UN WATER

Analytical Brief

Wastewater Management

A UN-Water Analytical Brief

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Contents

List of abbreviations

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
EU	European Union
FAO	Food and Agriculture Organization
IPPC	Integrated Pollution Prevention and Control
ISO	International Organization for Standardization
MDG	Millennium Development Goal
O&M	Operations and Maintenance
OECD	Organisation for Economic Co-operation and Development
PPP	Public-Private Partnership
SDG	Sustainable Development Goal
SUDS	Sustainable Urban Drainage System
UWWT	Urban Waste Water Treatment
WFD	Water Framework Directive
WHO	World Health Organization

Section 1

Background

As the timeframe for the Millennium Development Goals (MDG) nears completion, minds are turning to the post-2015 development agenda. This is accompanied by the realisation that the focus on drinking-water and sanitation without due attention being paid to the end products of water and sanitation provision (i.e. wastewater) may have exacerbated some of the water quality problems seen globally. It is increasingly being recognized that the issues of wastewater management and water quality have cross-linkages with a range of other water- and non-water issues, not least in respect of the water, energy and food nexus. It has also been acknowledged that wastewater management clearly plays a role in achieving future water security in a world where water stress will increase (OECD, 2012). Against this backdrop, there is an emerging consensus on the need for a dedicated water goal in the post-2015 Development Agenda, one which includes explicit recognition of the importance of good wastewater management and its contribution to protecting water quality.

This report looks at some of the problems caused by the neglect of wastewater management, but also at the benefits and opportunities that can be realized through proper attention to this area, and highlights why it is crucial that wastewater management and water quality stop being the 'poor relations' and receive attention in their own right.

Wastewater can have a number of definitions. The approach taken in this report is a very broad definition following that outlined in the UNEP/UNHABITAT document 'Sick Water?'.

Thus, wastewater is defined as "*a combination of one or more of*:

- *domestic effluent consisting of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater); .*
- *water from commercial establishments and institutions, including hospitals;*
- *industrial effluent, stormwater and other urban run-off;*
- *agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter*" (Corcoran *et al.* 2010).

Although, using this definition, the term 'wastewater' clearly encompasses domestic, commercial, industrial, agricultural components and also faecal sludge, these are sometimes covered separately in order to clarify or highlight the importance of the individual components or wastewater streams.

The report is structured into eight sections. The first two sections provide the context of the report and look, briefly, at why poor wastewater management is a problem. Section 3 builds on the Introduction and sets out the current situation – in terms of water quality issues and considers the main wastewater components (domestic, industrial and agricultural) in turn. Section 4 outlines some of the wastewater management options available and discusses aspects that need to be considered before implementing a system. Section 5 highlights the potential that wastewater has as a valuable resource. Section 6 looks at how wastewater management is being considered in the context of the Post-2015 Development Agenda and section 7 brings together some of the issues that need to be considered in acting upon wastewater management and water quality issues, including the need for strong governance and data gathering. Finally, section 8 presents the conclusions of the report and highlights the need to prioritize wastewater management.

Section 2

Introduction

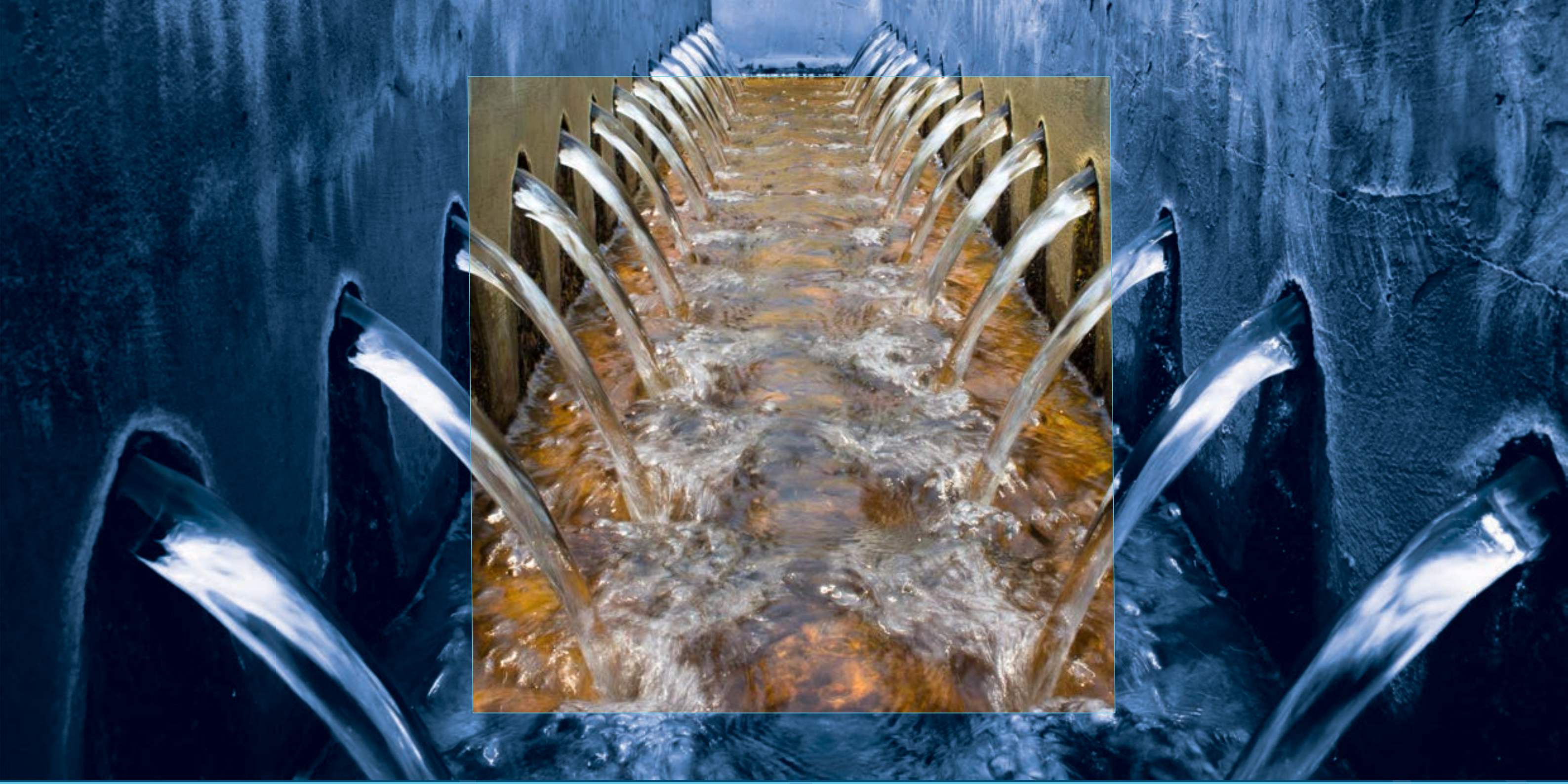
At the beginning of the 21st century, the world faces a water quality crisis resulting from continuous population growth, urbanization, land use change, industrialization, food production practices, increased living standards and poor water use practices and wastewater management strategies. Wastewater management (or the lack thereof) has a direct impact on the biological diversity of aquatic ecosystems, disrupting the fundamental integrity of our life support systems, on which a wide range of sectors, from urban development to food production and industry, depend. It is essential that wastewater management be considered as part of an integrated, full life cycle, ecosystem-based management system that operates across all three dimensions of sustainable development (social, economic and environmental), geographical borders, and includes both freshwater and marine waters (Corcoran et al. *2010). The World Water Forum meeting in March 2012 echoed the problems and the need to bring wastewater to the fore in world water politics and described the existing situation:*

The "…MDG targets on improved sanitation have focused resources on increasing service coverage in terms of access to improved toilet facilities, but with far less attention paid towards ensuring that waste streams are adequately collected and treated prior to discharge into the environment. Worldwide wastewater treatment is failing. … As a result, the majority of wastewaters, septage and faecal sludges are discharged without any form of treatment into the environment … spreading disease to humans and damaging key ecosystems such as coral reefs and fisheries. Dirty water is a key factor in the rise of de-oxygenated dead zones that have been emerging in the seas and oceans across the globe. This is becoming increasingly a global problem as urban populations are projected to nearly double in 40 years, from current 3.4 billion to over six billion people – but already most cities lack adequate wastewater management due to aging, absent or inadequate sewage infrastructure" (World Water Council, 2012).

According to the fourth World Water Development Report, presently only 20% of globally produced wastewater receives proper treatment (UNESCO, 2012). Treatment capacity typically depends on the income level of the country, thus treatment capacity is 70% of the generated wastewater in high-income countries, compared to only 8% in low-income countries (Sato, 2013).

Environmental conditions arising from inadequate or non-existing wastewater management pose significant threats to human health, well-being and economic activity. Efforts to secure access to safe drinking-water and basic sanitation, as guided by the MDG target on drinking-water and sanitation, have been partly hindered by this. It should therefore be recognized as a challenge in the progressive realization of the human right to water and sanitation. Furthermore, the damage done to ecosystems and biodiversity is dire. The Millennium Ecosystem Assessment (2005) reported that 60% of global ecosystem services, on which many social and economic activities depend, are being degraded or used unsustainably, and highlighted the inextricable links between ecosystem integrity and human health and wellbeing.

A paradigm shift is now required in water politics the world over not only to prevent further damage to sensitive ecosystems and the aquatic environment, but also to emphasize that wastewater is a resource (in terms of water and also nutrient for agricultural use) whose effective management is essential for future water security.



Section 3

Current situation

Ignoring wastewater management leads to two principle water quality impacts, namely chemical (and specifically nutrient) contamination and microbial pollution. This section briefly outlines the problems and impacts caused by those water quality issues and then looks at the current situation in respect to the different components making up wastewater (i.e. domestic, industrial and agricultural). It focuses on existing problems and deficiencies that have to be recognized and overcome before real progress can be made. Although the different components of wastewater are considered separately, it is important to note, for example, that industrial and commercial effluents are often mixed with domestic wastewater.

