continuously or periodically for evaluating the water quality) must be flexible and carefully chosen regarding local activities (domestic, hospital, agriculture or industry, mining), the environmental context (short/seasonal/long-term variations), the regional analytical and institutional capacities (accredited research centres and hospitals), and the cost associated with long-term water monitoring in the field and in laboratory.

Faecal bacteria are the most common microbiological contaminants in drinking water and therefore serve as a reliable indicator of water contamination by excreta. High levels of faecal bacteria such as Escherichia coli and Enterococcus faecalis (which is relatively heat resistant) are frequently associated with elevated levels of human pathogens which can spread disease to humans (Davis et al., 2015; Thevenon et al., 2012a; Mwanamoki et al., 2014). Most national legislations and international guidelines for drinking water quality stipulate that faecal indicator bacteria (e.g. Escherichia coli and Enterococcus) should be absent in a 100 ml sample (e.g. WHO, 2004). The WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation has assigned a Post 2015 Water Monitoring Working Group, which recommends improved drinking water to contain less than 10 colony forming units (CFU) of Escherichia coli per 100 ml. According to the European Directive 2006/7/CE concerning the management of bathing water quality, recreational waters are classified as poor if Escherichia coli levels exceed 900 CFU/100 ml and concentrations of Enterococcus exceed 330 CFU/100 ml.

4.2. Human health and environment protection

According to UN-Water, approximately 20 million hectares of arable land worldwide are reported to be irrigated with wastewater, but the unreported use of wastewater in agriculture can be expected to be significantly higher. This agricultural practice is particularly common in urban and peri-urban areas of developing countries facing water scarcity, and where insufficient financial resources and institutional capacities constrain the instalment and operation of adequate facilities for proper wastewater collection and treatment (Mateo-Sagasta et al., 2013). Domestic wastewater can provide the required quantities of water and major plant nutrients (i.e. nitrogen, phosphorus and potassium) for the cultivation of crops, ensuring sustainable food supply to cities and reducing the pressure on available freshwater resources. However, wastewater can also represent a significant source of pollution which can affect the environment and the health of farmers and consumers; because wastewater is generally highly enriched in anthropogenic pollutants and pathogens (**Tables 2** and **3**, **Boxes 7** and **8**). There is therefore a strong need to implement agricultural wastewater use practices and guidelines, with respect to national regulations and international guidelines and safety standards. This is especially important for low-income countries where the use of wastewater is an unregulated but common practice that will continue to develop in the forthcoming years in the context of climate change adaptation.

Waterborne and excreta-related diseases are caused by the ingestion of water contaminated by human or animal excreta, or urine, containing pathogenic bacteria and viruses potentially inducing cholera, typhoid, bacillary dysentery and other diarrheal diseases (Table 3). Infection commonly occurs during bathing, washing, drinking, and in the preparation or the consumption of food thus infected. By contrast, water-based diseases are caused by parasites found in the organisms living in water (e.g. helminths), and water-related diseases are caused by microorganisms with life cycles associated with insects that live or breed in water (e.g. dengue fever, malaria and yellow fever). Water can be also contaminated during (or after) its collection (and storage) because of improper hygiene and handling. Microbial analysis of drinking water samples (both home and source water) in Cameroon showed that although water collected directly from tap exhibited lower concentrations of both total coliform bacteria and Escherichia coli, non-tap sources collected indicated that once the drinking water began moving through the informal distribution system (e.g. into water suppliers' plastic containers), microbial contamination levels rose substantially for both total coliforms and Escherichia coli (Profitós et al., 21014; **Figure 12**). This observation also points at the importance to protect the water resources near the drinking water intake (e.g. river banks, natural source/well) against pollution (wastewater from industrial, agriculture or aquaculture operations, artisanal and municipal hazardous effluents, toxic leachate derived from solid waste dumping sites, and from pit latrines and septic tanks).

According to the WASH program of UNICEF, there is very clear evidence showing the importance of hygienic behaviour, in particular hand-washing with soap at critical times (after defecating and before eating or preparing food). Hand-washing with soap can reduce by almost half the incidence of diarrhoea which is the second leading cause of death amongst children under five years old. In the case of hand-washing facilities (or soap) are not available, some recent research demonstrated that the water treatment using Moringa oleifera seeds can be effective on the clarification of water; although a filtration step is afterwards necessary to remove organic matter introduced by the coagulant (Poumaye et al., 2012). Such substitution of imported flocculants by a local natural product which can be easily accessible, also avoids the use of chemicals, and is more compatible with environmental protection. Finally, when affordable, point-of use water treatment devices (e.g. activated carbon filter, distiller or filter) could be used to treat small amounts of drinking water for household. It is however important to understand that no single treatment can remove all contaminants in water; and that a treatment device requires regular maintenance otherwise it can make the water quality worse. Moreover, in opposition to purification devices which are designed to remove bacteria, water treatment devices which are designed to remove chemicals should be used only on water that is free of harmful bacteria. For all these reasons, there are major and urgent needs for compiling the policies and laws that countries could refer as a guide for improving household water safe storage and treatment.

Some large-scale risks of water contamination can also arise sporadically when associated with seasonal human activity (e.g. runoff from manure spread on agricultural fields, tourism or industry) or seasonal conditions (monsoon). For instance, the occurrence of blooms of toxic cyanobacteria or blue-green algae which are favoured by high solar radiation and temperatures during the summer season can produce toxins that are of concern for human health. Similarly, the discharge of raw or even treated wastewater (**Box 5**) that are highly enriched in chemical pollutants and

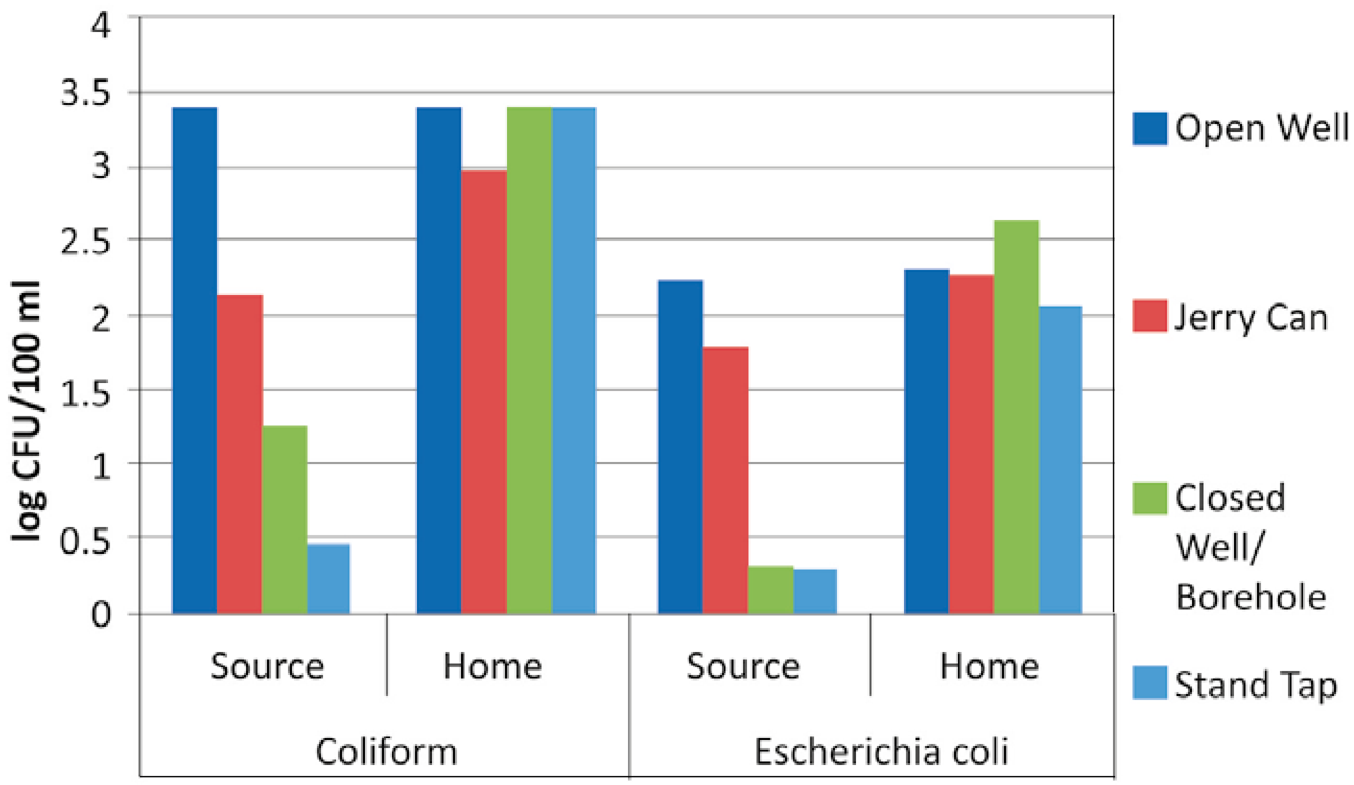


Figure 12. Total coliforms and Escherichia coli median concentration values from different types of drinking water sources and home storage container (Source: Profitós et al., 2014).

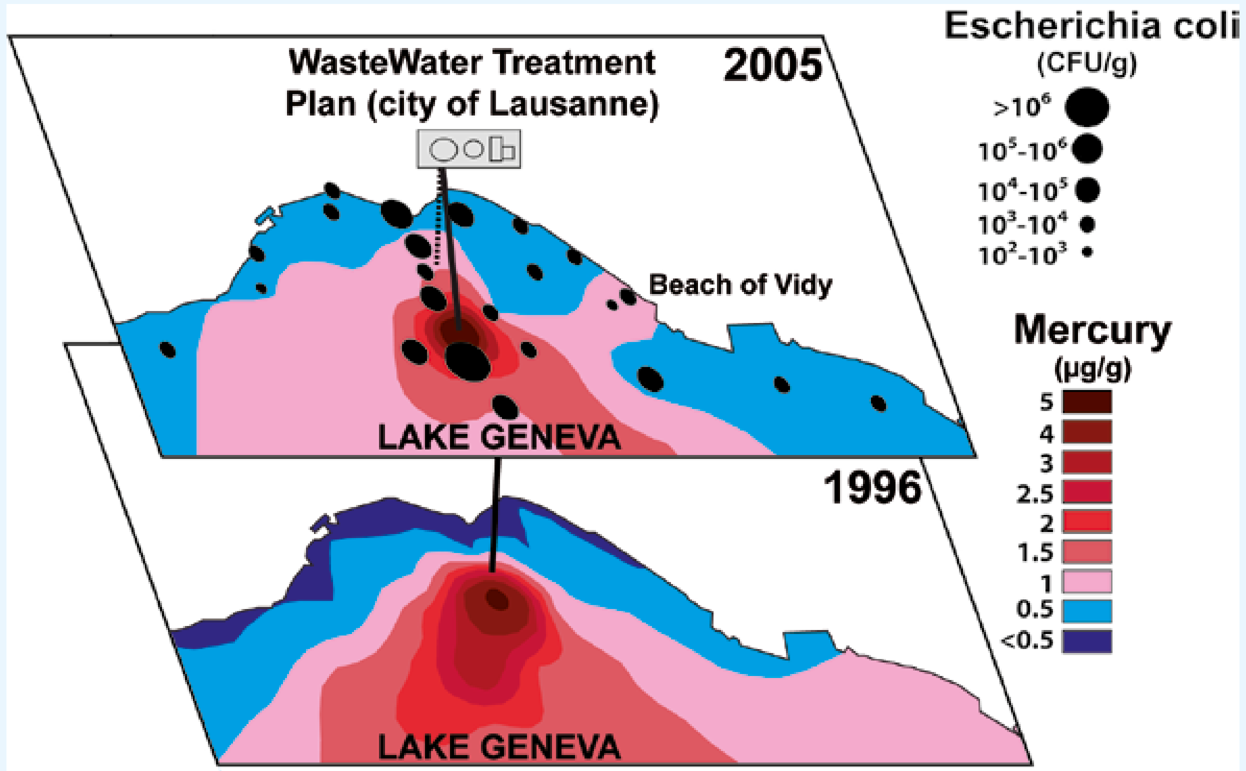
nutrients (especially phosphates and nitrates) in lakes, reservoirs, ponds and slow-flowing rivers, can induce an accumulation of toxic pollutants and an excessive growth of planktonic algae (i.e. eutrophication), respectively. The decomposing of these organisms depletes the water of available oxygen to other organisms such as fish, causing their death. Another major caution with the evaluation and protection of water quality, is the contamination by wastewater overflow following a high rainfall event or during the rainy season (monsoon). In general, huge rainfall that exceeds sewage treatment capacity is generally allowed to overflow directly from storm drains into receiving waters. Finally, in the absence of any municipal sewer systems, the channel and streams (as well as the latrine pits and septic tanks) should be cleaned regularly (**Figure 5**) otherwise they will more easily overflow and largely contaminate local drinking water resources. Indeed, in many heavily populated urban settlements, storm water drains have become the receptacles of different types of waste (such as untreated sewerage, dry waste, effluents from small and big industry) and plastic accumulation can cause the obstruction of the drains and sewage overflow.