3.1 Wastewater and water quality issues

Wastewater contains a number of pollutants and contaminants, including:

- plant nutrients (nitrogen, phosphorus, potassium);
- pathogenic microorganisms (viruses, bacteria, protozoa and helminths);
- heavy metals (e.g. cadmium, chromium, copper, mercury, nickel, lead and zinc);
- organic pollutants (e.g. polychlorinated biphenyls, polyaromatic hydrocarbons, pesticides); and biodegradable organics (BOD, COD); and
- micro-pollutants (e.g. medicines, cosmetics, cleaning agents).

All of these can cause health and environmental problems and can have economic/financial impacts (e.g. increased treatment costs to make water usable for certain purposes) when improperly or untreated wastewater is released into the environment; nutrient contamination and microbial water quality issues are considered further below.

3.1.1 Nutrient contamination and eutrophication

When water bodies receive excess nutrients, especially nitrates and phosphates, these nutrients can stimulate excessive plant growth – eutrophication - including algal blooms (which may release toxins to the water), leading to oxygen depletion, decreased biodiversity, changes in species composition and dominance, and a severe reduction in water quality. Although there are natural causes, much of the eutrophication seen today is a result of un/inadequately treated wastewater and agricultural run-off.

The deterioration in water quality resulting from eutrophication is estimated to have already reduced biodiversity in rivers, lakes and wetlands by about one-third globally, with the largest losses in China, Europe, Japan, South Asia and Southern Africa. The quality of surface water outside the OECD (Organisation for Economic Co-operation and Development) is projected to deteriorate further in the coming decades as a result of nutrient flows from agriculture and poor/non-existent wastewater treatment, with the number of lakes at risk of harmful algal blooms expected to increase by 20% in the first half of the century (OECD, 2012).

3.1.2 Microbial water quality

Wastewater (domestic wastewater, in particular) can contain high concentrations of excreted pathogens, especially in countries where diarrhoeal diseases and intestinal parasites are particularly prevalent. Table 1 outlines the diseases caused by some of the pathogens that have been found in untreated domestic wastewater.

It can be seen that many of the pathogens outlined in Table 1 cause gastroenteritis and it has been estimated that, globally,1.45 million people a year die as a result of diarrhoeal illness each year, 58% of which is caused by inadequate water, sanitation and hygiene. 43% of the deaths occur in children aged five and below. Infection can result from direct exposure to untreated wastewater but also exposure to wastewater-contaminated drinking-water, food and recreational water.

3.2 Domestic wastewater, stormwater and urban runoff

Domestic wastewater consists of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater). The mix and composition will depend on the water supply and sanitation facilities available, water use practices and social norms. Currently, roughly half of the world's population has no means of disposing of sanitary wastewater from toilets, and an even greater number lack adequate means of disposing of wastewater from kitchens and baths (Laugesen *et al.*, 2010).

The sanitation ladder used for MDG monitoring (Figure 1) illustrates the range of sanitation types, ranging from no sanitation facilities at all (where people practice open defecation) to facilities that have been defined as improved sanitation (WHO/UNICEF, 2008).

Figure 1: Sanitation ladder

UNIMPROVED SANITATION

Open defecation

Open defecation: when human faeces are disposed of in fields, forests, bushes, open bodies of water, beaches or other open spaces or disposed of with solid waste.

Unimproved facilities

Unimproved sanitation facilities: do not ensure hygienic separation of human excreta from human contact. Unimproved facilities include pit latrines without a slab or platform, hanging latrines and bucket latrines.

Shared

Shared sanitation facilities: Sanitation of an otherwise acceptable type shared between two or more households. Only facilities that are not shared or not public are considered improved.

IMPROVED SANITATION

Improved

Improved sanitation facilities: are likely to ensure hygienic separation of human excreta from human contact. They include the following facilities: flush/pour flush to piped sewer system, septic tank, pit latrine; ventilated improved pit (VIP latrina); pit latrina with slab; composting toilet.

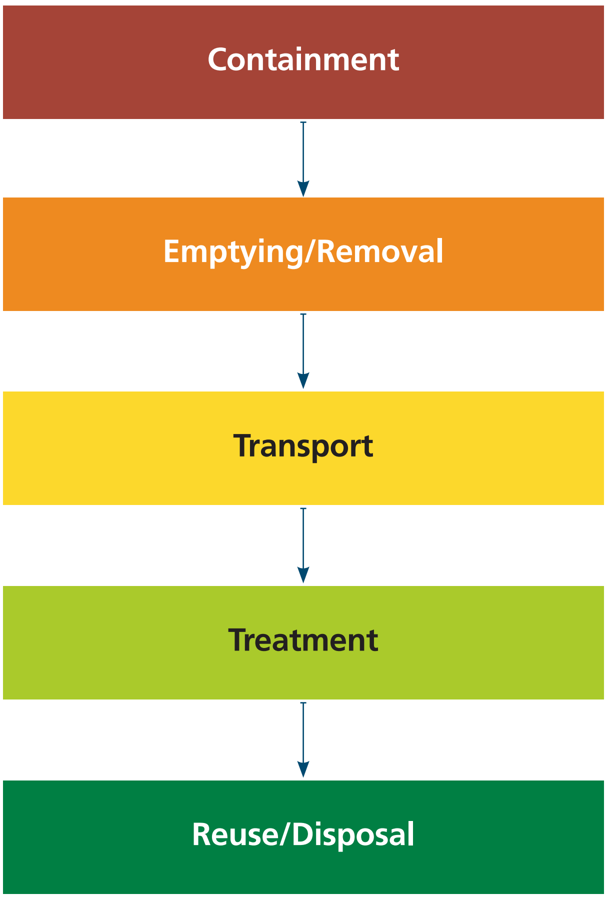
Table 1: Pathogens found in untreated wastewater (adapted from WHO, 2006)

Agent	Disease
Bacteria	
Campylobacter jejuni	Gastroenteritis (possible long term sequelae – e.g. arthritis)
Escherichia coli	Gastroenteritis
E. coli O157:H7	Bloody diarrhoea, haemolytic uremic syndrome
Helicobacter pylori	Abdominal pain, peptic ulcers, gastric cancer
Salmonella spp.	Salmonellosis, gastroenteritis, dairrhoea (possible long term sequelae – e.g. arthritis)
Salmonella typhi	Typhoid fever
Shigella spp.	Dysentery (possible long term sequelae – e.g. arthritis)
Vibrio cholerae	Cholera
Helminths	
Ascaris lumbricoides (roundworm)	Ascariasis
Ancylostoma duodenale and Necator americanus (hookworm)	Hookworm
Clonorchis sinensis (liver fluke)	Clonorchiasis
Fasciola (liver fluke)	Fascioliasis
Fasciolopsis buski (intestinal fluke)	Fasciolopsiasis
Opisthorchis viverrini	Opisthorchiasis
Schistosoma (blood fluke)	Schistosomiasis (Bilharzia)
Trichuris (whipworm)	Trichuriasis
Taenia (tapeworm)	Taeniasis
Protozoa	
Balantidium coli	Balantidiasis (dysentery)
Cryptosporidium parvum	Cryptosporidiosis
Cyclospora cayetanensis	Persistent diarrhoea
Entamoeba histolytica	Amoebiasis (amoebic dysentery)
Giardia lamblia	Giardiasis
Viruses	
Adenovirus	Respiratory disease, eye infections
Astrovirus	Gastroenteritis
Calicivirus	Gastroenteritis
Coronavirus	Gastroenteritis
Enteroviruses	Gastroenteritis
Coxsackie viruses	Herpangina, aseptic meningitis, respiratory illness, fever, paralysis, respiratory, heart and kidney disease
Echovirus	Fever, rash, respiratory and heart disease, aseptic meningitis
Poliovirus	Paralysis, aseptic meningitis
Hepatitis A and E	Infectious hepatitis
Parvovirus	Gastroenteritis
Norovirus	Gastroenteritis
Rotavirus	Gastroenteritis

The example facilities outlined in Figure 1 include both on-site and off-site (sewered) systems. Although improved sanitation facilities are considered to "*likely ensure hygienic separation of human excreta from human contact*", the sanitation ladder currently considers the containment part, of the sanitation service chain (Figure 2), and counts use of facilities at the household level. Future ladders will endeavour to cover the overall function of a sanitation system. Many of the current problems relating to domestic wastewater, particularly in urban and peri urban areas, come from a lack of consideration of the other components of the service chain.

As mentioned above, there are effectively two basic wastewater management systems: on-site (or non-sewered) and off-site (generally sewered with centralised treatment). In sewered systems the removal/transport part of the service chain is performed by the sewer; water washes the waste through a pipe system. This may require the use of pumping stations to ensure that the waste reaches the treatment or disposal point. In on-site systems, waste accumulates on-site in a pit or septic tank, which requires periodic emptying or re-siting; in the case of emptying, waste is taken by road for treatment and/or disposal. Dumping of untreated septic tank/pit contents into rivers, lakes and the sea is, in many low- and middle-income countries, a regular practice.

Figure 2: Sanitation service chain



3.2.1 Sewerage systems

Broadly speaking there are two types of 'conventional' sewerage networks that have been developed and introduced over time; the 'combined' system and the 'separate' system. In the combined system both surface run-off and foul sewage are conveyed in the same pipe, while in the separate system different pipes are used to transport the sewage and the surface run-off. When properly installed, operated and controlled the separate system is most effective, as it reduces the amount of sewage to be treated, avoids the problems of discharges from combined sewer overflows (CSOs) and deals more effectively with periodic and potentially large volumes of urban runoff which occur under storm conditions.

Based on the experiences of industrialized countries, the sewerage systems of a number of developing world cities were designed and built on the separate principle. However, in many cases the separate systems have not been well operated and the control of connections is virtually non-existent, or the system may have been overwhelmed by population growth and the expansion of impermeable surfaces associated with urbanization. So-called separate systems may have many illegal connections of foul sewage made to the surface water system (a situation that also occurs in industrialized countries) and not to the foul or sanitary sewers as intended. Frequently there are also cross-connections and thus, in many cases, separate systems are effectively operating as expensive combined systems. This has implications when collecting (intercepting) and transporting sewage for treatment as, if only discharges from recognized foul sewers are collected, much of the sewage will continue to be discharged (untreated) through the surface water system diminishing the benefit of collection. In China, Li *et al.* (2014) investigated the performance of separate and combined sewer systems in Shanghai and Hefei. They found that serious illicit connections exist in most of the separate sewer systems investigated and showed that, in terms of pollution control, there was no advantage to having a separate system over a combined sewer system.

Effective collection systems are a key for good wastewater management where off-site centralised treatment is chosen; they are also the most expensive element of total capital cost of good operational management. However, throughout the world most places have either no collection systems or systems that are dysfunctional. There are a number of reasons for this which can be briefly summarized as:

- the failure to plan and install collection networks (sewerage);
- old or decaying networks;
- installation of inappropriate systems;
- inappropriate sizing of systems (in relation to the wastewater flows or concentrations);
- inadequate resilience to storm events;
- ineffective operation and inadequate maintenance; and
- ineffective regulation and control of connections.

Ineffective sewerage systems severely limit the ability to quantify the true level of wastewater discharged to the environment. Decaying infrastructure also adds to the problem since broken pipes allow infiltration of water into the sewer network and/or exfiltration of wastewater into the groundwater when the water table is low, causing groundwater pollution and potential cross-contamination of drinking-water supplies.

In addition to 'conventional sewerage', there are two other major types of wastewater sewerage systems, namely simplified or shallow sewerage (also known as condominial) and settled sewerage. Simplified sewerage is characterised by smaller diameter pipes which are buried at a shallower depth than those used in conventional sewerage. Settled sewerage is designed for conveying the effluent component of wastewater after the solids have been settled in, for example, a septic tank.

The presence of a sewerage system, even an effective one, does not guarantee pollution-free disposal of domestic wastewater as, in many cases, the sewage may not be treated prior to disposal. Baum *et al.* (2013) compared the percentage of people with a sewerage connection to the percentage of people with access to both a sewerage connection and wastewater treatment. As can be seen from Table 2, even in high income countries, the presence of sewerage connections does not ensure that all domestic wastewater is treated.

The estimates presented above are still likely to be an overestimate as there may be issues relating to infrastructure falling into disrepair, causing problems such as inoperative pumping stations, leaking pipes and non-functional wastewater treatment works. In India, for example, nearly 40% of sewage treatment plants and pumping stations did not conform to operation and maintenance standards in 2012 (Hawkins *et al.*, 2013). Many treatment plants have also been abandoned (or are not operational) because of lack of funds for operation and maintenance or lack of technical capacity to perform these tasks, especially at the local level and when operated by small water utilities.

Table 2: Global access to sewerage connection and sewerage connection with treatment in 2010 by country income group (adapted from Baum *et al.*, 2013)

Country income level	Percentage of the population with access	
	Connection	Connection & treatment
Low income	3.6	0.02
Lower middle income	12.7	2.0
Upper middle income	53.6	13.8
High income	86.8	78.9

3.2.2 On-site systems

Worldwide, a large number of people rely on on-site systems for their sanitation with, for example, an estimated 2.5 billion people use unimproved facilities as the primary means of sanitation (JMP, 2014). In a study of sanitation services in 12 cities from Africa, South and East Asia (Peal *et al*. in press b), the percentage of the population using on-site or open defecation was found to range from 19% (Tegucigalpa in Honduras) to 100% (in Palu and Dumaguete in Indonesia and the Philippines respectively). In rural areas, on-site systems (such as pit latrines) may effectively operate without the need for formal removal/emptying and transport as the effluent from unlined pits will slowly percolate through soil (although this may contribute to pollution of groundwater) and full latrines can be covered and safely abandoned, with a new pit being constructed elsewhere. This, however, is not possible in urban areas, especially those with high population density (Hawkins *et al.*, 2013). On-site systems may be badly designed, with little or no thought as to how they can be emptied and, as a result, systems are often inaccessible. Where on-site systems are badly managed, faecal sludge can accumulate in poorly designed pits or can overflow and be discharged into storm drains and open water. Where pit emptying services exist they are often unregulated, hence on-site systems may be emptied with the contents often being dumped illegally. Currently, in many developing countries only a small percentage of faecal sludge is managed and treated to an appropriate level (Peal *et al.*, in press a).

In their study of on-site systems and faecal sludge management, Peal et al. (in press b) noted a number of key findings, including:

- The quality of household containment is generally poor and adversely affects owners' ability to empty their pits. Such poor quality pits are often unsafely abandoned.
- Illegal dumping by private manual and mechanical pit emptiers into watercourses, waste ground and landfill sites was common in most cities.
- Municipalities and utilities rarely provide pit emptying and transport services; these are usually provided informally by the private sector.
- There is a general lack of sludge treatment facilities; where treatment facilities do exist they are generally combined with sewage treatment. Often sludge is simply dumped into an existing wastewater treatment plant, which may negatively impact on the treatment of the waterborne sewage.

Part of the reason for the poor performance of on-site systems, which can work well and are often the most appropriate choice of wastewater management system, is the notion in many places that on-site systems are a temporary or stopgap solution (before the provision of sewerage) and mainly for illegal or informal settlements (Peal *et al.,* in press b). A lack of supporting capacity for operation and maintenance may aggravate this situation.

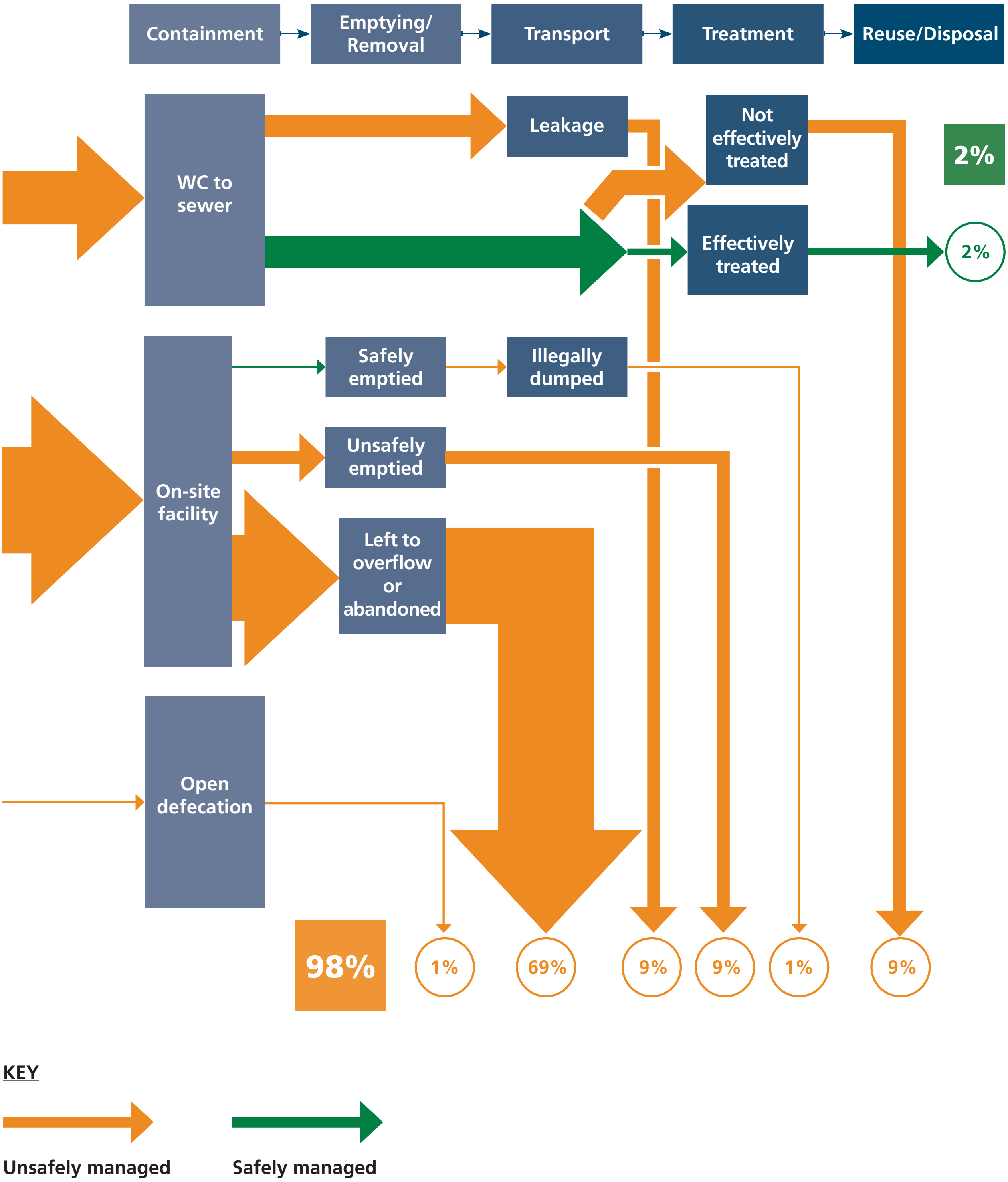
In terms of on-site systems "*the safe collection and treatment of faecal sludge … is arguably the weakest link in the sanitation chain*" and it has been estimated that 2.4 billion users of on-site sanitation systems generate faecal sludge that goes untreated (Muspatt *et al.*, in press).

3.2.3 Mixed provision

As noted by Hawkins *et al*. (2013) many towns and cities, especially in developing countries, have a mixture of on- and off-site sanitation facilities and services. These may be provided by householders, by developers or by the municipality or utility. The poor sanitary conditions experienced in many towns and cities around the world and the problems relating to badly managed and inadequate on-site and off-site sanitation systems can be illustrated using a faecal waste flow diagram (developed by Peal *et al.*, in press a/b), which illustrates the different pathways that faecal waste takes along the sanitation service chain. Figure 3, illustrates the problems seen in Dhaka in Bangladesh, where 20% of faecal waste is sewered and 79% goes to on-site containment.

The data behind Figure 3 are based on the estimated populations falling into each category of service. As there was a lack of primary data, there was a heavy reliance on secondary sources and partial analyses of the system (Peal *et al.*, in press a).