Although the use of contaminated water by pathogens from faecal matter for irrigation (as well as for aquaculture) is widely practiced in many countries of sub-Saharan Africa and Asia, in general little is known about the potential health risks associated with such agricultural practices (Ndiaye, 2009; Gemmell and Schmidt, 2012). Some scientific studies nonetheless demonstrate that pathogens (i.e. enteric viruses and Escherichia coli) contained in the wastewater

BOX 5: THE IMPACTS OF TREATED WASTEWATER EFFLUENTS IN LAKE GENEVA, SWITZERLAND

Pathogenic organisms and micropollutant contamination of freshwater drinking resources is a major problem that also concerns high-income countries and treated wastewater. Lake Geneva is the largest freshwater reservoir in Western Europe with a volume of 89 km³. Approximately 700,000 people are served by this freshwater resource. Lausanne, a city of 127,000 inhabitants on the northern lake shore, pumps about 60% of its water supply from the lake, while the city is also discharging the largest volumes of domestic, hospital and industrial treated effluents into the Bay of Vidy (**Figure 12**). From 1964 to 2001, the wastewater treatment plant effluents were released into the lake about 300 m from the shore, at a water depth of 15 m. In 2001, the outlet pipe was extended to a distance of 700 m from the shore at a 35 m water depth (**Figure 13**). Investigation of several lacustrine sediment cores show that in the deepest parts of the Lake, the maximum pollution occurred in the middle of the 20th century, because of the industrial and domestic effluents discharged into the lake; whereas the implementation of wastewater treatment plants in the 1960's and '70s caused their subsequent reduction (Thevenon et al., 2012c). Conversely, in the Vidy Bay which is receiving the wastewater treatment plant effluents, the maximum values for all the analysed pollutants were observed in the 1970's (Thevenon et al., 2011a). The chemical composition of water and surface sediments indicate that this bay is the most contaminated area of Lake Geneva; with very high levels of organic (phosphorus and carbon) and inorganic contaminants (heavy metals) as well as faecal indicator bacteria, including antibiotic resistant bacteria (Thevenon et al., 2012b). The bacterial marker genes (obtained by sequencing of DNA) indicate that more than 90% of these bacteria are from human origin (Thevenon et al., 2012a). The lake eutrophication in the 70s and early 80s highly enhanced the sediment microbial activity and the spread of multiple antibiotic resistant genes (Thevenon et al., 2012b).

Figure 13. The spatial distribution of the concentration of mercury (Hg) in 1996 (before) and 2005 (after the extension of the wastewater treatment plant outlet pipe) and of Escherichia coli in 2007 in the surface sediments of Vidy Bay (Source: Thevenon at al., 2012c).



used for irrigation can be transferred to raw vegetables and fresh products (Solomon et al., 2002; Cheong et al., 2009; Gemmell and Schmidt, 2012). Similarly, although wastewater represents a potential sustainable resource in terms of water and of nutrient for agriculture in many countries, domestic and hospital black waters are commonly enriched in inorganic pollutants (e.g. heavy metals) and in pathogenic microorganisms (e.g. viruses and antibiotic resistant bacteria) which can cause health, environmental, and economic/financial problems (UN-water 2014) (**Box 6**). For instance, a health risk assessment along the wastewater and faecal sludge management and reuse chain of Kampala (Uganda) has compared the level of a broad range of microbial and chemical pollutants to an epidemiological survey in selected exposure groups (Fuhrimann et al., 2014). The results revealed that the levels of pollution were in excess of thresholds put forth in the WHO guidelines for the safe use of wastewater in agriculture; with some water samples positive (i.e. above the international safety standards) for hookworm eggs, concentrations of thermo-tolerant coliforms, Escherichia coli and heavy metals. In term of intestinal parasitic infections, farmers were at the highest risk, followed by exposed community members, non-exposed community members, wastewater treatment plant workers, and faecal sludge collector. Similar public health aspects of both producers and consumers were reported in the raw wastewater reuse for aquaculture in Calcutta (see **Box 7**) and for agriculture in Mexico (see **Box 8**).

Depending on the treatment type, digested or stabilised faecal sludge can be applied to public or private lands for landscaping or agriculture. Sludge that has been treated (e.g. co-composted or removed from a planted drying bed) can be used in agriculture, home gardening, forestry, landscaping, parks, golf courses, mine reclamation, as a dump cover, or for erosion control. To reduce dependence on freshwater and maintain a constant source of water for irrigation throughout the year, wastewater of varying quality can be used in agriculture. However, only water that has had secondary treatment (i.e. physical and biological treatment) should be used to limit the risk of crop contamination and health risks to workers (Tilley et al., 2014) and faecal sludge should be analysed for physicochemical parameters (e.g. organic matter, heavy metals, pharmaceuticals and endocrine disruptors) before land application.

4.3. Innovations and financial sustainability

In addition to technical and scientific aspects such as the impacts of wastewater on human health and the environment, there are several other factors that need to be considered and appropriately addressed when pursuing a model of sustainable sanitation. For example, if the constructed latrines are not being used frequently by the local population (especially by men), the damaged toilets (e.g. by flooding) will not be repaired or replaced. In addition to instinctive repulsion towards excreta, there are several examples showing that people are regrettably not aware of the potential impacts of using a hygienic latrine on their family's health and finances. Local beliefs, traditions and practices, but also gender and generational differences, are therefore decisive factors in the planning and operating of water and sanitation.

There are, for instance, considerable differences in attitudes towards the use of sanitation facilities and the handling of excreta between diverse cultures and religions of the world. It is meaningful to note for example that the Democratic Republic of the Congo has made remarkable progress in increasing use of improved sanitation facilities, with 14.7 million new users since 1990 (WHO/UNICEF, 2014). However, although national averages indicate overall improvements, these have not been evenly distributed across the population. Hence, people with traditional animist religions tend to be more likely to practice open defaecation than those following Christianity, Islam or other established

Group exposed	Health risks		
	Helminths	**Bacterial/ Viruses**	**Protozoa**
Consumers	Significant risk of Ascaris infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; increase in non-specific diarrhoea if wastewater used 10^4 CFU/100 ml	No direct evidence of disease transmission but presence of pathogenic protozoa on crops irrigated with wastewater
Farm workers and their families	Significant risk Ascaris infection when in contact with untreated wastewater. Increased risk of hookworm infection for workers Risk remains for children even when wastewater is treated to <1 nematode egg/l	Increased risk of diarrhoeal disease for children in contact with wastewater >10^4 CFU/100 ml. Elevated risk of Salmonella infection in children exposed to untreated wastewater. Elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of Giardia intestinalis infection insignificant for contact with both untreated and treated wastewater; increased risk of Amoebiasis when in contact with untreated wastewater
Nearby communities	Ascaris transmission not studied for sprinkler irrigation but significant for flow and furrow irrigation	Increased rates of infection from sprinkler irrigation with poor water quality if >10^6-10^8 CFU/100 ml; and high aerosol exposure associated with increased rates of infection	No data on transmission of protozoan infections during sprinkler irrigation with wastewater

Table 3. Summary of health risks associated with wastewater use in agriculture, based on epidemiological studies; CFU: Colony Forming Units (modified from FAO, 2006).

religions (**Figure 17**). In general, the percentage of the population practicing open defaecation generally declines with increasing levels of education. However, some countries still have a large proportion of the population practising open defaecation, even though they have secondary education (e.g. Cambodia). In Ethiopia, it is notable that there is still a relatively high percentage of the population with tertiary (or university level) education that practices open defaecation (WHO/UNICEF, 2014).

The lack of motivation to change sanitation habits is particularly important when the sanitation infrastructures have been implemented by international organisations, development agencies or NGOs, without having considering peoples' real needs and demands, habits, local environmental conditions (e.g. ecosystems preservation and climate variations) and long-term maintenance by local communities and institutions. The implication of local community chiefs, traditional/civil leaders, and national governments is necessary to ensure the long-term operation of the infrastructures, which also requires provisional fund for renewing and maintenance (e.g. monitoring, cleaning, running costs and training technicians and dwellers) (**Box 9**). There are three particularly important reasons why the achievement of sustainability poses challenges to the sanitation sector according to WaterAid (2011): The first is the limited capacity (in the sense of knowledge, skills and material resources) of communities, local government institutions and other service providers to manage systems. The second is the

BOX 6: DATA AND ASSESSMENT OF WATER QUALITY IN DEMOCRATIC REPUBLIC OF CONGO

A recent collaboration between universities of Geneva (Switzerland) and Kinshasa (Democratic Republic of Congo) has fostered advanced interdisciplinary/multidisciplinary research collaborations between researchers on the impacts of human activities on different water resources. Results of an environmental survey in the copper-cobalt mine complex in the Katanga region show that the rivers and soils are under serious threat of degradation resulting from regular discharge of untreated industrial effluents - as well as to the mining and artisanal mineral exploitation activities (Atibu et al., 2013). In the sediments of the Congo River, pollution due to heavy metal, pathogenic bacteria and persistent organic pollutants (including pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs)) has been evidenced due to urban runoff and domestic and industrial raw wastewaters discharge (Mwanamoki et al., 2014a, 2014b and 2015) (**Figure 14**). Heavy metal pollution (including lead and mercury) has been also characterised in sediments and consumable fishes from the Kwilu Ngongo River (Province of Bas-Congo); showing higher values than maximum tolerable limits recommended by the European Commission Regulation for Food. Here, sediment toxicity tests using benthic crustaceans (ostracods) revealed mortality rates of up to 30% after six days of exposure to the sediments near a sugarcane industry outlet pipe discharge. The contamination of the sediments and fishes by metals - and the bio-accumulation of mercury in fishes - most likely arises from the adjacent agricultural fields where intensive sugarcane cultivation has probably contaminated the soils through the long-term use of fertilizers and pesticides (Ngelinkoto et al., 2014). Faecal indicator bacteria (including Escherichia coli and Enterococcus) were also quantified to assess the quality of hospital effluents and of rivers receiving wastewaters from the city of Kinshasa. The results revealed very high bacteria concentration in the hospital effluent waters, with more than 98% of bacteria from human origin (Kilunga et al., 2016). Draining leachate composition, as well as the contamination status of soil/sediment, were investigated in lagoon basins receiving leachates from landfill in a suburb of Kinshasa. Affected soil/sediment showed higher values for toxic metals than leachates, indicating the possibility of using a lagoon system for the purification of landfill leachates, especially for organic matter and heavy metal sedimentation. However, ecotoxicity tests demonstrated that leachates are still a significant source of toxicity for terrestrial and benthic organisms, so that landfill leachates should not be discarded into the environment without prior treatment. Finally, the contamination of groundwater quality with micropollutants and human-bacteroides was also demonstrated in sub-urban shallow wells due to the lack of adequate sanitation and protection of (open) wells; the presence of pit latrines located in the proximity of wells, open defaecation, and uncontrolled landfills (Kapembo et al., 2016).

Figure 14. Garbage dumped on river banks in Kinshasa (Photo credit: John Poté).

BOX 7: HEALTH IMPACT OF WASTEWATER USE IN AQUACULTURE - CALCUTTA

The East Kolkata Wetlands which are the largest of their kind in the world (12,500 hectares) were designated as a Ramsar site in 2002 because of their important wetland habitats (**Figure 8**, **Box 2**). The fish ponds receive screened raw sewage from Calcutta which can flow into the ponds that are stocked with a polyculture of fish. In the same way as the raw wastewater reuse practise in Mexico (**Boxes 3** and **8**), there is abundant grey literature explaining the advantages of such sewage-fed systems; but also a lack of consistent scientific investigation on environmental pollution risk assessment (analysis of pollutant levels in water, soils or fishes). Moreover, no epidemiological studies have been carried out in East Kolkata Wetlands, to assess the human risk attributable to the use of sewage in aquaculture ponds, Total coliform counts of-10^6/100 ml in the influent sewage to the Calcutta fish ponds, and 10^2-10^3/100 ml in the pond water have been reported (Strauss and Blumenthal 1989). Such levels are far above the current WHO criteria for microbiological quality for aquaculture (i.e. zero nematodes and less than 1000 faecal coliforms per 100 ml; Pescod, 1992). Vibrio parahaemolyticus, the second most important diarrhoea-causing agent (after V. cholerae), has been found in the intestines of fish from the sewage-fed ponds of the Calcutta area. Diarrhoeal diseases, typhoid fever and hepatitis A are diseases of greatest concern, although protozoan cysts (Giardia and Cryptosporidium) are likely to be also present in the upper layers of pond water and constitute a risk. With the relatively low levels of total coliforms in the pond water over the growing season, the fish are likely to be of good enough quality for human consumption, if they are well cooked and high standards of hygiene are maintained during their preparation (Strauss and Blumenthal, 1989). Conversely, studies on Vibrio parahaemolyticus have indicated that it could be transmitted to fish consumers or fish farmers during the summer months. The public health effects of sewage fertilisation of aquaculture ponds in Calcutta remain unclear and further microbiological and epidemiological studies are required. These observations also clearly underscore the importance of effective pre-treatment of domestic wastewater before application to culture crops and fishes for human consumption (**Figure 15**). Although some organic compounds present in water can be removed in the ponds (and most microbial pollutants should be killed during fish cooking), the major toxic chemicals (e.g. heavy metals and pesticides) from industrial, agricultural and artisanal activities are not removed and may accumulate in sediment, soils, groundwater, crops and food chain.

Figure 15. Although wastewater can provide a major source of nutrients for aquaculture, it can also present health and environmental problems due to the accumulation of toxic substances such as heavy metals in fishes, sediments and groundwater (Photo credit: Florian Thevenon).

BOX 8: HEALTH IMPACT OF WASTEWATER USE IN IRRIGATED AGRICULTURE IN MEXICO

The historical practice of disgorging Mexico City's excess rain and sewage water to irrigate fields, where produce for human and animal consumption is grown, generates numerous health concerns (**Figure 16**, **Box 3**). Analyses of faecal coliforms in the Valle Mezquital indicate values which are 10^2 to higher than WHO guidelines for wastewater reuse. Here, authorities have enforced restriction on crops irrigated with wastewater due to the spread of cholera, and the incidence of infection by roundworm in children appeared to be 10 to 20 times higher compared to areas with rain-fed irrigation (Romero, 1997). A study on the health effects of the use of wastewater on agricultural workers in Guadalajara concluded that a high prevalence of parasitic diseases in both exposed and control group workers was due to poor environmental sanitation, poor hygienic habits and lack of health education. However, a significant prevalence of infection in the exposed group was found for Giardia lamblia (17% in exposed *vs* 4% in control group) and Ascaris lumbricoides (50% in exposed *vs* 16% in control group). This led Strauss and Blumenthal (1989) to recommend further epidemiological studies, on the increased health risk to farm workers, and at least partial treatment of wastewater in future wastewater-use schemes in Mexico to remove helminth eggs and protozoan cysts. Here, every year, each farmer specifies the crops he is going to plant and irrigate with water allocated by the Irrigation District. The Ministry of Health sets the basic rules for crop restriction and the District's directing committee specifies in detail the crops which may not be cultivated under its jurisdiction; with lettuce, cabbage, beet, coriander, radish, carrot, spinach and parsley being specifically excluded. Maize, beans, chilli and green tomatoes, the staple food in the area, are not restricted and neither is alfalfa because it is used as animal feed. Although excess irrigation water likely recharged the near-surface aquifer that is used as a domestic water supply source, high total coliform levels in surface water and lower levels in groundwater at all sites indicate fecal contamination and a potential risk of gastrointestinal disease in populations exposed to inadequately disinfected groundwater (Downs et al., 1999). There is, however, a lack of scientific knowledge on environmental pollution risk assessment (i.e. pollutant levels in water, soils and crops).