Figure 3: Faecal waste flow diagram – Dhaka, Bangladesh (Peal *et al.*, in press a)



Width of the bars represents the proportion of faecal waste at each step in the chain; orange shading represents unsafe management; green shading represents effective management

It can be seen from Figure 3 that in Dhaka a large percentage of faecal waste is generated in on-site systems. It is also clear that only a tiny percentage (2%) of the waste generated is treated adequately prior to disposal.

For a long time, the main focus relating to wastewater treatment has been (and often still is) on construction of facilities and not on their operation and maintenance (Starkl *et al.,* 2013a), a focus that has contributed to many of the problems highlighted in Figure 3, especially in relation to the sewered component (comprising 20% of the total faecal waste).

A slightly better picture is seen in Maputo (Mozambique), where 26% of faecal waste is safely managed, although there is a lack of hygienic de-sludging services and in most cases (an estimated 60% of non-sewered households) latrines are emptied by the users or small contractors, with the sludge often being buried in the user's backyard, dumped into the stormwater drainage system or in skips designed for the collection of solid waste (Peal *et al.,* in press a).

3.2.4 Urban drainage and stormwater flows

It is not only systems for the collection of domestic, commercial and industrial wastewaters that are of concern. Surface water run-off and stormwater drainage from paved areas in towns and cities is a major problem for a number of reasons. In addition to the potential hazards from flooding resulting from insufficient coverage and capacity of stormwater drainage, serious health problems often arise with open channel surface water drains in developing world towns and cities where there is an absence of 'foul' or 'sanitary' sewers. Unfortunately these open channels also collect wastewater and garbage which become a health hazard through direct contact. However, there is another major problem as these open channels are frequently used by slum dwellers to run pipelines from illegal water distribution connections to local households; in places where there is inadequate power supply and frequent outages, distribution pressure can fall and wastewater can be 'back-siphoned' into the distribution system through the illegal pipelines which are frequently full of holes. This can lead to serious and widespread health problems.

Another problem that affects both the developing and developed world is the pollution load from urban surface waters. This can be considerable, especially during the "first flush" following a dry period when spillages and drips of fuel and oil and also dust and other pollutants accumulate on road surfaces along with general rubbish. Not only does this impose high organic loads that de-oxygenate watercourses, but also much of the polluting load is toxic. This situation is likely to be further exacerbated by the impacts of increasingly frequent extreme weather conditions linked to the process of climate change. Over the years, techniques under the general heading of Sustainable Urban Drainage Systems (SUDS) have been developed to mitigate the effects of storm flows. These systems introduce decentralized storage facilities such as lagoons, wetlands, storage tanks and the use of permeable paving materials to hold back surface water flows, thus relieving the initial high flow problems which often results in flooding. Suitably designed SUDS systems can also minimise pollution and can even be designed to introduce attractive water features and civic amenities, some of which become fishing lakes and bird sanctuaries.

3.3 Industrial wastewater

Among the possible classifications of industrial wastewaters, one distinguishes between diffuse industrial pollutants, such as those from mining and agri-industries, and end-of-pipe point discharges and mostly illegal discharges from tankers. The former are frequently highly polluting and difficult to contain and treat, while the latter can be contained, controlled and treated in circumstances where there is sufficient political will, regulatory power and resources (economic and human capacity) to ensure compliance. Large end-of-pipe discharges are generally easy to identify and can be regulated, controlled and treated. However, some wastewaters arise from concentrations of small enterprises that discharge wastewaters wherever they can and not necessarily to any identifiable sewer. Many are highly polluting containing acids and toxic metals from, for example, small metal finishing (plating) enterprises which have developed in specific localities. Not only do such discharges inflict considerable environmental damage especially to sensitive ecosystems but they also often come into direct (as well as indirect) contact with humans and animals with consequent damage to health.

The discharge/disposal of industrial wastewaters can be classified as follows:

- Uncontrolled discharges to the environment.
- Controlled (licensed) discharges to the environment (watercourses) possibly after pre-treatment.
- Illegal, mostly clandestine, discharges to sewerage systems.
- Controlled discharges to sewerage systems under agreement or licence, possibly with pre-treatment.
- Wastewaters collected by tanker for treatment/disposal elsewhere.

It is important to note that, in many cases, large volumes of industrial wastewaters which are legally discharged to decaying and/or badly operated sewerage networks, both combined and separate, never actually reach a treatment plant. Much is lost en-route through broken pipes or ends up in surface water drains with consequential pollution of both groundwater and surface watercourses.

It is estimated that 5-20% of total water is used by industry (UNESCO, 2009). The global situation relating to the control of industrial wastewater varies from 'highly effective' to virtually 'non-existent'. Generally speaking, 'highly effective' control has been developed over long periods and is grounded within sound institutional and legal frameworks, and due consideration has been given to both environmental protection and the requirements of industrial processes. By contrast, much of the world has little or no institutional or legal provision or fails to enforce that which might exist. It is estimated that 70% of industrial discharges in developing countries is dumped untreated (UNESCO, 2009). Many countries even lack a basic register of industrial discharges and are thus unable to quantify the problem aside from describing it as 'bad' or 'severe' or some other relative term. The number of places where industries discharge highly toxic substances using processes that are no longer used in other parts of the world raises great concern.

Various approaches to effective industrial wastewater control are available such as the use of appropriate technology (specified, for example, as the best economically available) or the issuing of 'permits' or 'consents' based on volumes and quality standards for discharges either to sewers or directly to watercourses. In some countries (e.g. United States) pre-treatment standards apply to all industrial users wishing to discharge to the sewerage system (to control pollutants that may pass through or interfere with the treatment works processes or which may contaminate the sewage sludge). In others each discharge is treated on its own merits irrespective of its general type or classification, and standards are set according to the nature and condition of the receiving water. Normally standards include numerical limit values for chemicals, solid materials, temperature, pH and the like, while some substances are banned completely. There are various 'red list' or 'priority pollutants' that fall into this category such as arsenic, mercury and cadmium and their compounds, cyanides, selected pesticides and a multitude of complex organic compounds. In 1982 the European Community issued a list of 129 priority substances (later updated to 132) and the list is currently under review in the implementation of the EU Water Framework Directive (2000/60/EC); other countries have similar lists. Some approaches complement those outlined above by considering economic instruments such as wastewater charges or tradable permits. In the UK industrial effluents discharged to public sewers, by agreement, are subject to a financial charge according to a formula that estimates the cost of collection and treatment. Thus the costs of industrial production are not externalized to the environment, or to the taxpayer.

Highly effective control can be observed in the developed world and improvements continue with time. In many cases, the key to success is a clear allocation of responsibilities for wastewater management or the formulation of precise definitions (supported by effective control and monitoring systems) for discharge of wastewater into the environment or sewage systems.

As described in the EU Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) and the Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC), the 'polluter-pays' has become a guiding principle among these countries followed by laws and regulations designed and enforced to implement it. Such legal systems not only define industry's obligations to

Table 3: Agricultural impacts on water quality (adapted from FAO, 1996)

Agricultural activity	Impacts	
	Surface water	Groundwater
Tillage/ploughing	Sediment/turbidity: sediments carry phosphorus and pesticides adsorbed to sediment particles; siltation of river beds and loss of habitat, spawning grounds etc.	
Fertilising	Runoff of nutrients, especially phosphorus, leading to eutrophication causing taste and odour in public water supply, excess algae growth (leading to deoxygenation of water and fish kills) and, in some reservoirs, the development of potentially toxic algal blooms.	Leaching of nitrate to groundwater
Manure spreading	Carried out as a fertilizer activity; if done under inappropriate conditions can result in high levels of contamination of receiving waters by microorganisms, metals, phosphorus and nitrogen leading to eutrophication and potential contamination.	Contamination of groundwater, especially by nitrogen
Pesticides	Runoff of pesticides (including insecticides, herbicides, fungicides and bactericides etc.) leads to contamination of surface water and biota; dysfunction of ecological system in surface water by loss of top predators due to growth inhibition and reproductive failure; public health impacts from eating contaminated fish.	Some pesticides may leach into groundwater causing human health problems from contaminated wells
Feedlots/animal corrals	Contamination of surface water with microorganisms and residues of veterinary drugs, contamination by metals contained in urine and faeces.	Potential leaching of nitrogen, metals etc. to groundwater
Irrigation	Runoff of salts leading to salinization of surface water; runoff of fertilizers and pesticides to surface waters with ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can occur with serious ecological damage and potential human health impacts.	Contamination of groundwater with salts and nutrients (especially nitrate)
Clear cutting	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat etc. Disruption and change of hydrologic regime, often with loss of perennial streams and decreasing flow in dry periods; concentration of nutrients and contaminants; causes public health problems due to loss of potable water.	Disruption of hydrologic regime, often with increased surface runoff and decreased groundwater recharge
Silviculture	Broad range of effects: pesticide runoff and contamination of surface water and fish; erosion and sedimentation problems.	
Aquaculture	Release of pesticides (e.g. tributyltin) and high levels of nutrients to surface water and groundwater leading to serious eutrophication.	

treat wastewater in compliance with regulations but also generate economic and financial incentives, help internalize the cost of wastewater treatment, encourage savings of energy and resources and introduce cleaner production processes.

3.4 Agricultural wastewater

Agriculture has long been recognized as an important source of non-point or diffuse water pollution. Key problems include:

- Sediment runoff – this can cause siltation problems and increase flood risk;
- Nutrient runoff – nitrogen and phosphorus are key pollutants found in agricultural runoff, they are applied to farmland in several ways, including as fertilizer, animal manure and municipal wastewater, and can result in eutrophication in receiving waters;
- Microbial runoff – from livestock or use of excreta as fertilizer (domestic animals, such as poultry, cattle, sheep and pigs, generate 85% of the world's animal faecal waste – Dufour *et al.,* 2012);
- Chemical runoff from pesticides, herbicides and other agrichemicals can result in contamination of surface and groundwater; in addition residues of veterinary drugs may also cause water pollution.

Table 3 outlines the agricultural impacts on water quality. In addition to its polluting properties, agriculture is also the single largest user of freshwater resources, accounting for almost 70% of global water withdrawals (FAO, 2012b).

Conventionally, in most countries, all types of agricultural practices and land use (including animal feeding operations) are treated as non-point source or diffuse pollution and, in OECD countries, agricultural non-point pollution has overtaken contamination from point sources as the major factor in inland and coastal eutrophication (FAO 2012a). Table 4 shows the relative contribution of different agricultural production systems to non-point source pollution, although it does not consider the use of human and animal wastes as fertiliser, or the application of wastewater irrigation.

The main characteristics of non-point source pollution are that it responds to hydrological conditions and is not easily measured or controlled directly (meaning the regulation is difficult); hence, for control, the focus must be on land and related management practices (FAO, 1996). The impact of hydrological conditions on agricultural pollution is illustrated by the pulses of contamination (microbes, nitrogen, phosphorus and pesticides) seen from field runoff and farmyards during rainfall events (Neumann *et al.* 2002; Edwards *et al.* 2008).

Although the impact of agriculture on water pollution (relative to other types of human impacts) has not been extensively researched and monitoring of agricultural pollution is uncommon, it is recognized that the problem is global. In OECD countries, agriculture is the main source of nitrogen loading (OECD, 2012). In the United States, for example, agricultural non-point source pollution was found to be the leading source of water quality impacts, the second largest source of impairment to wetlands and a major contributor to contamination of estuaries and groundwater (USEPA, 2002).

Table 4: Relative contribution of agricultural production systems to non-point source pollution (FAO 2012a)

	Nutrients	Salts	Sediments	Pesticides	Pathogens	Organic carbon	Drug residues
Crop production	***	***	***	***	-	*	-
Livestock	***	*	***	-	***	***	***
Aquaculture	**	*	-	-	*	**	**

In England, nitrate concentrations in water draining from much of the agricultural land are high, especially in arable systems, which amply explains the high nitrate concentrations seen in many surface and ground waters (ADAS, 2007). While not solely attributable to agricultural pollution, nitrate is the most common chemical contaminant in the world's groundwater and aquifers, and the mean nitrate concentrations have increased in the last decade in watersheds around the world (UNEP, 2010). A comparison of domestic, industrial and agricultural sources of pollution from the coastal zone of Mediterranean countries found that agriculture was the leading source of phosphorus compounds and sediment (UNEP, 2010). In China, agriculture is extremely polluting and is responsible for over 40% of the nation's chemical oxygen demand, for 67% of phosphorus and 57% of nitrogen discharges, with significant over-use of fertilizers pin-pointed as one of the major problems (Watts, 2010). In Argentina, up to 50 groundwater wells (both shallow and deep) in suburban areas of Mar del Plata were analysed for a number of selected pollutants (Massone *et al.* 1998): the wells located in an area known for its horticultural activity were found to be contaminated with lindane, heptachlor and nitrate. In Morocco, agricultural practices cause serious nitrate pollution in some areas of the country (Tagma *et al.,* 2009).

Section 4

Wastewater management

The previous section highlighted the current situation and how untreated or inadequately treated wastewater can cause problems. This section briefly outlines some of the (domestic) wastewater management options available and aspects that need to be considered when implementing a wastewater management approach.

Wastewater management should consider the sustainable management of wastewater from source to re-entry into the environment ('reuse/disposal' in the sanitation service chain) and not only concentrate on single or selected areas or segments of the service provision process. Many of today's poorly thought-out and badly managed systems (section 3) overload natural processes that purify water and maintain soil structure. It is clearly important to design wastewater management systems that "*work with rather than against natural ecosystem processes*" (Laugesen *et al.*, 2010) and, thus, understanding these processes before designing infrastructure/artificial systems is fundamental for choosing a sustainable wastewater management approach.

Different management approaches are required depending on whether the area is urban or rural, the size and density of the population, level of economic development, technical capacity and system of governance in place. Approaches can also vary according to the quality required for end users or that required for safe disposal and thus "*wastewater management should reflect the community and ecological needs of each downstream ecosystem and user*" (Corcoran *et al.*, 2010).

There are many different wastewater management approaches available (see, for example, the EAWAG Compendium of sanitation systems and technologies – Tilly *et al.*, 2008) but, as noted by Laugesen et al. (2010), understanding the receiving environment is crucial for technology selection and Massoud *et al.* (2009) recommend that this should be accomplished by conducting a comprehensive site evaluation process that determines the carrying capacity of the receiving environment; this could be done as part of an environmental impact assessment that could help to identify preventative or remedial measures.

4.1 Centralised versus decentralised

Wastewater management can be conducted through centralised systems (which are large-scale systems that gather wastewater from many users for treatment at one or few sites) or decentralised systems (typically on-site systems, dealing with wastewater from individual users or small clusters of users at the neighbourhood or small community level). Traditionally, much of the urban wastewater management in developed countries has relied on centralised systems. Industrial effluent in developed countries is generally treated on-site, although some may also be sent to centralised municipal systems following pre-treatment on-site (UNEP, 2010).

The choice between centralised (sewered) or decentralised (on-site/neighbourhood-level) wastewater management systems will depend upon a number of factors, but it is important that full consideration be given to both options rather than the situation that has existed in the past where sewerage is often considered to be the only 'proper' form of urban sanitation (Hawkins et al., 2013). The flip side of this mindset is that on-site systems are often seen as temporary or stopgap solutions and primarily for illegal or informal settlements, which may then be reflected in local building regulations and/or technical standards which fail to specify appropriate on-site systems but are based on the assumption that new housing will be provided with networked sewerage (Peal et al. in press b).

Whichever approach is preferred, there needs to be an emphasis on continued management aspects; no system has the capability to be 'fit and forget'. There is a need for appropriately trained staff and capacity (financial, technical etc.), irrespective of wastewater management system. Traditionally the operation and maintenance of many on-site systems has been left to homeowners or local authorities, leading in many cases to system failure due to lack of, or improper, maintenance. The effectiveness of the decentralised approach could therefore be improved by an enforced regulatory framework that includes incentives and sanctions and the establishment of a management program that ensures the regular inspection and maintenance of the system (Massoud et al., 2009).

4.2 Treatment

The aim of treatment is to reduce the level of pollutants in the wastewater before reuse or disposal into the environment, the standard of treatment required will be location and use-specific. The year 2014 marks the centenary of the publication of the seminal paper on activated sludge which provided a basis to treat sewage by biological means (Ardern and Lockett, 1914). Since then there have been extensive developments in both scientific knowledge and processes to treat wastewaters of all types. There are now many aerobic, anaerobic and physico-chemical processes that can treat wastewaters to almost any standard of effluent from the simple removal of gross solids to membrane systems that can produce drinking water quality (these are summarized in broad terms in Appendix 1). They vary from the very simple to the highly complex and each has its own characteristics in terms of efficiency, reliability, cost, affordability, energy consumption, sludge production, land requirements and so on. Treatment strategies range along a continuum from high technology, energy-intensive approaches to low-technology, low-energy, biologically and ecologically focused approaches (UN Water, 2011). Starkl et al. (2013b), for example, explored the potential of natural treatment technologies (i.e. those based on natural processes that use attenuation and buffering capacity of natural soil aquifer and plant-root systems, where the process of contaminant removal is not aided by the input of significant amounts of energy and/or chemicals) including waste stabilization ponds, duckweed and hyacinth ponds and constructed wetlands for wastewater management in India. In an examination of 12 cases they found that performance varied widely and that institutional and organizational issues were very important for sustainable system operation.

4.3 Locally appropriate

Wastewater management systems need to be locally appropriate, a point that was alluded to above. The choice of approach and technologies within that system should be context-specific and needs to be made based on the local environment (temperature, rainfall), culture and resources (human, financial, material and spatial). Although sewerage and centralised wastewater treatment can be a good option, it is important that it is not seen as the default position and something to be aimed for irrespective of environment and resources. As noted by Massoud et al. (2009) "given the huge differences between developed and developing countries in political structures, national priorities, socioeconomic conditions, cultural traits and financial resources, adoption of developed countries strategies for wastewater management is neither appropriate nor viable for [many] developing countries."

The 2006 WHO Guidelines recognize this reality and provide flexibility for countries to adopt a combination of treatment and non-treatment options in order to manage health risks and progressively improve over time.

Section 5

Wastewater as a resource

Reuse of wastewater already happens although, currently, in many locations this is largely on an unplanned/indirect basis, resulting from the use of water (e.g. for irrigation) that has been contaminated with untreated or poorly treated wastewater (i.e. driven by poor wastewater management). It is recognized, however, that there needs to be a move towards more planned use (Drechsel et al. *2010) and a reframing of wastewater from being a problem to be 'disposed of' to being a resource to be valued and exploited. Although planned and direct wastewater use is currently practiced in some places, it has been said to need "a change of mindset" before such water reuse becomes a mainstream option (Anon, 2011).*

Wastewater can act as a:

- drought-resistant source of water (especially for agriculture or industry);
- source of nutrients for agriculture;
- soil conditioner; and
- source of energy/heat.

However, in order to gain public acceptance and maximize benefits of reuse while minimizing negative impacts, health risks of reuse need to be assessed, managed and monitored on a regular basis.

The scale of reuse can range from individual households practicing ecological sanitation (where urine is separated from faecal matter at source and then diluted and applied directly to plants, while the faecal matter is stored [composted] until it is safe for land application) to major urban irrigation systems or biogas production. Planned wastewater use varies on a country-by-country basis and Sato *et al.* (2013) has noted that wastewater use in Europe differs somewhat by geography (with climate playing an important role). In southern Europe, for example, reclaimed wastewater is used predominantly in agricultural irrigation (44% of projects) and urban or environmental applications (37% of projects), while in northern Europe environmental applications predominate (51%). Spain illustrates multiple uses of reclaimed wastewater with 71% of reclaimed supplies used for irrigation, 17% for environmental applications, 7% for recreation, 4% in urban reuse and less than 1% for industrial purposes (Sato *et al.* 2013).