Figure 16. Despite reported diarrhoeal diseases suffered by their children, farmers from the Valle Mezquital prefer to irrigate with wastewater, rather than freshwater, because of its rich nutrient content (Photo credit: Janet Jarman).

inadequacy of financial revenues to cover the full operation, maintenance and capital maintenance costs of infrastructure. The third relates to the historical approach to service delivery of different actors which has been carried out in a fragmented way, with competing agendas and a general disregard or lack of understanding of government frameworks. Although coordination between different sector players has seen improvements in recent years, hindrances have been entrenched for a long time and their legacy continues to frustrate progress. From the review on sustainability in the water, sanitation and hygiene sectors carried out by WaterAid (2011), it is possible to stress five general needs to ensure sustainable WASH services and hygiene practices:

- There must be real demand from users which is evidenced in the consistent use of improved water and sanitation services and the practice of improved hygiene behaviours.
- There must be adequate revenue to cover recurrent costs, with appropriate tariff structures that include the poorest and most marginalised.
- There must be a functioning management and maintenance system comprising tools, supply chains, transport, equipment, training and individuals/institutions with clear responsibilities.
- Where systems are managed by communities or institutions there must be effective external support to those community-level structures and institutions.
- The natural resource and environmental aspects of the system need due attention.

The identification of adequate sanitation technology to be applied in urban (e.g. sewerage system) or rural (e.g. onsite sanitation) areas with contrasting population density and resource availability will depend on several factors: The amount/flux of wastewater and faecal sludge materials to be processed, the level of complexity for the technology to be implemented, the requirements set by the regional authorities; but also the available financial resources for construction,

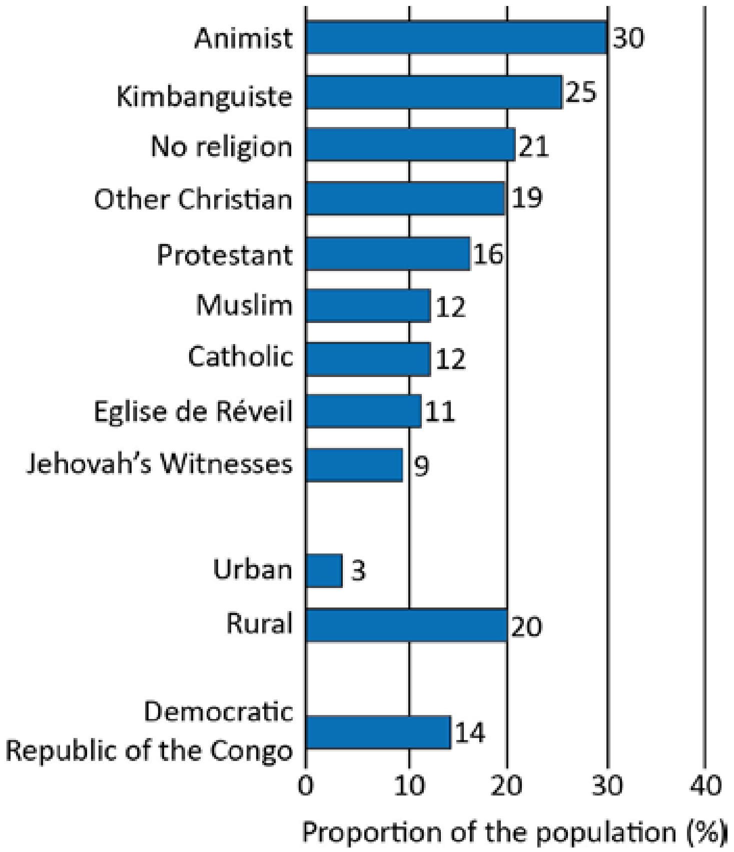


Figure 17. Open defaecation practises in the Democratic Republic of the Congo show disparities according to the religion of the head of the household (Source: WHO/UNICEF, 2014).

operation and maintenance (Nikiema et al., 2014). There are different ways to implement financially sustainable collective or autonomous wastewater treatment and faecal sludge management, by linking different sectors (e.g. health, environment, land planning) and partners (public, ministers and private companies) to solve local problems using regional or national institutional and financial responses. In this context, it is important to note that improving sanitation is of public interest because of the significant resulting benefits for human health and economic development, as well as for the protection of the environment and ecosystem services at a local/regional scale.

Furthermore, experiences worldwide show that sanitation can be a viable business opportunity,

BOX 9: COMMUNITY-LED TOTAL SANITATION IN ZAMBIA

In Zambia, Community-Led Total Sanitation (CLTS) is leading to the rapid spread of improved sanitation to rural and urban communities (UNICEF, 2009). CLTS is increasing awareness of sanitation's importance from the household to the district level and motivating a desire to improve living conditions for all. Through the promotion of self-reliance, CLTS is empowering local stakeholders and serving as a catalyst for sustainable development that extends beyond the sanitation sector. UNICEF (2009) has identified some key elements for CLTS success:

- Led by government (e.g. Ministry of Health) but also traditional/civil leaders (e.g. chiefs and mayor) including non-traditional stakeholders (e.g. the media, police officers and the judiciary) when there is no NGO leading the process.
- Achieved without external subsidies (given the potential difficultly in replicating and sustaining this practice) to catalyse enthusiasm and action for other community development activities. In cases where subsidies are available for certain disadvantaged groups, such as people with disabilities or households led by children, they should be managed by the community as part of the collective plan for overall community sanitation improvement.
- To foster sustainability, attention is paid to market development, such as encouragement of local artisans' associations to engage in CLTS by marketing their skills and demonstrating latrine construction.
- Enforcement officers (health inspectors, police officers and councillors) are trained in CLTS and the Zambian laws that address sanitation and hygiene to prepare judicial and security officials to handle the sanitation and hygiene cases that go through the legal system.

Interestingly, initial efforts to introduce CLTS in peri-urban areas met with a range of challenges, such as the predominance of shared housing, high population density and weaker community structures compared to rural communities. In later stages, CLTS facilitators realized that the approach needed to be adapted specifically for urban areas. CLTS is now included as a key national strategy in the National Rural Water Supply and Sanitation Programme, inspiring a friendly competition between districts.

Figure 18. Community members are drawing the community map of defaecation in the Volta Region of Ghana under the guidance of Environmental Health Assistants, with blue coloured papers (landmarks) and green coloured papers (households) (Photo credit: Jesse Coffie Danku).

and has the potential to provide multiple benefits to the poor (SuSanA, 2012). Market-based approaches seek to address the challenges of financial sustainability and to strengthen the role of the private business sector, while empowering local communities and individuals to make their own informed decisions about obtaining sanitation products and services. Sanitation is then seen as a vehicle for businesses to provide services and earn revenues that can be reinvested to keep expanding coverage of sanitation facilities and to develop economic activity while improving peoples' living conditions (see examples of sanitation business in developing countries in SuSanA, 2012).

The construction and expansion of treatment infrastructures require significant and long-term capital investments, which generally do not attract the private sector, and should for this reason be at least partially supported by public funds or loans, or by grants from development cooperation agencies or NGOs. On the other hand, several previous experiences have demonstrated that sustainable models of financing cannot only rely on subventions or on donor-driven models (e.g. free or heavily subsidised toilets) which are susceptible to political stability and willingness to pursue sanitation priority (**Box 9**). In general, these models have poor records of effectiveness of use, efficiency of investments, sustainability of services, and scaling up access (Frias and Mukherjee, 2005). Moreover, an excessive undervaluation of the tariffs (under-priced user charges) also represents a barrier to sustainable cost recovery options, economic instruments and creation of sustainable business opportunities.

The financial viability of sanitation services increases significantly when the revenues from the users represent sufficient funding to cover at least some of the operating costs, i.e. shifting from beneficiary to potential consumer business model. The charging system needed to keep the facilities clean and perform necessary small repairs can be in the form of a pay-per-use system in middle and high income countries, or charged on a family sanitation flat rate in low-income informal settlements (SuSanA 2012). Another advantage in this latter situation is that the consumers are more concerned by the quality of the services, and therefore encouraged to participate in the expected public consultation process.

In the absence of a consumer cost recovery mechanism and of sufficient public funding, other options should be encouraged, such as the development of small entrepreneurs and in general of the private sector (e.g. for the emptying and the transportation of faecal sludge) as well as private public partnership (PPP) or participation for wastewater and faecal sludge management (e.g. management contract, lease, affermage, concession, or divestiture). One advantage of such a sanitation business model is a better estimation of the costs and expenditures of the existing services and of faecal sludge end-products (market prices). Governments can also attract private funding in the sanitation infrastructure development in the form of project financing, such as build–operate–transfer (BOT) or build-own-operate-transfer (BOOT). The over-taxation of drinking water services can also be used as a reliable source of cross-funding for investing in sanitation services, especially when a single entity is managing (and factoring) both services. Different contracts can also be established with the private sector supporting the water services through taxes and cross-subsidies.

The provisional cost of sustainable sanitation is particularly challenging in informal settlements, because (i) of the lack of funding and of political willingness to foster development initiatives to improve the quality of life for the poorest and marginalised groups, (ii) informal settlements are generally built on areas not suitable to construction, (iii) and because the residents are worried about expulsion and are therefore not likely to invest in expensive but fixed sanitation infrastructures. In such unfavourable contexts, and in agreement with local government for enabling construction and recognition of property rights (cadastre and land registration authority), microfinance, investors and local entrepreneurs can play a significant role in triggering household sanitation investments, also to support the development of a complete range of sanitation services (e.g. construction and installation of sanitation systems, latrine emptying and safe disposal of faecal sludge, training and reuse opportunities).

To conclude, providing affordable water and alternative (small-scale) decentralised sanitation services, can be a massive challenge that does not only require a robust business model and financing investments; but also a strong and effective collaboration between different stakeholders and government offices, efficient management instruments, and a regulatory framework. Such an enabling environment (**Figure 19**) can further be used (1) to develop and harmonise sanitation policies, regulations and guidelines, (2) to organise advocacy campaigns focusing on policy makers, (3) to integrate hygiene education into all water supply and sanitation projects, and (4) to enforce institutions (empowerment) and encourage local and national governments to fight corruption. For all these reasons, the human rights-based approach to water and sanitation management, presented in the next chapter, is probably one of the best ways to achieve SDG 6; including targets 6.1 and 6.2 (Table 4). Improved water and sanitation services need to be safe, equitable, culturally acceptable and affordable, for the benefit for all, and addressing socio-economic and gender inequalities (the vision of the 2030 Agenda on eliminating inequalities "Leave no one behind"; UN-Water 2016).

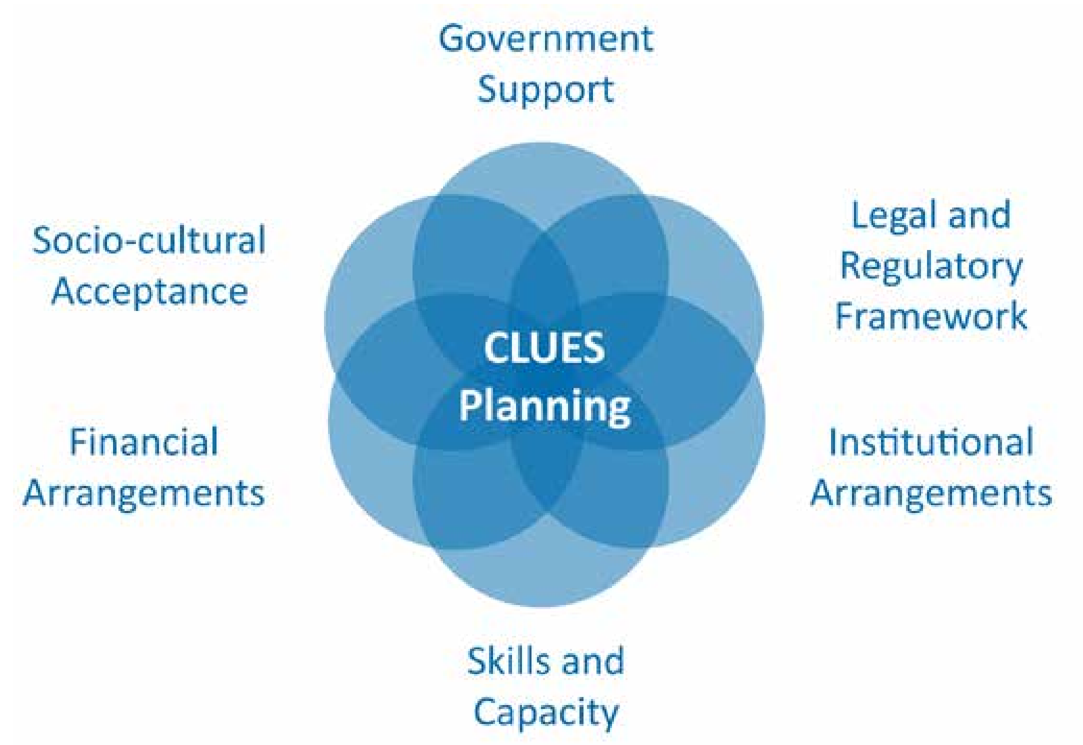


Figure 19. The six elements of the enabling environment, necessary for the success of Community-Led Urban Environmental Sanitation (CLUES) (Source: Luethi et al., 2011).

5. Human rights-based approach to water and sanitation governance

5.1. Water and the Sustainable Development Goals (SDGs)

At the UN Sustainable Development Summit on 25th September 2015, more than 150 world leaders adopted the new 2030 Agenda for Sustainable Development to end poverty and promote prosperity for all, while protecting the environment and addressing climate change, including the SDGs (**Figure 20**). Unlike the MDGs which focused on developing countries, the SDGs have a global agenda. The 17 new SDGs aim to end poverty, hunger and inequality, take action on climate change and the environment, improve access to health and education, and build strong institutions and partnerships.