Table 5: Composition of raw wastewater for selected countries (Hanjra *et al.*, 2012)

Parameters (mg/l)	USA	France	Morocco	Pakistan	Jordan
Biochemical oxygen demand	110-400	100-400	45	193-762	152
Chemical oxygen demand	250-1000	300-1000	200	83-103	386
Suspended solids	100-350	150-500	160	76-658	-
Total potash and nitrogen	20-85	30-100	29	-	28
Total phosphorus	4-15	1-25	4-5	-	36

While there are a number of possible uses, agriculture is the principal user of reclaimed water, with use for this purpose reported in around 50 countries (FAO, 2010). Various figures are quoted on the extent of agricultural irrigation with reclaimed wastewater, with estimates ranging between 20 million to 45 million hectares worldwide (Sato *et al.*, 2013).

Wastewater (in the sense of the effluent) is composed of 99% water and 1% suspended, colloidal and dissolved solids. Municipal wastewater contains organic matter and nutrients (nitrogen, potassium and phosphorus), inorganic matter and dissolved minerals, toxic chemicals and pathogenic microorganisms (Hanjra *et al.*, 2012). The composition of typical raw wastewater (Table 5) depends on the socioeconomic characteristics of the residential communities and number and types of industrial and commercial units.

Drought resistant source of water

The use of reclaimed wastewater in agriculture can provide a reliable source of irrigation water for farmers. Cities have been described as 'sponges' soaking up water from other areas (Amerasinghe *et al.*, 2013) and, as noted in FAO (2010), at times of scarcity, authorities often divert water from farmers to cities as water used for urban and industrial purposes tend to have a higher economic value than that used for most agricultural purposes and, obviously, supplies for human consumption take priority over other uses. In developed countries, wastewater is often used to irrigate non-agricultural land, such as parks, golf courses and highway verges or to replace drinking water used for toilet flushing.

Source of nutrients

Wastewater is nutrient-rich and can reduce the need for the application of chemical fertilizers. Phosphorus, for example, is essential to all life and is a key component of fertilizers. The main source of phosphorus (phosphate rock) is non-renewable and is becoming increasingly expensive. Human faeces, however, contains about 0.5% phosphorus by weight and recovery/reuse could improve phosphorus security and reduce pollution (Cordell *et al.*, 2011).

Source of energy/heat

Anaerobic digestion is a bacterial decomposition process that stabilises organic wastes and produces a mixture of methane and carbon dioxide (known as biogas), which is a valuable energy source. Anaerobic digestion is usually carried out in a specially built digester and is common at some wastewater treatment works. The use of faecal sludge as a fuel has also been investigated in developing countries. Muspratt *et al.* (in press), for example, collected sludge samples from pit latrines, septic tanks, drying beds and stabilization ponds from Ghana, Uganda and Senegal for the determination of calorific value. The average calorific value of the sludge was 17.3 MJ/kg total solids which compares well with other biomass fuels, although partial drying of the sludge was required.

Soil conditioner

When faecal solids are properly treated and of good quality they can be used on agricultural land or gardens as a soil conditioner/fertilizer and are often termed 'biosolids'. Soil conditioner may be produced on a variety of scales from municipal wastewater treatments plants down to individual households practicing ecological sanitation.

5.1 Challenges

Wastewater has been described as both "a resource and a problem" (Hanjra *et al*., 2012), as such the challenges relate to maximizing the resource potential and minimizing the problems. Some of the challenges in relation to the use of reclaimed water for irrigation are outlined in this section.

Potential problems principally relate to the presence of toxic chemicals (from industrial sources of effluent) and the presence of pathogenic microorganisms. Irrigation with even treated wastewater can lead to excess nutrients, pathogens, heavy metals and salts building up on the irrigated land, unless care is taken. The separation of industrial and domestic wastewater will facilitate the likelihood of safe reuse (Qadir *et al.*, 2010) from a toxic chemical standpoint. Amerasinghe *et al.* (2013) showed that in India there were financial benefits associated with wastewater farming compared to freshwater agriculture, but only where domestic wastewater was not mixed with industrial sewage.

Wastewater can be treated to minimise the risks from pathogenic microorganisms. Existing WHO guidelines (WHO, 2006) promote an integrated risk assessment and management approach along the chain from the wastewater source to the consumption of produce grown with wastewater (or excreta). This approach is similar to the water safety planning approach promoted for drinking-water supply (from source to tap). Where wastewater treatment is not available or is insufficient to reduce risks to acceptable levels, additional risk mitigation measures, such as appropriate crop choice, irrigation type and protective clothing for farmers can be implemented to protect public health (WHO, 2006). Although, as Qadir *et al.* (2010) point out, many farmers and consumers are unaware of the potential negative health impacts of wastewater and suggest that public programmes informing farmers and consumers about health impacts and mitigation measures could be a valuable public health measure.

Perception of water quality and also control over irrigation choices may play an important role in the acceptability of the use of wastewater in agricultural irrigation. In Greece, farmers were more willing to use reclaimed water when it was referred to as recycled water rather than treated wastewater (Menegaki *et al.*, 2009). In Jordan, for example, farmers who had no control over the use of treated wastewater (i.e. indirect use, through its provision in rivers) had a more negative perception of the water and its quality than farmers choosing to adopt direct reuse (Carr *et al.*, 2011).

Plant nutrients in wastewater may not be present in the ideal concentration for direct crop production and meeting one nutrient requirement may lead to an imbalance in another nutrient level. It has been determined that wastewater can meet about three quarters of the fertilizer requirements of a typical farm in Jordan, but excess nutrients have also been found to reduce productivity, depending upon the crop (Hanjra *et al.*, 2012). It is likely that farmers would use the nutrient content of reclaimed water more effectively if they had better information about crop requirements and also nutrient levels in the wastewater and in the soil (Qadir *et al.*, 2010). The lack of information on nutrient levels can lead farmers to combine nutrient-rich irrigation water with chemical fertilizers (Corcoran *et al.*, 2010).

An additional challenge is presented by the cross-cutting nature of wastewater management, where collaboration and dialogue are required between partners who may not traditionally talk to each other, including farmers, public health officials, municipal and waste managers, water utilities, regulatory agencies, environmental authorities, planners and developers (Corcoran *et al*., 2010).

Section 6

Wastewater management in the Post-2015 Development Agenda

Given the importance of good wastewater management and the urgent need to address this on a global basis, it is refreshing that its importance is, increasingly, being recognized, not least by recommendations for its specific inclusion in the future sustainable development agenda after 2015.

In 'The Future We Want', the outcome document of the United Nations Conference on Sustainable Development (Rio de Janeiro, Brazil, June 2012), United Nations Member States clearly highlighted the importance of good management of wastewater to support the future sustainable development agenda.

The following year, in May 2013, the Secretary-General's High-Level Panel of Eminent Persons on the Post-2015 Development Agenda released its report, which provides recommendations on advancing the development framework beyond the target date for the Millennium Development Goals (MDGs). In its report, the High-Level Panel presents, among others, an illustrative goal on water and sanitation, including a target on wastewater management.

Meanwhile, between the end of 2012 and the beginning of 2013 the United Nations Department of Economic and Social Affairs (UN-DESA) and the United Nations Children's Fund (UNICEF) facilitated, under the umbrella of UN-Water, the World We Want 2015 Water Thematic Consultation co-hosted by the Governments of Jordan, Liberia, Mozambique, the Netherlands and Switzerland. As a part of the Water Thematic Consultation, discussions on wastewater highlighted the options and opportunities in wastewater management as an untapped resource.

In June 2013 the Sustainable Development Solutions Network released its report 'An Action Agenda for Sustainable Development' in which wastewater management is included at the indicators level.

Building on the lessons learned from the MDG implementation and monitoring as well as on the water dialogues in selected countries, UN-Water conducted broad inclusive consultations and consolidated the experience and expertise of the UN system into a technical advice on a possible water goal in the Post-2015

Figure 4: Components of the proposed global goal for water (UN-Water, 2014)

Development Agenda (UN-Water, 2014). This technical advice recognises that there are a number of interrelated water issues, which need to be addressed coherently internally in the water sector, as part of management of the water cycle, but also linking out to other sectors (Figure 4). Wastewater management is therefore one of five proposed inter-linked target areas.

Building on all the inputs above, in July 2014 after eighteen months of consultations the Open Working Group (OWG) on Sustainable Development Goals released its proposal for Sustainable Development Goals. The OWG had been established by the UN General Assembly in January 2013 as mandated in the Rio+20 outcome document. The OWG was co-chaired by Hungary and Kenya and comprised 30 'seats' shared by several Member States in an innovative rotational procedure. The OWG proposal introduces, among others, a goal on ensuring availability and sustainable management of water and sanitation for all, including a specific target on improving wastewater management.

At the time this Analytical Brief was finalized, Member States were agreeing on the calendar of negotiations in preparation for the summit in New York in September 2015 where Member States are expected to adopt the Post-2015 Sustainable Development Agenda. The exact architecture of this agenda depends on the outcome of the Member States' negotiations.

Section 7

Challenges for implementing effective wastewater management

While there is clearly a need to act to put in place effective and appropriate wastewater management and reuse systems, implementation of strategies is not necessarily straightforward and there are a number of issues (such as governance, financial aspects, barriers to innovation and data needs) that require addressing; this section outlines aspects of these issues, using case study examples to illustrate points.

7.1 Strong governance

There is a need for strong and effective governance; without regulations backed up by monitoring, control and enforcement, there is little incentive to act. In the UNEP document 'Clearing the waters' (UNEP, 2010) the central role of governance is stressed with the statement "*there is a water crisis, and there is an increasing understanding that it is a crisis of governance rather than one of physical scarcity*". It is also noted that "*the lack of good governance, including ineffective policies, enforcement, and institutions; corruption; and the lack of appropriate infrastructure, along with a shortage of new investments in building human capacity, all contribute to ongoing water quality problems. Weak institutions, inadequate water quality policies and regulations, and limited enforcement capacity underlie many water quality problems worldwide*". This clearly highlights a number of issues, including the problems caused by a lack of human and institutional capacities. With the best will in the world, if countries lack the necessary human, technical, financial and institutional capacities they will be unable to meaningfully implement policies, as they will lack the capabilities to measure and monitor water quality parameters and identify violations and thus will be unable to enforce compliance.

The need for governance is recognized in the proposed UN-Water goal (section 6), with the target '*all countries strengthen equitable, participatory and accountable water governance*', which aims to promote an enabling environment such that institutional structures relevant to water are effective and that their administrative systems function for the benefit of society as a whole. The governance target underpins all the other water targets and supports linkages to other development themes (UN-Water, 2014).