Universal access to clean water and sanitation is one of 17 Global Goals that make up the 2030 Agenda for Sustainable Development, since water and sanitation issues are addressed by a dedicated goal (SDG 6) with eight targets (**Figure 20** and **Table 4**); not only on drinking water, sanitation and hygiene (WASH) but also on water resources management. The first two targets (6.1 and 6.2) build on the MDG drinking-water and sanitation targets, providing continuity while expanding their scope and refining definitions. The other four new SDG targets 6.3 to 6.6, address the broader water context that was not explicitly included in the MDG framework, but whose importance was acknowledged at the Rio+20 Conference: Wastewater treatment and water quality, water use and water-use efficiency, Integrated Water Resources Management (IWRM) and water-related ecosystems. The Global Enhanced Water Monitoring Initiative (GEMI) is an inter-agency partnership comprising UNEP, WHO, FAO, UNICEF, the United Nations Educational, Scientific and Cultural Organization (UNESCO), UN-Habitat, and the World Meteorological Organization (WMO); under the umbrella of UN-Water which is the UN interagency coordination platform for water-related matters, including sanitation and SDG 6 implementation plans. The UN-Water family aims to support Member States in global monitoring

Figure 20. In 2015, countries adopted a set of goals to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the next 15 years (Source: Resolution adopted by the General Assembly on 25th September 2015).

TARGETS	INDICATORS	SOURCES OF DATA
6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all	**6.1.1** Proportion of population using safely managed drinking water services	WHO/UNICEF JMP
6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defaecation, paying special attention to the needs of women and girls and those in vulnerable situations	**6.2.1** Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water	WHO/UNICEF JMP
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 substantially increasing recycling and safe reuse globally	**6.3.1** Proportion of wastewater safely treated **6.3.2** Proportion of bodies of water with good ambient water quality	WHO, UN-habitat, United Nations Statistics Division (UNSD) UN Environment
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	**6.4.1** Change in water-use efficiency over time **6.4.2** Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	FAO FAO
6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	**6.5.1** Degree of integrated water resources management implementation (0-100) **6.5.2** Proportion of transboundary basin area with an operational arrangement for water cooperation	UN Environment United Nations Economic Commission for Europe (UNECE), UNESCO
6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	**6.6.1** Change in the extent of water-related ecosystems over time	UN Environment
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.a.1** Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan	WHO, UN Environment, Organisation for Economic Co-operation and Development (OECD)
6.b Support and strengthen the participation of local communities in improving water and sanitation management	**6.b.1** Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	WHO, UN Environment, OECD

Table 4. UN Sustainable Development Goal 6 (SDG 6) targets, indicators and sources of data (Source: The Sustainable Development Knowledge Platform; https://sustainabledevelopment.un.org/sdg6; June 2017).

of SDG 6 (see indicators and sources of data in **Table 4**). The monitoring of SDG targets 6.1 and 6.2 (drinking water, sanitation and hygiene) is supported by the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP). For the new targets on ambient water quality and wastewater treatment, water scarcity and water-use efficiency, IWRM and water-related ecosystems (SDG targets 6.3 to 6.6), a new global monitoring initiative, GEMI (Integrated monitoring of water and sanitation related SDG targets) has been developed and is currently being rolled out, based on existing monitoring initiatives. Finally, the monitoring of the means of implementation (SDG targets 6.a and 6.b) can build on the UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) and the GEMI reporting towards target 6.5 on IWRM, which is based on the existing UN-Water IWRM status reporting.

Water is the first resource impacted by climate change which is exacerbating other environmental and social problems that threaten (large) city's development and people's health and livelihoods. In addition to the SDG 6 dedicated to water and sanitation, some important interlinkages (i.e. synergies but also potential conflicts) exist between water and most SDGs, for example with food (SDG 2), health (SDG 3), sustainable cities and communities (SDG 11 and target 11.5 on water-related disasters), food security (SDG 12), climate change (SDG 13), life under water (SDG 14) terrestrial life (SDG 15), peace and justice (SDG 16) and partnerships for the goals (SDG 17) (**Figure 20**). Peace, stability, human rights and effective governance based on the rule of law are important conduits for sustainable development and can play an important role in ensuring the realisation of the Human Rights to Water and Sanitation (HRWS). The SDGs aim to significantly reduce all forms of violence, and work with governments and communities to find lasting solutions to conflict and insecurity, and to ensure that no one is left behind; in particular, the most vulnerable and marginalised communities. Strengthening the rule of law and promoting human rights obligations is therefore key in the process of improving access to safe drinking-water, as is strengthening the participation of developing countries in the institutions of (global) governance.

5.2. Human Rights to Water and Sanitation (HRWS)

In 2010, the UN General Assembly declared the right to drinking water and sanitation as essential to the full enjoyment of life and all human rights (United Nations General Assembly, 2010). That same year, the Human Rights Council affirmed by consensus access to water and sanitation as a legally binding human right. The initial resolutions adopted in 2010 have been supplemented by a recent resolution adopted in 2015, which recognises the distinction between the human right to water and the human right to sanitation (United Nations General Assembly, 2015). With this resolution, the UN General Assembly clarifies that the rights to water and sanitation are separate from one another and have distinct features, despite their evident linkages, while they remain part of the right to an adequate standard of living. Furthermore, the separate recognition of the rights to water and to sanitation provides States a policy instrument with which to focus more attention and effort on their obligations related to sanitation (Giné-Garriga et al., 2016).

Human rights obligations related to access to safe and clean drinking water and sanitation are included in different human rights treaties and international humanitarian laws. There are also a growing number of good practices in the implementation of this right, including many countries recognising the Human Rights to Water and Sanitation (HRWS) in their constitutions, laws, policies and courts (WaterLex 2014a).

The HRWS are derived from the right to an adequate standard of living and is inextricably related to the right to the highest attainable standard of physical and mental health, as well as to the right to life and human dignity. The HRWS entitle everyone to sufficient, safe, accessible,

Human rights criteria and principles	Content and scope	Implementation
AVAILABILITY	Water must be available in sufficient quantities for personal and domestic uses. A sufficient number of sanitation facilities must be available.	WHO: 50 to 100 litres of water per person per day to meet health requirements.
QUALITY	Water must be safe for consumption and other uses and not threaten human health. Sanitation facilities must be hygienic and safe (no contact with human excreta).	Access to water for cleansing and hand-washing after use is essential.
ACCEPTABILITY	Water and sanitation facilities and services must be culturally and socially acceptable. Establish WHO quality standards.	Separate facilities for women and men in public places, and for girls and boys in schools.
ACCESSIBILITY	Water and sanitation services must be accessible to everyone in the household or its vicinity.	WHO: Distance of less than 1 km or less than 30 minutes return trip.
AFFORDABILITY	Access to sanitation/water facilities and services must be affordable for all and must not compromise the ability to pay other essential necessities guaranteed by human rights, such as food, housing and health care.	Does not mean that water should be free as a rule: Household spending in water should not exceed 3% of family income.
NON DISCRIMINATION	Non-discrimination based on race, colour, sex, age, language, religion, political or other opinion, national or social origin, property, birth, physical or mental disability, health status or any other civil, political, social or other status, both in law and in practice.	Positive targeted measures. Priority to the most marginalised and vulnerable including people with disabilities and children.
ACCESS TO INFORMATION	The right to seek, receive and impart information concerning water issues, using multiple channels of information.	Capacity development and training may be required.
PARTICIPATION	Processes related to planning, design, construction, maintenance and monitoring of sanitation and water services should be participatory. Crucial to include representatives of all concerned individuals, groups and communities in participatory processes (including poor people and members of marginalised groups).	Community participation in the planning and design of water and sanitation programmes is essential to ensure that water and sanitation services are relevant and appropriate, and sustainable.
ACCOUNTABILITY	The realisation of human rights requires responsive and accountable institutions, a clear designation of responsibilities and coordination between different entities involved.	Access to effective judicial or other appropriate remedies (courts, national ombudspersons or human right commissions).
SUSTAINABILITY	Practices have to be economically, environmentally and socially sustainable so that future generations can enjoy the right too.	The achieved impact must be continuous and long-lasting.

Table 5. The content, scope and implementation of Human rights criteria and principles (Source: WaterLex Toolkit http://www.waterlex.org/).

culturally acceptable and affordable water and sanitation services for personal and domestic uses, which are delivered in a participatory, accountable and non-discriminatory manner (**Table 5**). Human rights criteria (the normative content of the right): Availability, quality, acceptability, accessibility and affordability; and human rights principles (the procedural aspects or cross-cutting criteria): Non- discrimination, access to information, participation, accountability and sustainability; all precise the content and scope of the rights and guide its implementation process (**Table 5**). These elements give meaning to the HRWS, and must be considered for their implementation. For example, accessibility addresses three levels (physical accessibility, economic accessibility and non-discrimination), affordability falls within the State's obligation to respect and fulfil the right to water and sanitation; and sustainability means that under the HRWS framework, governments are expected to adopt comprehensive and integrated strategies and programmes to ensure that there is sufficient and safe water for present and future generations (Alabaster and Kruckova, 2015). The Office of the United Nations High Commissioner for Human Rights (OHCHR) indicator framework has three types of indicators to measure progress in the implementation of international human rights norms and principles (compliance and performance assessments): Structural (regulatory frameworks), process (action taken to realize human rights) and outcome (actual access to water/sanitation services). The conceptual and methodological framework provides concrete examples of indicators identified for a number of human rights - all originating from the Universal Declaration of Human Rights - to support the realization of human rights at all levels (OHCHR, 2012). It is here meaningful to note that WHO/ UNICEF JMP and UN-Water GLAAS mechanisms are well positioned to monitor States compliance with the HRWS: (i) JMP which is responsible for the monitoring of progress towards the WASH related target of the Agenda 2030 for sustainable development, contributes with outcome indicators to measure right holders' enjoyment of the right, and (ii) GLAAS adds structural and process ones to measure duty bearers' conduct (Flores Baquero et al., 2015).

The human rights to water and sanitation impose specific legal obligations on States: (i) to respect requires States to refrain from interfering with the enjoyment of the right to water and sanitation; (ii) to protect requires States to prevent third parties from interfering in any way with the enjoyment of the right to water and sanitation; (iii) to fulfil requires States to take positive steps to ensure the enjoyment of the rights to water and sanitation. As a general obligation, governments are obliged to ensure that everybody gains access to these services over a considered timeframe, through creating an enabling environment: Namely by adopting appropriate legislation, policies, programmes and ensuring that these are adequately resourced and monitored. States have the international obligation to move towards the goal of universal access as expeditiously and effectively as possible, within available resources and within the framework of international cooperation and assistance where needed (i.e. principle of progressive realisation of human rights) (WaterLex 2014a).

It is however noteworthy that additional to some inherent challenges to good water governance, and as recently highlighted by the UN and governments, climate change also responds to it (adaptation and mitigation) and could have adverse effects on some human rights (**Box 10**); including the HRWS but also the fundamental rights to life, to food, to health, to adequate housing and to land and property, and the rights of indigenous peoples. It is therefore urgent for States to take action to mitigate and guarantee human rights using international (financial) mechanisms. Other actors such as communities and civil society organisations (CSOs) (e.g. non-governmental development and advocacy organisations, social movements, faith-based organisations, research and academic institutions, media professional bodies and other similar organisations) can also play an important role in implementing and/or promoting the rights to water and sanitation; especially where they operate water and sanitation services, monitor government performance or engage in policy advocacy and advice (COHRE, 2007). Non-governmental organisations (NGOs) have also the responsibility to influence the political authorities at local, national, regional and international levels in order to promote the sustainable development and the respect to human rights. NGOs and CSOs can look to National Human Rights Institutions (NHRIs) for support on this.

NHRIs serve as independent institutions with a constitutional and/or legislative mandate to protect and promote human rights. One of their roles is also to monitor the implementation of national human rights commitments. These independent institutions, when accredited by the Global Alliance of National Human Rights Institutions (GANHRI) with the highest status, have a mandate to find remedies to both individual and systemic human rights violations; including human rights violations of the HRWS, or resulting from the adverse impacts of climate change (**Box 10**). While court procedures remain the basic mechanism for the protection of human rights, States/ governments bear the ultimate international responsibility, NHRIs can usefully complement the work of both the judiciary and government (WaterLex 2014b).

NHRIs can also be used to carry out impact assessments of human rights and to evaluate human rights issues arising from HRWS or from the adverse effects of climate change. NHRI are particularly welcome to strengthen their role in the protection of the rights to water and related human rights, and for better contributing to improve human rights-based water governance (WaterLex 2014a). NHRIs in emerging economies and transitional countries have been vocal advocates for the adoption of a human rights-based approach to development. However, for such an approach to be meaningfully implemented, governments must be held to account when their development plans or socioeconomic policies fail to address patterns of preventable human rights deprivations, such as hunger, illiteracy, unsafe drinking water, lack of basic health services, social discrimination, physical insecurity, and political exclusion (Corkery, 2015). Moreover, NHRIs do not have world coverage yet and are not always independent, so NHRIs should have a strengthened role and should be operational both in terms of financial resources and independence (WaterLex, 2014b).

5.3. Policy reform for SDG 6 implementation

Water is the primary medium through which climate change influences the Earth's ecosystem and thus the livelihood and well-being of societies. The increasing phenomena related to climate extremes (drought or flooding), and of water-related crises, may generally threaten water/ food security and furthermore increase the risk of conflicts and epidemics (IPCC, 2014). To cope with the twin challenges of high rates of population growth and negative consequences of climate change on Human Rights to Water and Sanitation (HRWS; **Box 10**), a greater understanding of the natural-related challenges facing the water sector are needed; as well as enhanced monitoring, technological innovations and behaviour changes. However, these developments also call for the strengthening of law and policy frameworks, and of the regulatory and governance capacity of policy makers and civil society. The recent international mobilisation of scientists, civil society and political decision-makers to cope with climate change impacts on water and the human rights, point out at the obligations of both governments and private actors in responding to climate change; including those relating to rights to information, public participation in decision-making and access to justice, as well as obligations relating to adaption and mitigation. UNEP (2015b) recently published a report assessing the relationship between climate change and human rights laws, stressing some of the obligations of governments and private actors to respond to the human rights implications of climate change:

- Procedural obligations for all governments to ensure that the affected public is: (i)

BOX 10: UNFCCC CONFERENCE OF THE PARTIES (COP 21 AND 22) AND HUMAN RIGHTS

The United Nations Climate Change Conferences are annual conferences held in the framework of the United Nations Framework Convention on Climate Change (UNFCCC). They serve as the formal meeting of the UNFCCC Parties (Conferences of the Parties, COP) to assess progress in dealing with climate change. The Paris Agreement is an agreement within the UNFCCC dealing with greenhouse gases emissions mitigation, adaptation and finance starting in the year 2020. It entered into force in 2016. In 2015, COP 21 specifically highlighted the importance of human rights:

> *Acknowledging* that climate change is a common concern of humankind, Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity
>
> *Recognizing* that climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions.

As part of the Adoption of the Paris Agreement, the COP 21 established the Paris Committee on Capacity-building (PCCB) to address gaps and needs, both current and emerging, in implementing capacity-building in developing country Parties and further enhancing capacity-building efforts.

At COP 22 in Marrakech in 2016, the PCCB was invited to manage the 2016–2020 workplan and (i) take into consideration cross-cutting issues such as gender responsiveness, human rights and indigenous peoples' knowledge, and (ii) also encourage Parties to integrate local and traditional knowledge in the formulation of climate policy and to recognize the value of the participation of grassroots women in gender-responsive climate action at all levels (**Figure 21**).

Figure 21. Bangladesh is suffering from acquit riverbank erosion which compels millions persons to be displaced from their place of origin (Photo credit: Sumon Yusuf with courtesy of Photoshare).

adequately informed about the impacts of climate change and the measures undertaken to both mitigate and adapt to climate change; (ii) adequately involved in public decisions about climate change; and (iii) given access to administrative, judicial, and other remedies when rights are violated as a result of climate change and responses to it.

- Substantive obligations for all governments to: (i) protect human rights from climate-related harms; (ii) respond to the core drivers of climate change by regulating greenhouse gas emissions within their jurisdiction; (iii) cooperate internationally to protect human rights against climate-related harms; (iv) address the transboundary impacts of climate change; and (v) safeguard human rights in all mitigation and adaptation activities.
- States also have unique obligations with respect to certain groups, including women, children, and indigenous peoples. Notably, states must obtain free, prior and informed consent before undertaking any measures that would adversely affect the traditional lands and resources of indigenous peoples.
- Private actors also have obligations to address the human rights implications of climate change, and should refer to the UN Guiding Principles on Business and Human Rights to ensure that they fully respect human rights in all activities.

To ensure the enforceability of the HRWS which are (at least implicitly) included in many constitutions, legal options must first address the gaps identified in the existing legal framework. The review of active legislation, policy frameworks and programmes is thus necessary to ensure that they are consistent with the HRWS (e.g. country mapping of Uganda in Alabaster and Kruckova, 2015; **Box 11**). Existing national laws and regulations, local government policies and operating procedures, should then be revised for identifying the needs and priorities to enable HRWS compliance and delivery, and to ensure that they refrain from discrimination (COHRE et al., 2007).

In the case of the decentralisation of frontline basic services (including, delivering water and small-scale alternative sanitation systems), local governments have responsibilities for planning, budgeting, supervising and accounting for implementation of water and sanitation services. Although many services can be undertaken in collaboration with local communities (**Box 9**), policies should encourage innovative financing to increase funding for (rural/urban) sanitation services to poor and marginalised communities. In addition, to enable construction and recognition of property rights in informal settlements of urban areas, or to design effective resettlement plans, local and national governments should also develop a legal and policy framework for public-private partnership on wastewater and faecal sludge management. A policy framework for attracting private investment in the sector, including in densely populated and poor/informal urban areas is also requested. Both civil society and private sector organisations play a vital role with respect to human resource strengthening service delivery, community mobilisation, institution strengthening and capacity building, resource mobilisation and advocacy (Alabaster and Kruckova, 2015). Specific advocacy action plans can be further developed focusing on local and state governments, to ensure that the subsidy reaches the real poor, while mobilising local communities to raise their demand (FANSA 2013). Strong advocacy actions can allocate increased budgetary actions for WASH programme and awareness campaigns, and to promote innovative financing mechanisms (e.g. simplification of the registration of micro-business in the sanitation sector; SuSanA, 2012). In addition to the encouragement of private small-scale enterprises for taking tasks such as faecal sludge collection, emptying latrines and septic tanks, composting and recycling, field awareness campaigns and advocacy actions are needed to focus on improving water quality (e.g. regular monitoring of surface water sources) and hygiene practices.

National governments, and local authorities in the case of decentralisation, also have the

BOX 11: UGANDA COUNTRY MAPPING FOR THE REALISATION OF THE RIGHTS TO WATER AND SANITATION

In 2015, the WaterLex WASH Programme focused on Uganda for a full legal and WASH country mapping to establish the status of implementation and monitoring of the HRWS in Uganda, and to provide support for increased alignment of the legal framework, key sector policy frameworks, implementation and monitoring strategies; with the existing human rights commitments of the government (Alabaster and Kruckova, 2015; **Figure 22**). This study examined Uganda's compliance with its international obligations and commitments, regarding the HRWS, and sought to determine how the State's existing national legal framework is aligned with each of the right's criteria and related procedural guarantees.

Based on the varied levels of assessment, four key recommendations for promoting universal access to safe water and sanitation in Uganda have been advanced and detailed in the Action Plan:

1. Enhanced Legal Framework: Consider legal options that will address gaps identified in the current legal framework for enhancing the enabling environment for HRWS compliance and delivery in Uganda.
2. Harmonized National Standards: Revise current national water, sanitation and hygiene standards and the sector performance measurements to align with HRWS norms and service criteria and the SDG goals and targets.
3. Baseline Analysis and Target Setting for HRWS Implementation: (i) Establish a baseline with clear disaggregated data of the unserved areas and groups based on the specification of minimum core obligations with respect to substantive and procedural rights that apply nationally irrespective of rural/urban divide; and (ii) Define a Targeted Strategy for Progressive Realization of Safe Water and Sanitation for all.
4. Accountability: Review the current Governance Framework to promote accountability and independent regulation to support enforcement of norms and standards that will accelerate universal access. Expedite the process of setting up the independent regulator.

Figure 22. Uganda country mapping for the realisation of the right to water and sanitation (Photo credit: Franz Hollhuber, 2015).

responsibility (i) to ration water use and pollution through issuance of user permits and licensing, (ii) to monitor water quality of aquatic ecosystems and evaluate the impact of pollution and how to alleviate it, (iii) to facilitate the monitoring of drinking water quality and ensure that water is safe for human consumption, but also to provide information about water quality conditions, and (iv) to revise current water, sanitation and hygiene standards and the sector performance measurements to align with HRWS norms and service criteria and the SDG goals and targets (Alabaster and Kruckova, 2015). As an example, the status of implementation and monitoring of the HRWS in Uganda (**Box 11**) revealed that more than 80% of the population in Kampala was not connected to the sewerage system. Moreover, there were no formal guidelines for standards and guidelines for regulating the faecal sludge management particularly for the private sector.

The monitoring and global reporting of the SDG 6 indicators, as recently proposed through the step-by-step monitoring methodologies by UN-Water (2016), will help national governments and the international community (i) to track trends and changes over time and space, (ii) to better evaluate the short/long-term evolution of the impact of water management practices (including on HRWS), and (iii) to ensure sustainable management of water and sanitation for all, through coherence in decision making and implementation. The 2030 Agenda stresses the importance of "leaving no one behind" which is grounded in the human rights framework and represents a paradigm shift compared to the MDGs. Concerning SDG 6, targets 6.1 and 6.2 (**Table 4**) build on the MDG targets on drinking water and sanitation, and further address the normative criteria of the human right to water (availability, quality, acceptability, accessibility and affordability). Nevertheless, there are yet many critical gaps between the SDG 6 normative interpretation of the targets, the definition and rationale of the indicators, and the normative criteria of the human rights to water and sanitation (United Nations Economic and Social Council, 2002; Flores Baquero et al., 2016):

- Indicator 6.1.1 (**Table 4**) incorporates aspects of quality (safe, free of contamination), accessibility (located on premise), availability (available when needed), and affordability (access for all and socioeconomic inequalities). From a human rights perspective, it should therefore consider for example (i) the physical accessibility (e.g. security during access to water facilities and services at all times of the day or night), (ii) the equality and affordability (e.g. household expenditure, the inability to pay and disconnections), as well as (iii) the quality/safety: The toxic chemical water pollution resulting from human activities is not yet considered, since only two priority chemicals (naturally occurring arsenic and fluoride) are included in this indicator (i.e. not the WHO guidelines for drinking water quality constituents of water that are known to be hazardous to health).
- Indicator 6.2.1 (**Table 4**) incorporates aspects of accessibility (at the household level), acceptability, safety (not shared with other households) and socioeconomic inequalities (access for all). Concerning the SDG classification of shared facilities as unimproved, from a human rights perspective, public toilets or toilets shared between households, although not optimum, can be an interim solution where they are well managed, culturally acceptable, kept in a hygienic condition and where access is affordable or free (Giné-Garriga et al., 2017). Moreover, indicator 6.2.1 should for example, address the equality and the discrimination related to WASH services; as well as the affordability (and the inability to pay) for sanitation facilities and services (construction, emptying and maintenance of facilities, as well as treatment and disposal of faecal matter) which should be available at a price that is affordable for all people; i.e. without limiting their capacity to acquire other basic goods and services, including water, food, housing, health and education guaranteed by other human rights.

The SDG 6 monitoring and global reporting will

require considerable political, financial and institutional investments to allow countries to measure incremental progress towards the different targets. In addition, the harmonised and validated indicators will have to be gathered from very different sources (e.g. statistical offices and national agencies/ministries) and reported using UN-Water guidelines to the local/national authority/agency responsible for data collection and management. Target 6.b furthermore supports the implementation of all SDG 6 targets (targets 6.1 - 6.6 and 6.a) by promoting the meaningful involvement of local communities, which is also a central component of Integrated Water Resources Management (IWRM) and target 6.5 (**Table 4**). The degree to which IWRM is implemented (indicator 6.5.1) by assessing the four components of policies, institutions, management tools and financing, takes into account the various users and uses of water with the aim of promoting positive social, economic and environmental impacts at all levels; including the transboundary level where appropriate (UN-Water 2016). Defining the legal and policy developments to support and strengthen the participation of local communities in improving water and sanitation management (Target 6.b, **Table 4**), is vital for ensuring that the needs of all in a community are met, including the most vulnerable. It is also essential for ensuring the sustainability of water and sanitation solutions over time; for example, the choice of appropriate solutions for a given social and economic context, the full understanding of the impacts of a certain development decision, and local ownership of the solutions (UN-Water 2016). The government officials responsible for water resources management in the country will therefore establish a system to complete the surveys and for storing the results, in order to be accessible over the full 15 years of implementing the 2030 Agenda. A mechanism for using the results of the survey to inform policy and actions should also be established so that any aspect of IWRM that is lagging behind can be addressed.

Taking into consideration the entire range of sustainability criteria that we mentioned before, it is important to observe some basic principles when planning and implementing a sanitation system. Such principles were for instance proposed as the underpinning basis for a new approach in environmental sanitation, by a group of experts and were endorsed by the members of the Water Supply and Sanitation Collaborative Council as the "Bellagio Principles for Sustainable Sanitation" during its 5th Global Forum in November 2000:

1. In line with good governance principles, decision making should involve participation of all stakeholders, especially the consumers and providers of services.
2. Waste should be considered a resource, and its management should be holistic and form part of integrated water resources, nutrient flow and waste management processes.
3. The domain in which environmental sanitation problems are resolved should be kept to the minimum practicable size (household, neighbourhood, community, town, district, catchments and city).

In the light of these compelling arguments, the Household-Centred Environmental Sanitation approach proposes a radical departure from past central planning approaches as it places the household at the core of the planning process (**Figure 23**). The approach responds directly to needs and demands of the user. Successful implementation of this approach requires the dissemination of information and assistance to those responsible for improving environmental services, such as municipal officials, urban planners, and policy makers responsible for creating an enabling environment (Schertenleib, 2005). States should also ensure that the public, including the marginalized, disadvantaged and excluded populations, have the right to meaningful participation, access to information and an active role in decision making. Human rights criteria (availability, quality, acceptability, accessibility and affordability) and principles (non-discrimination, access to information, participation, accountability and sustainability) should therefore be used to improve and monitor wastewater governance.