It is helpful, however, if policies and regulations are harmonized. Kvarnström *et al.* (2011) highlight the problem when regulations and policies are not coherent. In South Africa, for example, they note that the White Paper on Sanitation (passed in 2001) is based on principles rather than technology, which allows for innovative and appropriate solutions to be adopted. The National Building Regulation, however, is not function-based and thus specific options tend to be prescribed (such as the compulsory connection of buildings to sewers), essentially cancelling out the flexibility to implement alternatives.

The problems caused by a lack of clear, well-thought out policy backed by appropriate and enforced regulation are illustrated by the case study below.

Case study 1: Faecal sludge management in Burkina Faso

Currently, there is no management or treatment of the faecal sludge from on-site systems in Burkina Faso, and the legal framework only weakly addresses these aspects. A decree sets the basic conditions for the collection of faecal sludge from on-site systems, along with its end use or disposal, and the 'Code of Public Hygiene' defines municipalities to be responsible for the provision of sanitation services and prohibits the spreading of faecal sludge in agricultural fields. There are a number of stakeholders currently offering collection and transport services, although there are no faecal sludge treatment plants. Stakeholders in charge of collection, transport, treatment and end use/disposal are not defined in official documents and, as such, the businesses offering collection and transport services are not regulated, and are not considered to be legitimate by the authorities. An institutional analysis showed that faecal sludge management is the overlapping responsibility of a number of government departments and there is a lack of coordination and no clear demarcation of responsibility between departments (Bassan *et al.*, 2013).

The establishment of specific, binding water quality standards is an indispensable prerequisite for efforts to improve water quality by increasing accountability for implementation of water quality monitoring and pollution-control measures (UNEP, 2010). Case studies 2 and 3, outlined below, illustrate two approaches to wastewater monitoring and pollution control; both are simple in principle, have monitoring and reporting requirements, have procedures to ensure operational efficiency, have been successfully implemented and both have financial incentives to ensure compliance with the required standards.

Case study 2: International experiences in wastewater monitoring and pollution control - European Union

The EU Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) was adopted in May 1991 with specific deadlines for implementation of the various measures. The Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC) is also in operation and is aimed principally at industrial discharges. Effective pollution control requires that both Directives be considered together.

The UWWT Directive lays down minimum standards to be met by effluents based on population equivalent, with different standards for discharges into 'sensitive' and 'non-sensitive' areas. The term sensitive area covers regions where eutrophication is a problem, or a potential problem. In addition to defined standards there are minimum sampling requirements and analytical procedures are also specified. The standards are the minimum standards to which all wastewater treatment plants must adhere. It is up to the Member States to implement and monitor these standards as deemed appropriate, to impose higher standards if necessary and to determine sensitive areas.

The IPPC Directive has been modified substantially since its introduction and has now been superseded (2008/1/EC). In general, the IPPC Directive requires industrial and agricultural activities with a high pollution potential to have a permit. This permit can only be issued if certain environmental conditions are met, so that industrial companies themselves bear responsibility for preventing and reducing any pollution they may cause. The directive applies *inter alia* to energy industries, metal production and processing, mineral and chemical industries, waste management, livestock farming, etc.

The implementation of the UWWT and IPPC Directives along with any other that might be relevant is a matter for individual Member States and each has its own procedures. Failure to comply with the Directives can result in the imposition of substantial financial penalties which are usually a sufficient incentive to rectify deficiencies and to meet the standards.

In addition to the UWWT and IPPC Directives (which both focus principally on point source pollution), European Member States are now in the process of complying with the Water Framework Directive (WFD – adopted in October 2000) which recognizes that diffuse sources have a marked effect on the environment. Its principle objective is to restore European water bodies to good ecological and chemical condition.

Case study 3: National experiences in wastewater monitoring and pollution control - PRODES (Brazil)

PRODES (Programa Despoluição de Bacias Hidrográficas) was introduced in 2001 by the National Water Agency (http://www.ana.gov.br/prodes/). It is an innovative programme that aims to encourage the development of new wastewater treatment plants and to improve the performance of existing ones. Its great innovation lies in the fact that it departs from traditional funding routes and is grounded in an output-based system of financial incentives according to performance against a set of pre-determined standards. It was conceived against a background of previous public investments that were frequently overestimated, unfinished or abandoned after construction. Encouraging new investments was not enough; it was deemed necessary to guarantee that the undertakings were effectively concluded and well-managed afterwards.

PRODES does not finance works or equipment, nor does it make any payment before the start of treatment. It is an incentive payment to utilities that invest in the construction, enlargement or improvement of wastewater treatment plants. There is only payment for the proven reduction of pollutant loads over a three year period in accordance with performance targets pre-established on each contract. Reimbursement of some or all of the capital costs of the proposed undertakings can be made in return for the achievement of targets. The program also encourages the transition from capital-intensive projects to more economical alternatives that offer similar operational results for lower costs.

Contract values are based on the project's expected final benefits according to the size of the population served and the pollution load removed. There are nine quality performance targets (specifying minimum removal efficiencies of the specified constituents), each with a per capita estimation of capital cost as a function of plant size. The maximum value of the incentive payment varies according to the size (population equivalent) of the wastewater treatment plant. Payment is not in one lump sum but is spread out over a three-year period, during which 12 payments are made; one every three months provided that the period has been one of successful operation and all targets met. Failure to meet targets initially generates a warning; thereafter payments would be withdrawn or not made. Failure to meet the targets at the end of the period could result in all payments being returned to the treasury.

Binding water quality standards are usually established at the national level, although regional standards exist as well, such as the Water Framework Directive in Europe (UNEP, 2010). In terms of the development of enforceable water quality standards by individual countries, international guidelines can help establish appropriate levels of protection (providing that consideration is given to differences in economic development, institutional capacity and geographical characteristics). The existence of such guidelines can reduce the amount of evaluation, cost-benefit analysis and research that needs to be done at a country level and also help to promote acceptance of any standards.

World Health Organization (WHO) Guidelines are available on drinking-water quality (WHO, 2011) and the safe use of wastewater, excreta and greywater (WHO, 2006). The Food and Agriculture Organization (FAO) offers information on irrigation water quality (Westcot and Ayers, 1984) and guidance on sampling, terms, measurement and reporting of water quality have been developed by the International Organization for Standardization (ISO).

In order for regulation to be effective it needs to be backed up by proper monitoring and enforcement, creating or revising legislation is not enough in its own right. As noted by UNEP (2010) the way that countries implement and enforce policies varies, but many countries have a system that can impose fines. In addition, withholding public funds can be another strategy, since in many cases both public and private sector polluters rely on some form of public funding whether it is through direct loan programmes or through partial public funding for infrastructure.

7.2 Financial aspects

This section encompasses financing investments, cost recovery, equity and economic benefits. Water, sanitation and wastewater management are expensive and capital-intensive, but the available evidence all suggests that the costs of inadequate investment are far, far greater, in terms of actual money spent and also both direct and indirect damages to health and socioeconomic development. As noted by Jouravlev (2004) "*it is important to note that water pollution does not only affect public health, the environment and local economic activities, but also national competitiveness, mainly owing to the increasingly close relationship between external market access and the environment, and the increase in disputes relating to the use of environmental standards as non-tariff barriers in international trade*."

In order to create a sustainable system, policies are needed to support more effective water- and wastewater-pricing systems that permit sufficient cost recovery, ensure adequate investments and support long-term operation and maintenance (UN-Water, 2011). As pointed out by Corcoran *et al.* (2010) "*financing of appropriate wastewater infrastructure should incorporate design, construction, operation, maintenance, upgrading and/or decommissioning. Financing should take account of the fact that there are important livelihood opportunities in improving wastewater treatment processes*". It is also important to consider that wastewater management requires finance for more than just infrastructure and running costs. Most funding, which is typically grossly inadequate, goes to infrastructure development, much less is invested in operations and maintenance and even less goes towards developing institutions and human capacities (UNESCO, 2012).

7.2.1 Financing investments

There are multiple pressures and calls on finances and, in the past, wastewater management and water quality have not been seen as a priority. Indeed, it has been estimated that there is an annual global shortfall in funds (between 2002 and 2025) for municipal wastewater treatment of US$ 56 billion (Camdessus, 2003 – cited by Hutton and Wood, 2013). To date, few countries have put in place sector financing strategies for urban sanitation and some governments are reluctant to allocate funds because improvements (often assuming sewerage as the norm) are perceived as capital intensive, rarely generate significant revenue, do not always deliver the intended benefits and are relatively 'invisible'. One reason for the unfavourable view of sanitation and wastewater management is the development paradigm of the last 50 years which typically involves the "*building of infrastructure and service capacity, with major emphasis on getting the money out of the door within the project cycle and on having a 'handover' of infrastructure to governments*" (Hutton and Wood, 2013). This approach gives very little attention to factors that ensure sustainability, efficiency and affordability of services related to governance, behaviour change, operations and maintenance and capacity building.

Traditional financing sources are commonly categorised as the 3Ts, namely: taxes, tariffs and transfers, which refer to government, private sector and donors/non-governmental organization sources, respectively. As noted by Hutton and Wood (2013), "*in general, taxes and transfers are subsidies spent primarily with the aim of enhancing social welfare and producing services that people need or demand, even in the absence of the people's ability to pay. There are many types of subsidy that can be chan-*

nelled through a variety of mechanisms. Private financing, however, is attracted to the … sector primarily not to provide subsidies but for the purpose of making a financial return."

Frequently, services are provided using a mixture of financing sources including public-private partnerships (PPP), which might include community contractors, service contracts, management contracts, leases, concessions (build-operate-transfer), divestures and public-private companies (Hutton and Wood, 2013). Camdessus (2003), however, highlighted a number of specific risks for the participation of private providers in the water sector (which also apply in relation to wastewater management) including, absent, weak and/or inconsistent regulations (further highlighting the need for appropriate and enforced regulations), low rate of financial return and the risk of political pressure on contracts and tariffs.