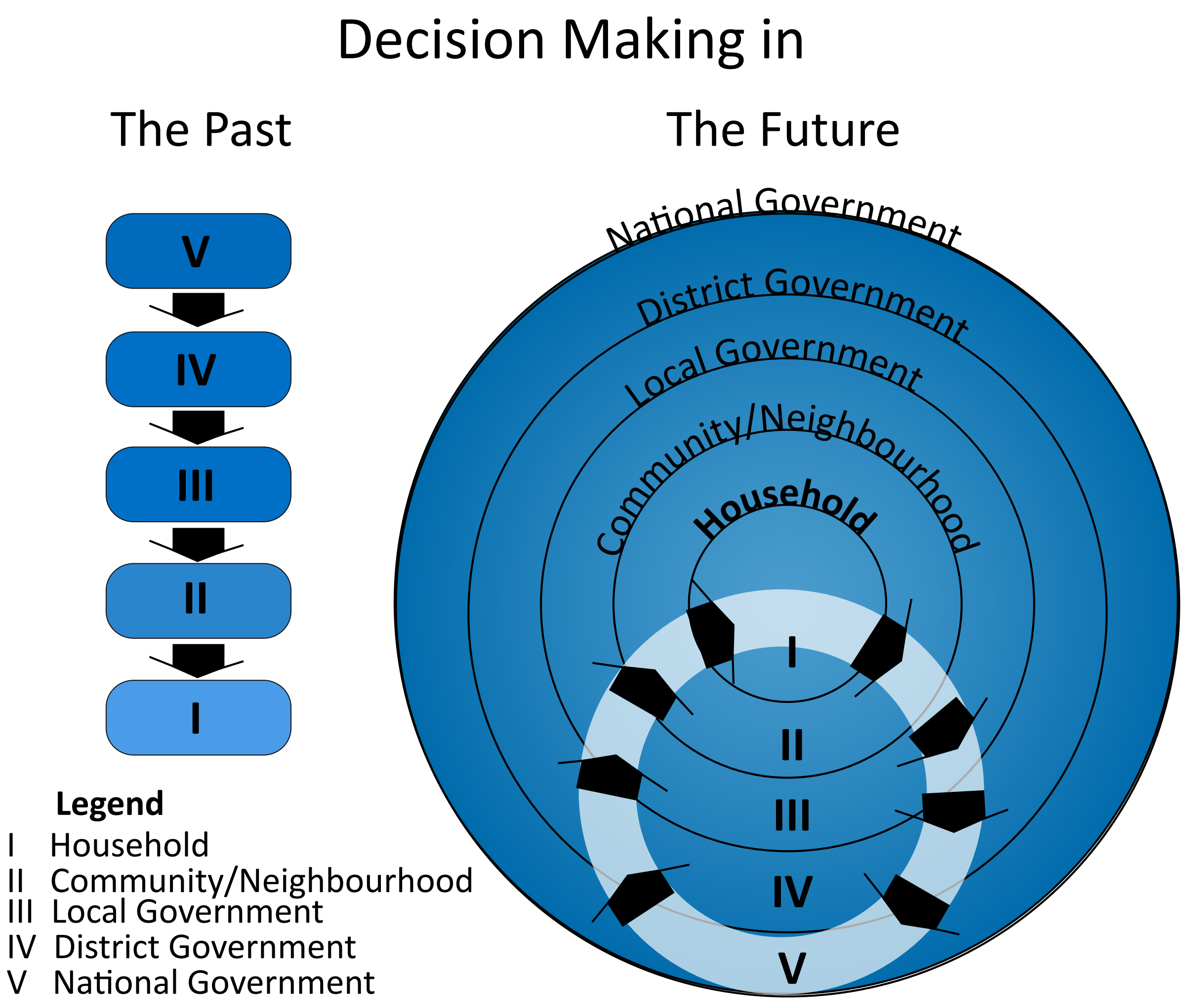


Figure 23. The household at the core of the planning process. The Household-Centred Environmental Sanitation Model attempts to avoid the problems resulting from either "top-down" or "bottom-up" approaches, by employing both within an integrated framework (Source: Schertenleib, 2005).

6. Perspectives and recommendations

Monitoring (waste) water quality and quantity

There are several technical and scientific aspects that need to be appropriately addressed when implementing sanitation projects. The impacts of sanitation systems on the environment need to be evaluated (i.e. the discharge of (treated) wastewater effluents and sewage irrigation). The public should be informed regularly about the water quality status and the possible risk of water contamination. Early warning monitoring networks should be established upstream to provide information about changes in water quality and the transport of pollutants, in order to protect downstream populations (e.g. industrial pollution, water quality degradation following a storm). Academic institutions and the scientific community should be involved, to provide support and share their knowledge (e.g. state-of-the-art and routine water surveillance systems) in order to:

- ☑ **Assess the interaction between surface water sources and groundwater systems (i.e. understand the local hydrological cycle) to protect critical surface and groundwater resources from wastewater contamination and overexploitation.**
- ☑ **Understand the interaction between human activities and water quality (environmental assessment); because contaminants from anthropogenic sources contribute to the eutrophication of surface waters and represents a serious threat to drinking water supply and water-related ecosystems (services) and biodiversity.**
- ☑ **Evaluate the possible effects of wastewater discharge, but also reuse, on aquatic ecosystems, soils and food safety; because fertilisers, pesticides, heavy metals but also emerging pollutants (e.g. antibiotics and endocrine disruptors), are important sources of long-term chemical pollution threatening human health, aquatic organisms and biodiversity, but also food production.**

Sustainable sanitation systems should be part of a holistic approach to Integrated Water Resource Management (IWRM) for managing and protecting local/regional water resources. They should encourage wastewater recycling, safe water reclamation and reuse, and consider human activities (e.g. water withdrawals and pollution) and ecological services at the watershed from a long-term perspective. A human rights-based approach to IWRM is therefore recommended; in which States have the procedural obligations to assess environmental impacts and make environmental information public, facilitate public participation in environmental decision making, and provide access to remedies for harm (CapNet 2017).

Sustainable sanitation systems

Although most households can agree to accept options for improved sanitation systems, both the public and authorities must consider that improved sanitation systems have not only to respect some technical guidelines, but also to protect human health and the environmental resources of (downstream) communities. For instance, faecal sludge from sanitation facilities in low-income areas should not be discharged in uncontrolled areas; but safely emptied and transported to unloading sites or treatment plants for further adequate treatment before discharge. To avoid the overflow of wastewater, septic tanks and drainage systems should be emptied and cleaned regularly, including in informal settlements with poor access roads and insufficient space for emptying trucks. Achieving acceptable, safe and affordable sanitation services accessible to all, including the most vulnerable or marginalized sections of the population and without discrimination, is a priority that should consider the following issues:

- ☑ **Sanitation systems need to be adapted to specific local environmental, political and socio-economic contexts, and accompanied by improved policy and legislation. They should consider the long-term management of sanitation infrastructures and services, including the provisional fund for renewing and maintenance. The feasibility of keeping the technology running should be based on trained and skilled staff, and on the possibility to repair the sanitation infrastructures using locally available materials and human resources, to ensure sustainable systems affordable for the community.**

- ☑ **Alternative sanitation systems should be encouraged because these technologies can protect public health and the environment, and have the potential to improve agricultural production. Attention should be however paid to the health of the workers involved, and of the public at large, regarding the toxicity of wastewater and faecal sludge for disposal and reuse (e.g. abundance of pathogenic faecal bacteria and toxic chemicals). The community should be involved in the monitoring of the water quality, and in the running of the sanitation infrastructure, as well as in the management of the drain sludge.**

- ☑ **Faecal sludge from septic tanks is frequently removed manually by informal private actors or manual cleaners without protective equipment. Local authorities which do not have the financial capacity to establish an effective system should encourage private sector innovative partnership approaches for low-cost sewerage. For example, private entrepreneurs providing services for pit and septic tank emptying and transport of the faecal sludge. Authorities should therefore establish an economic regulatory framework for the sewerage industry; including the establishment of a licensing regime, the regulation of prices, customer service standards (e.g. complaint and redress procedures) and performance monitoring.**

There are different ways to implement financially sustainable collective or autonomous wastewater and faecal sludge management (i.e. to ensure the economic viability of the system); and to develop market-based approaches with business models that provide both long-term social benefit and profit in a sustainable manner. Collaborations should be established with all actors based on local demands and needs (local authorities, associations, private companies and users). When possible, the revenues from the users should be used to (at least partially) cover the operating costs, whereas the valorisation of the end products (e.g. source of organic fertiliser or energy) needs to respond to the local consumer demand and should subsidize a part of the sanitation chain. Once the locally appropriate technologies have been identified with the communities (e.g. Community-Led Total Sanitation), public awareness programs and WASH campaigns need to be developed.

Challenges of sanitation in the context of climate change

The human right to sanitation is a key element which should be considered as a priority to ensure the protection of other human rights (e.g. to water, land, food and health), and to secure sufficient safe water supply at an affordable cost to meet basic needs and sustainable development. However, climate variations and climate change (i.e. long-term change in the frequency and the intensity of extreme weather events) are threatening freshwater resources, equipment, facilities, and businesses. This is especially the case in low-income countries and water stress areas, where the mortality and economic losses from disasters are much higher (UNISDR, 2015). It is therefore crucial for the sanitation sector to integrate disaster risk reduction and climate risks, into the design of sustainable sanitation systems and infrastructures to:

- ☑ **Protect the sanitation facilities as well as surface water and groundwater resources, against rising sea level and pollution in the case of heavy rainfall and (urban) storm water runoff events.**

- ☑ **Anticipate the impacts of climate change regarding the decline of freshwater resources, by promoting irrigation with partially treated wastewater in agriculture, and considering (inter-) national water quality guidelines for protecting human health and the environment.**

- ☑ **Contribute to the reduction of CO2 emissions using sewage sludge as a local energy source, sustainable and renewable, to produce biogas and electricity, and building material.**

- ☑ **Pay attention to groups in vulnerable situations, including women and children; but also indigenous people, because States have a duty to secure the livelihoods of indigenous people and to recognize their rights with respect to the territory that they have traditionally occupied (United Nations Declaration on the Rights of Indigenous Peoples, 2007).**

According to the Intergovernmental Panel on Climate Change (IPCC) experts, typhoons, hurricanes and other extreme weather events may become more frequent and intense due to climate change, and will pose dangers to densely populated urban areas (IPCC, 2014). There is therefore a crucial need to assess how climate change will affect freshwater resources (quantity but also quality) that need to be sufficient through the year and on a long-term perspective. Water sources need also to be protected against contamination by wastewater effluent overflow or sewer system obstructions. States and other duty-bearers (including businesses) have the obligation and responsibility to foster policy coherence and help ensure that climate change mitigation and adaptation efforts are adequate, sufficiently ambitious, non-discriminatory and compliant with human rights obligations (OHCHR's Key Messages on Human Rights and Climate Change).

Human rights-based approach to sanitation

The human rights-based approach to sanitation is certainly one of the best ways to achieve sustainable development in sanitation and reach target 6.2 (By 2030, achieve access to adequate and equitable sanitation and hygiene for all). However, providing safe, affordable and sustainable sanitation services in poor urban and rural areas is a massive challenge that does not only require robust business models and financing investments, but also strong and effective water governance (e.g. OECD, 2015) which is obligatory to:

- ☑ **Develop and harmonise sanitation policies, regulations and guidelines, and organise advocacy campaigns focusing on policymakers; taking in account the needs and capacities of the poor communities, including people living in informal settlements.**
- ☑ **Integrate health and hygiene education (WASH) activities and human rights criteria and principles into sanitation action plans, and involve the empowerment of (poor) communities to change their circumstances and to promote well-being and freedom based on the inherent dignity and equality of all people.**
- ☑ **Enforce the mandates of National Human Rights Institutions (NHRIs) and encourage local and national governments to fight corruption and include the poorest and marginalised communities in the consulting and decision-making processes.**

Ensuring that everyone has access to adequate sanitation facilities is not only fundamental for human dignity and privacy, but is one of the principal mechanisms for protecting the quality of drinking water supplies and resources. In accordance with the rights to health and adequate housing, State parties have an obligation to progressively extend safe sanitation services, particularly to rural and deprived urban areas, taking into account the needs of women and children (United Nations Economic and Social Council, 2002). The effective implementation of the 2030 Agenda through the lens of the pledge of "leaving no one behind", can only be achieved by addressing socioeconomic and gender inequalities, and by meeting the targets under Goal 6; especially 6.1 (Drinking water) and 6.2 (Sanitation and hygiene) which are both grounded in the human rights framework. This requires national, regional and international cooperative endeavours and road maps, to promote the three dimensions of sustainable development and to monitor the progressive realization of the human right to sanitation.

Policy reform and laws

The benefits from investments in sanitation infrastructure and hygiene education are not sustainable without capacity building efforts and strong institutional frameworks. Governments of many low and middle income countries are facing major issues surrounding the decentralisation of responsibility for infrastructures to local governments. Inadequate institutional, human and financial resources often contribute to the slow rate of implementation of adequate sanitation programs in some of these countries. Affordable alternative sanitation and hygiene models are nonetheless emerging, offering market-based strategies and solutions which can be more sustainable, cost-effective, and easier to scale up. The design of appropriate policies and laws which are necessary to address the problems that people are facing in realising the human right to sanitation can be done through several ways, which include:

- ☑ **Revision of existing laws, regulations, policies and operating procedures to ensure that they align with international guidelines and agreements, and with policy actions in national development programmes.**
- ☑ **Review of the legislation, policies and programmes to ensure that they are consistent with human rights frameworks, i.e. to complete a detailed country mapping of progress using human rights-based indicators through a broad multi-stakeholder evaluation.**
- ☑ **Empowerment of institutions, including of civil society, in the management of sanitation infrastructures, and in the formulation and promotion of equitable (national) laws and policies for protecting water resources, human health and the environment.**

In the context of SDG 6 and climate change impacts on human rights, national and local governments need to integrate their commitment for improving access to sanitation into policies, action plans, programmes, and budgets; at all levels and within relevant frameworks.

Authorities need to provide legal frameworks and effective policy guidelines to facilitate agreements with the private sector, NGOs, social/water entrepreneurs and the civil society.

The water and sanitation sector in low- and middle-income countries undergoing decentralisation processes are facing major challenges which require strong capacity building efforts.

Central governments have to (i) support institutions responsible for the national water and sanitation (public) chain development strategy and its application, (ii) create models to control, regulate, and coordinate the different actors (e.g. municipalities or public/private partnerships) that are responsible for ensuring provision and operation/maintenance of basic sanitation services, and (iii) address the normative criteria (availability, accessibility, quality/safety, affordability, acceptability) and cross-cutting ones (non-discrimination, participation, accountability, impact, sustainability) of the human rights to water and sanitation.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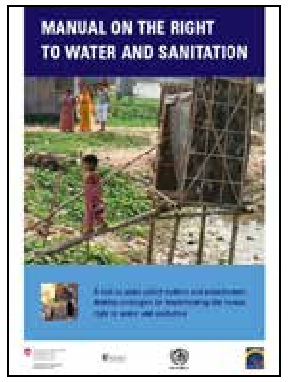
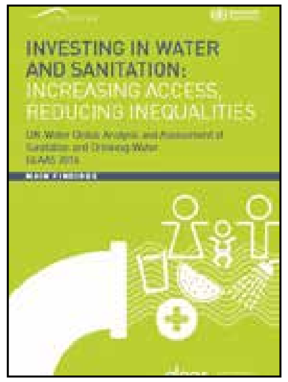
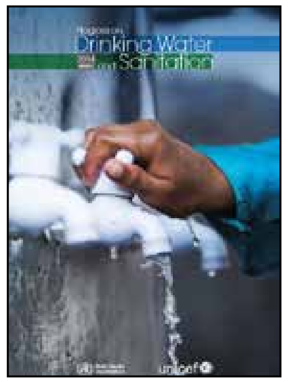
Annex 1: Major reports about wastewater and sanitation



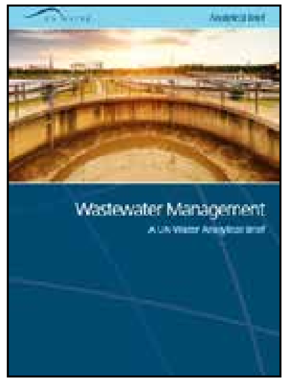
Manual on the right to water and sanitation (2007). This manual is designed to assist policy makers and practitioners in implementing the right to water and sanitation. This publication, addresses the vital need to clarify how human rights can be practically realised in the water and sanitation sector.



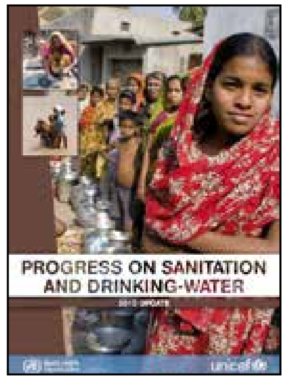
Investing in Water and Sanitation: Increasing Access, Reducing Inequalities (2014). The UN-Water GLAAS Report is the third biennial GLAAS report. It presents data from 94 countries, covering all MDG regions. It also includes data from 23 external support agencies (ESAs), representing over 90% of official development assistance (ODA) for sanitation and drinking-water. Since the start of GLAAS in 2008, the number of participating countries, and the amount of information collected, has grown.



Progress on Drinking Water and Sanitation update (2014). Even though progress towards the Millennium Development Goal target represents important gains in access for billions of people around the world, it has been uneven. Sharp geographic, sociocultural and economic inequalities in access persist and sometimes have increased. This report presents examples of unequal progress among marginalized and vulnerable groups.



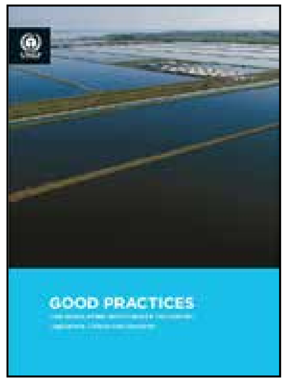
Wastewater Management, A UN-Water Analytical Brief (2015). As the time frame for the Millennium Development Goals nears completion, minds are turning to the Post-2015 Development Agenda. This is accompanied by the realization that the focus on drinking-water and sanitation without due attention being paid to the end products of water and sanitation provision may have exacerbated some of the water quality problems seen globally.



Progress on sanitation and drinking-water 2010 Update is the 2010 report of the WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation provides data for drinking-water and sanitation, along with the implications and trends these new data reveal for reaching the basic sanitation and safe drinking-water MDG target.

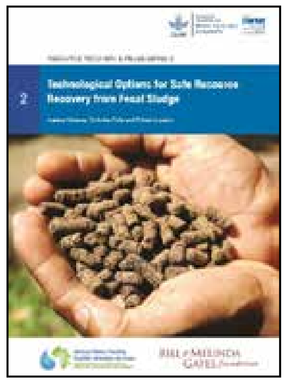
Sick water? (2010). With global action and positive momentum towards improving access to safe water and sanitation, the United Nations Environment Programme (UNEP), the UN Human Settlements Programme (UN-HABITAT), and the UN Secretary General's Advisory Board on Water and Sanitation (UNSGAB), in partnership with the members of UN-Water have collaborated to bring together their collective experience and expertise to bear on the challenges posed by illegal and unregulated wastewater.

Annex 2: Major reports about wastewater treatment/reuse

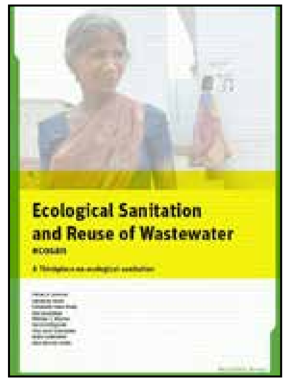


Good Practices for Regulating wastewater Treatment: Legislation, Policies and Standards (2015). This report aims to provide an overview of wastewater legislation adopted by a range of developed and developing countries; to make local lessons in wastewater treatment, disposal and reuse accessible to those who may be considering reform of their own wastewater management practice.

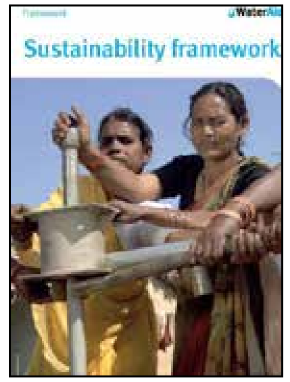
Faecal Sludge Management (2014). This book compiles the current state of knowledge of this rapidly evolving field, and presents an integrated approach that includes technology, management and planning. It addresses the planning and organisation of the entire faecal sludge management service chain, from the collection and transport of sludge and treatment options, to the final end use or disposal of treated sludge.



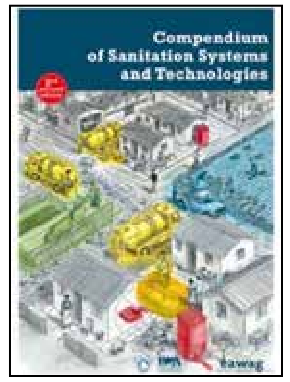
Technological Options for Safe Resource Recovery from Fecal Sludge (2014). This document describes technical solutions for the recycling of faecal sludge to benefit agriculture: This is particularly important for developing countries where there is an urgent need to enhance, at low cost, soil fertility for agricultural purposes).



Ecological Sanitation and Reuse of Water-ecosan (2004). This paper is a "Thinkpiece" to show that there are comprehensive experiences and available technologies that meet new and sustainable sanitation requirements. Ecological sanitation constitutes a diversity of options for both rich and poor countries, from household level up to wastewater systems for mega-cities.

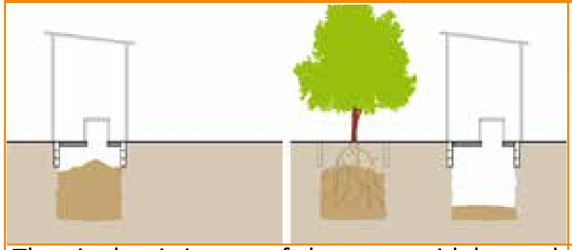
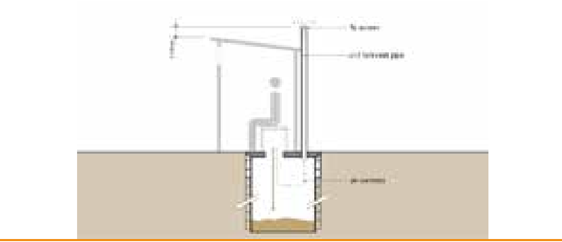
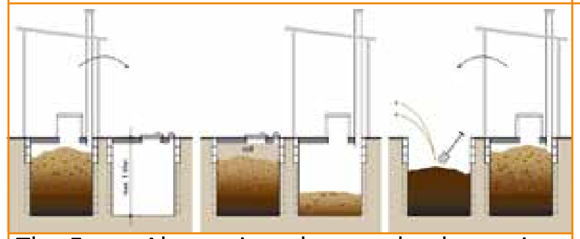
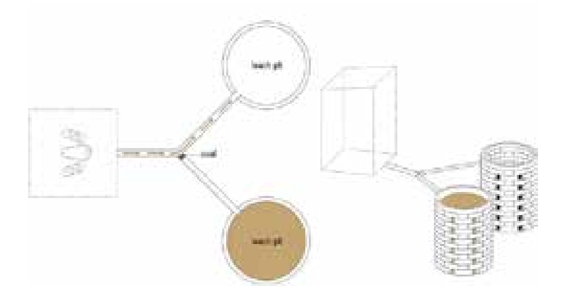
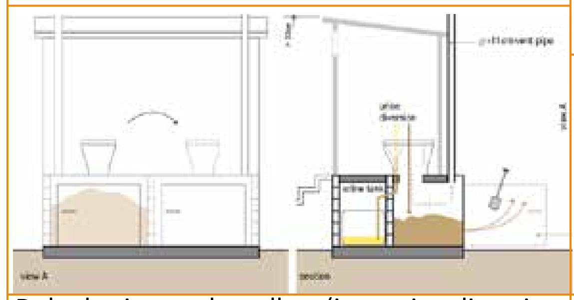
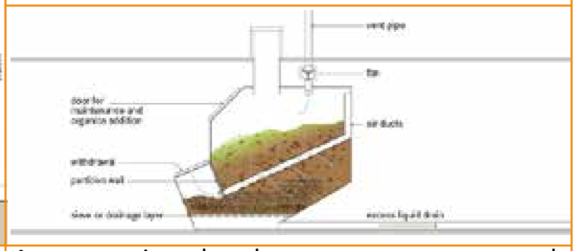
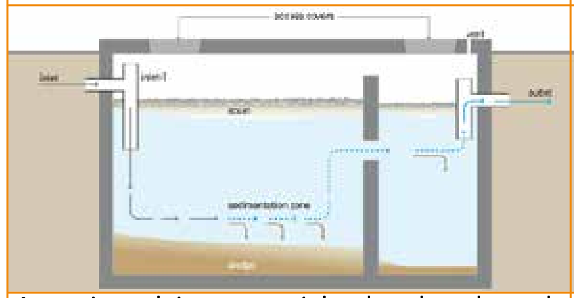
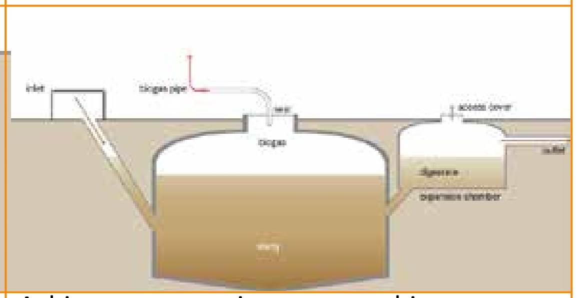


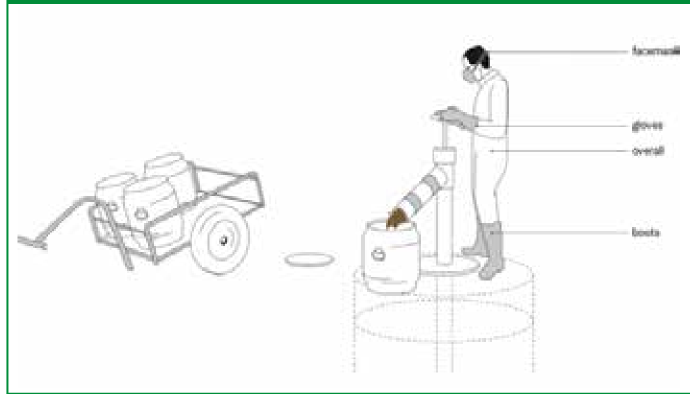
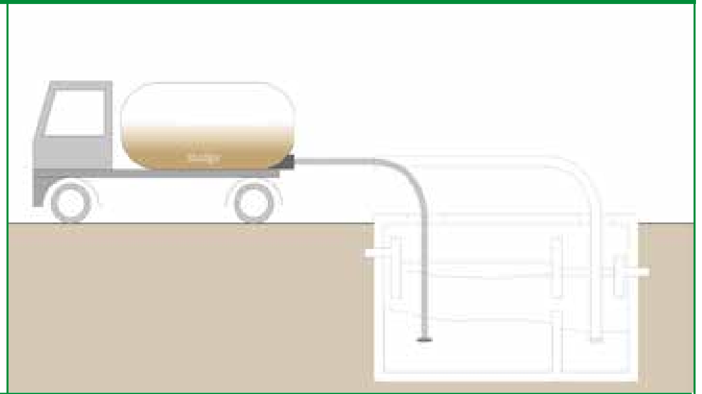
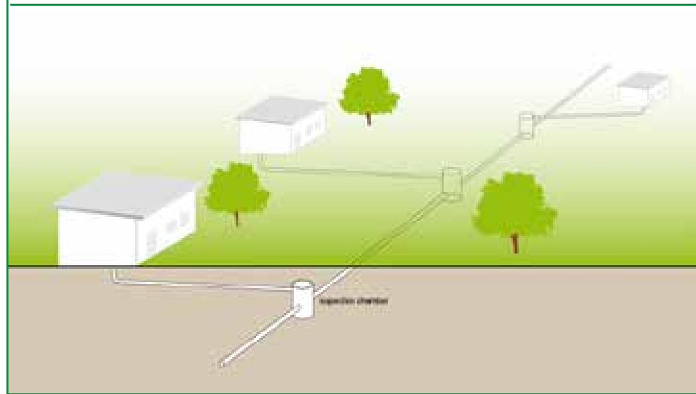
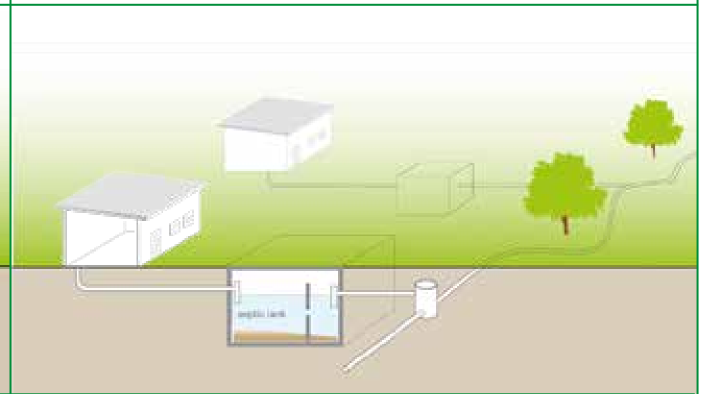
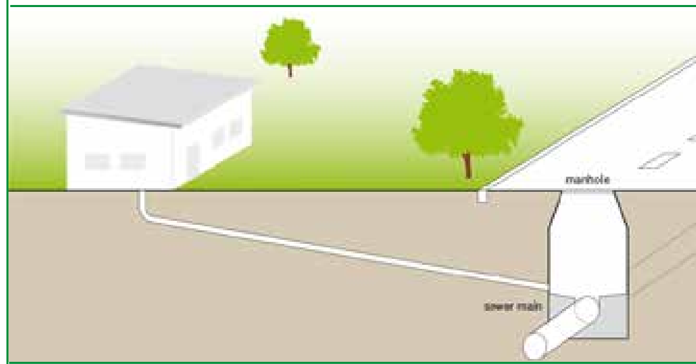
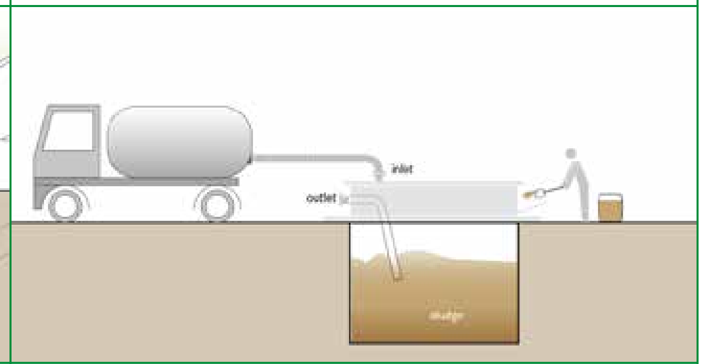
Sustainability framework (2011). This document sets out a framework for sustainable water supply and sanitation services and hygiene behaviour change in low-income countries. It is intended primarily to guide WaterAid country programmes, but it is hoped it may stimulate the thinking of other agencies too. Its focus is primarily on rural populations who constitute the majority of those as yet unserved by improved water supply and sanitation services.

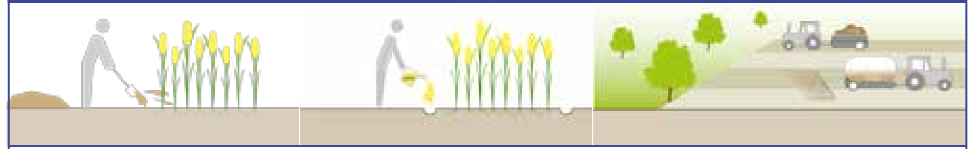
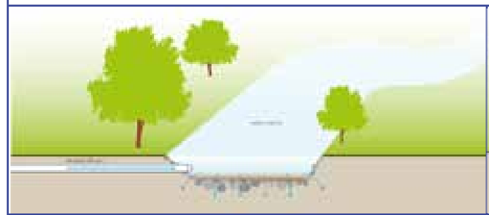
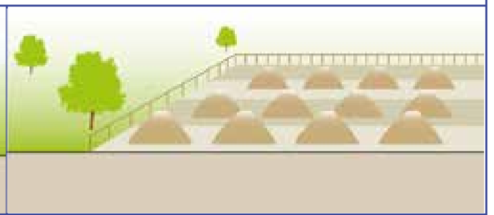
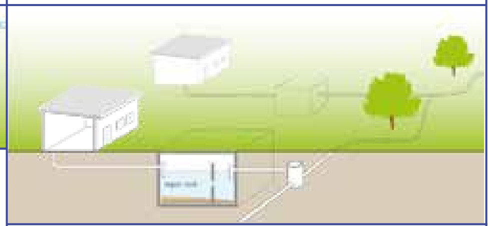
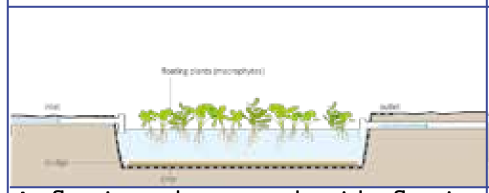
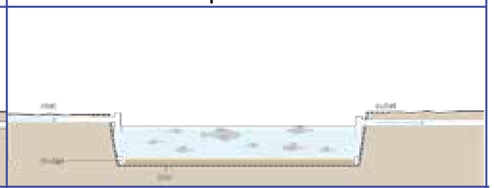
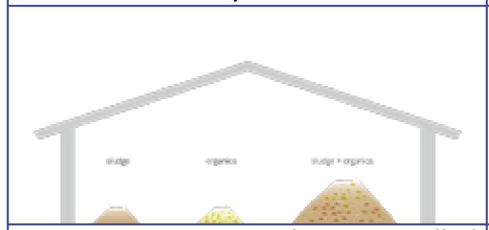
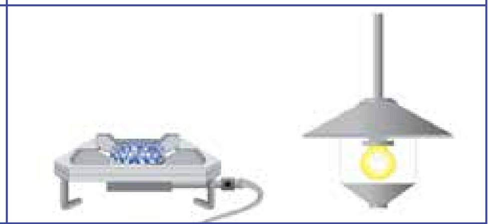


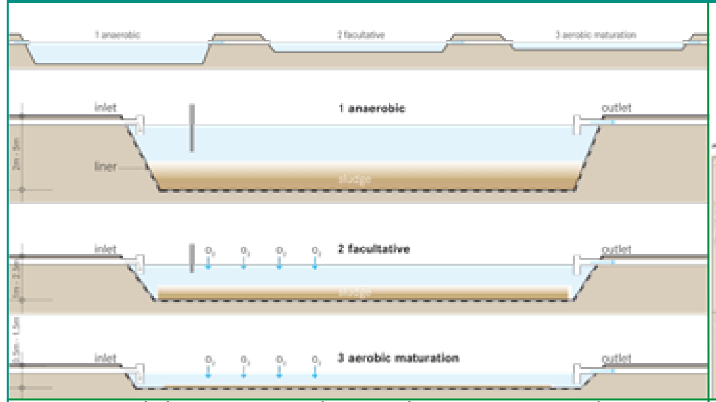
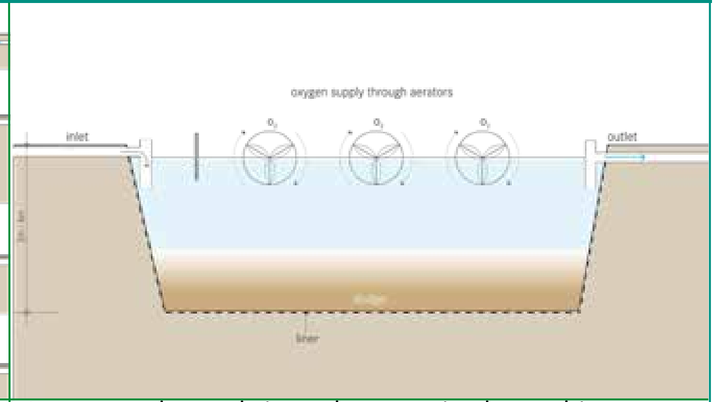
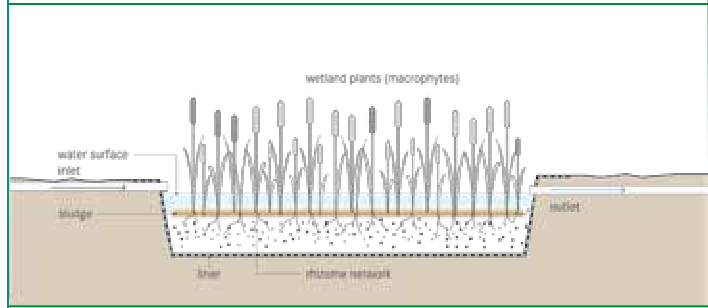
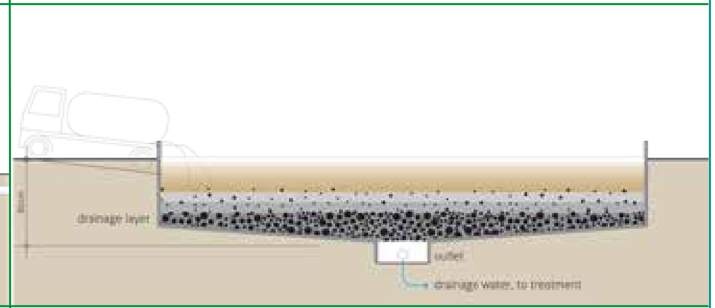
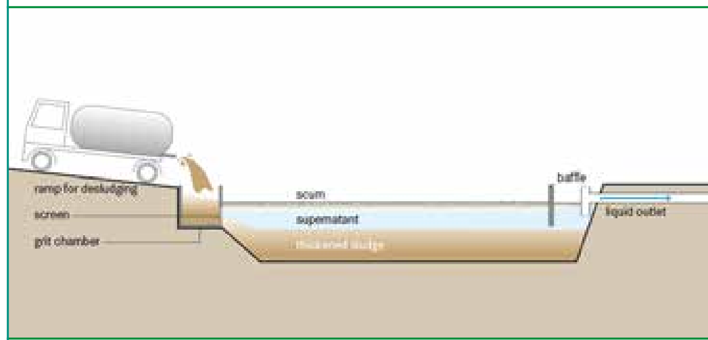
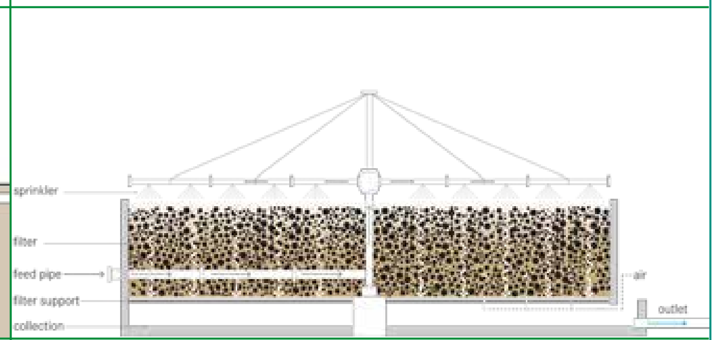
Compendium of Sanitation Systems and Technologies (2014). This document gives a systematic overview on different sanitation systems and technologies and describes a wide range of available low-cost sanitation technologies.

Annex 3: Sanitation systems and technologies

Annex 3.1: Sanitation systems and technologies for collection and storage (Tilley et al., 2014)	
 The single pit is one of the most widely used sanitation technologies. Lining the pit prevents it from collapsing and provides support to the superstructure. The Arborloo is a shallow pit on which a tree can be planted after it is full.	 The single VIP is a ventilated improved pit because continuous airflow through the ventilation pipe vents odours and acts as a trap for flies as they escape towards the light.
 The Fossa Alterna is a short cycle alternating, waterless (dry) double pit technology designed to collect, store and partially treat excreta; to make an earth-like product that can be used as a nutrient-rich soil conditioner.	 The twin pits for pour flush technology consists of two alternating pits connected to a pour flush toilet. The blackwater is collected in the pits and slowly infiltrates into the soil.
 Dehydration vaults collect (in a urine diversion dehydration toilet), store and dry faeces; the vaults need to be well ventilated.	 A composting chamber converts excreta and organics into compost. Compost can be safely handled and used as a soil conditioner.
 A septic tank is a watertight chamber through which blackwater and greywater flow for primary treatment.	 A biogas reactor is an anaerobic treatment technology that produces a digested slurry that can be used as a fertilizer and biogas.

Annex 3.2: Sanitation systems and technologies for conveyance (Tilley et al., 2014)	
 Human-powered emptying and transport refers to the different ways in which people can manually empty and/ or transport sludge and solid products generated in on-site sanitation facilities.	 Motorized emptying and transport refers to a vehicle equipped with a motorized pump and a storage tank for emptying and transporting faecal sludge and urine.
 A simplified sewer describes a sewerage network that is constructed using smaller diameter pipes laid at a shallower depth and at a flatter gradient than conventional sewers. The simplified sewer allows for a more flexible design at lower costs.	 A solids-free sewer is a network of small-diameter pipes that transports pre-treated and solids-free wastewater (such as septic tank effluent). It can be installed at a shallow depth and does not require a minimum wastewater flow or slope to function.
 Conventional gravity sewers are large networks of underground pipes that convey blackwater, greywater and, in many cases, stormwater from individual households to a (Semi-) Centralized Treatment facility.	 Underground tanks act as intermediate dumping points for faecal sludge when it cannot be transported to a (Semi-) Centralized Treatment facility. A vacuum truck is required to empty transfer stations when they are full.

Annex 3.3: Sanitation systems and technologies for use/disposal (Tilley et al., 2014)	
	
Compost is the soil-like substance resulting from the controlled aerobic degradation of organics. Stored urine is a concentrated source of nutrients that can be also applied as a liquid fertilizer in agriculture. Digested or stabilized sludge can be applied to public or private lands for landscaping or agriculture.	
	
Treated effluent and/or stormwater can be directly discharged into receiving water bodies or into the ground to recharge aquifers.	Surface disposal refers to the stockpiling of sludge, faeces or other materials that cannot be used elsewhere.
	
wastewater of varying quality can be used in agriculture. However, only water that has had secondary treatment should be used to limit the risk of crop contamination and health risks to workers.	A leach field, or drainage field, is a network of perforated pipes that are laid in underground gravel-filled trenches to dissipate the effluent.
	
A floating plant pond with floating plants such as water hyacinths on the surface uptakes nutrients and filter the water that flows by.	Fish can be grown in ponds that receive effluent or sludge where they can feed on algae and other organisms that grow in the nutrient-rich water.
	
Co-composting is the controlled aerobic degradation of organics, using more than one feedstock.	Biogas can be used like other fuel gas (i.e. cooking or electricity generation with large anaerobic digester).

Annex 3.4: Sanitation systems and technologies for (semi-) centralized treatment (Tilley et al., 2014)	
	
Waste Stabilization Ponds are large, man-made water bodies. The ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics.	An aerated pond is a large, mixed aerobic reactor. Mechanical aerators provide oxygen and keep the aerobic organisms suspended and mixed with water to achieve a high rate of organic degradation. The increased aeration allows for increased degradation and increased pathogen removal.
	
A free-water surface constructed wetland aims to replicate the naturally occurring processes of a natural wetland, marsh or swamp. As water slowly flows through the wetland, particles settle, pathogens are destroyed, and organisms and plants utilize the nutrients.	An unplanted drying bed is a simple, permeable bed that, when loaded with sludge, collects percolated leachate and allows the sludge to dry by evaporation. Approximately 50% to 80% of the sludge volume drains off as liquid or evaporates.
	
Sedimentation or thickening ponds are settling ponds that allow sludge to thicken and dewater. The effluent is removed and treated, while the thickened sludge can be further treated in a subsequent technology.	A trickling filter, is a biological reactor that operates under (mostly) aerobic conditions. Pre-settled wastewater is continuously sprayed over the filter. As the water migrates through the pores of the filter, organics are aerobically degraded by the biofilm covering the filter material.

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