Given the current shortfall in funds and the failure of some past investments it has been suggested that a new financing model is required, which draws on new sources of capital (blending different capital sources from the private sector, philanthropic sources and government) and focuses on outcomes (where the financial incentive is based on the delivery of tangible, auditable social outcomes) rather than inputs (amount of money to be invested) – Hutton and Woods (2013).

7.2.2 Cost recovery

In many countries, wastewater management services are undervalued, under-priced and regulations (where they exist) may not be rigorously enforced, as a result cost recovery may be difficult. In a survey of 27 Asian cities, it was found that less than three quarters of the O&M costs for water and sanitation provision were met from tariffs (ADB, 2009). However, there are signs that, in some regions among larger utilities, tariffs are being used to cover not only O&M costs but also some depreciation costs (Ferro and Lentini, 2013). Cost recovery options include economic instruments and creating business opportunities. As noted by UN-Water (2013), regulation has to set standards regarding pricing. While water and sanitation may be a human right, this does not imply that they should be provided free of charge. To meet human rights, any tariff and connection costs need to be designed in a way that makes them affordable to everybody. Tariffs can serve multiple objectives including financial sustainability (cost recovery), environmental sustainability (reduced water consumption) and social protection (UNECE/WHO Europe, 2012).

Although wastewater discharge charges are the most common method of raising funds, it has been suggested that other economic instruments could aid in the implementation of water quality regulations where behaviour, such as reducing pollution, is encouraged through market signals (including water pollution charges or taxes and water quality or nutrient trading). The case study (case study 4) outlines a nutrient trading scheme designed to reduce nutrient inputs (especially nitrogen) to a lake in New Zealand.

Case study 4: Tradable nutrient rights to reduce nutrient flows in Lake Taupo

Lake Taupo in New Zealand supports an important fishery and the regional government considered that it was important to reduce nutrient inputs in order to maintain or improve water quality. The scheme set up to achieve this was a 'cap-and-trade' scheme which involved the following steps:

- Definition of the 'cap' – i.e. the nutrient load that maintains lake quality.
- Definition of the players in the market – i.e. those who release the most nutrients into the lake catchment.
- Allocation of nutrient polluting allowances.
- Trading allowances (i.e. having a market place and setting a price).
- Monitoring compliance.

Initially, the system aims to ensure that any increases in nitrogen leaching are offset by corresponding and equivalent reductions in nitrogen leaching within the catchment; ultimately the target is to reduce the nitrogen load by 20% (OECD, 2012). The system became operative in 2011 and was the culmination of more than ten years of policy development (Waikato Regional Council, 2013).

Although economic instruments may, in some circumstances, be effective, they are not a simple option (as illustrated by case study 4) and there are also concerns that, unless stringent controls are in place, pollution can simply be transferred to other locations (e.g. poor neighbourhoods) or remain unchanged (UNEP, 2010). It has also been questioned whether economic-incentive policies are generally workable in developing countries as discharge fees and marketable permit programs require regulatory institutions to be able to set fees, allocate permits, monitor emissions, invoice polluters, keep track of permit trades, collect payment and enforce the system (Blackman, 2006).

The case study outlined below highlights some of the inter-linkages between finance (in this case from discharge fees) and also requirements for regulatory capacity, enforcement and data.

Case study 5: Wastewater discharge fees

The Government of Colombia introduced a fee which covered wastewater discharge as a means to reduce country-wide water pollution levels. This has had limited success in that, in several river basins, pollution levels seem to have decreased since its introduction. The programme, however, was far from problem-free and it is likely that the perceived effectiveness of the discharge fee doesn't entirely reflect reality.

The idea behind the discharge fee is that the polluter should pay, and that a fee provides an incentive to cut emissions in a cost-effective way in order to reduce discharges and hence penalty payments. Its use in developed countries is common and it can provide an effective and cost-efficient way of cutting pollution. However, as pointed out by Blackman (2006), in Colombia, it is likely that the incentives created for regulatory authorities to improve permitting, monitoring and enforcement were probably as important as the potential fees, if not more.

In 1997, before the introduction of the discharge fee, permitting, monitoring and enforcement of water pollution regulations were inadequate in virtually all regions. To implement the discharge fee program regions needed to remedy the deficiencies and thus had to develop an inventory of dischargers, create an information management system, calculate facilities' pollution loads and develop monitoring systems. Each of these tasks is a precursor to effective implementation of command-and-control emissions standards as well as discharge fees. As a result of the much improved monitoring, emissions standards in many jurisdictions had a far greater impact after 1997 irrespective of the actual discharge fee.

Murray *et al.* (2011) have suggested that public-private partnerships based on cost-recovery from the reuse of human waste could help to incentivise and even co-finance the sanitation/wastewater sector while, at the same time, promoting small- and medium-scale entrepreneurs. They put forward four waste-based business models (involving aquaculture, biogas recovery, compost production and the use of faecal sludge as an industrial fuel) and they proposed a number of efficiency indicators in order to allow a comparison between different reuse options and hence allow a financial assessment to be made of different reuse business scenarios. The efficiency indicators include:

- Required waste (product) receiving capacity of the end user (e.g. sufficient agricultural land to accommodate the output of compost);
- Marginal production gain through reuse;
- Market value of marginal production gain;
- Capital cost of additional water reuse; and
- Operation and maintenance costs of additional waste reuse.

The most critical condition for implementing a given reuse is the availability of end users who can absorb the supply of product and are willing to pay for it.

Although in its early stages and not a complete solution, the Peepoo programme outlined in the case study 6, below, demonstrates how innovative thinking and the use of community engagement and local entrepreneurs can deal with a sanitation problem and encourage reuse of human waste.

Case study 6: Peepoo programme in Kibera, Kenya

The Peepoo bag is a personal, single-use, self-sanitising biodegradable toilet. The bag contains a small amount of urea which, when in contact with faeces and urine, breaks down to form ammonia which inactivates microorganisms. The used bag is odour free for at least 24 hours and the contents are fully sanitised after only four weeks. The Peepoo bags have been successfully applied in a number of humanitarian crises. They are also increasingly being used in slum settlements to reduce open defecation and provide affordable sanitation. They were launched in areas of Kibera (the largest slum settlement in Africa) in 2010. The bag is a dual purpose product, selling both as a toilet and when used as a fertilizer. The bags are sold to the community via kiosks and local entrepreneurs. There are a number of drop points where the used bags are taken and people receive a refund for each Peepoo bag they return (approximately one third of the purchase price). Although people can drop off their own bags, the majority of the collection work is done by female microentrepreneurs, who take a proportion of the refund money. The bags are collected from the drop points and taken to a single sanitation yard where they are kept for four weeks to ensure they are fully sanitised. The fertilizer used in direct form (i.e. with the toilet bags buried in the ground and crops grown alongside) has been shown to be very effective. Currently the fertilizer is being used for demonstration and research purposes, but commercialization of the product is the next phase and the whole system is expected to be self-sustaining by 2020 – ten years after the initial introduction (Wachira, pers. comm.).

7.2.3 Equity

Dodane *et al.* (2012) demonstrated that in low-income countries faecal sludge management systems can be an affordable option while, in many cases, sewer-based systems may be prohibitively expensive. They compared a sewer-based system with activated sludge, with a faecal sludge management system consisting of on-site septic tanks, collection and transport trucks and drying beds in Dakar (Senegal) and found that the combined capital and operating costs for sewer-based system was five times higher than that for the faecal sludge management system ($54.64 /capita/year compared to $11.63/capita/year). The problem, however, is that the majority of costs for the on-site system are borne at the household level. The high costs experienced by the householder mean that 37% of the poorest households resort to illegal manual emptying of their system, resulting in untreated faecal sludge being directly disposed of in the environment and negating many of the benefits of a sanitation system.

Equity is a global issue and this is recognized in the Protocol on Water and Health to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Protocol on Water and Health). In the recent document 'No one left behind' the issue of price disparities is addressed through a number of examples, two of which are outlined below (UNECE/WHO Europe, 2012).

Case study 7: Addressing price disparities

Spain: To meet targets set by the EU UWWT Directive, the Government of Aragon launched the Special Plan for Sanitation and Water Treatment in 2006. The plan involves the construction of over 130 treatment plants in 172 population centres. This is a major financial challenge and one that could, easily, have been an equity challenge, given that the costs of wastewater treatment provision are much higher in the rural areas of the region compared to Zaragoza (the main city and home to half of the region's population). To preserve equity, the financing and operation of the new plants has been designed so that the inhabitants of Zaragoza effectively cross-subsidise the costs for rural Aragon, with each user paying the same amount for wastewater treatment, irrespective of the cost of providing the service.

Portugal: The uptake of connections to wastewater infrastructure was found to be slower than expected and a study suggested that this may be because of the relatively high cost of connection. Although, on average, connection represents 26% of monthly income, in some low-income households the cost of connection can be up to three times the monthly household income and clearly unaffordable. To address the problem, the water regulator has recommended that the connection charge is eliminated, with the loss of revenue being made up by gradually increasing the fixed part of the tariff over a five-year period. In this way, all users contribute to pay the cost of connecting the unserved.

7.2.4 Economic benefits

There are few studies that capture the full benefits from sanitation and good wastewater management, as studies need to include the benefits of toilets and other domestic systems as well as those due to the safe containment, collection and treatment of the wastewater and related sludge (UN-Water, 2014) and also positive externalities in terms of health, school attendance, employment opportunities and economic growth (including tourism and agriculture). Hutton and Haller (2004) estimated the costs and benefits of expanding the coverage of drinking-water and sanitation services and suggested that, in the Latin America and Caribbean region, universal access to drinking water supply with a household connection and sewerage with a household connection would cost US$ 14.1 billion a year, while delivering benefits of US$ 69.2 billion a year. A Water and Sanitation Program study for India suggests that the benefits in 2006 from avoiding the costs of inadequate sanitation could amount to approximately USD 33 billion, around 3.9% of GDP (WSP, 2010).

7.3 Barriers to innovation

Despite the multiple and wide-ranging benefits of good, locally-appropriate wastewater management there are numerous barriers to the application of innovative solutions, including politics, regulations and monitoring.

7.3.1 Politics

Politics and politicians are, perhaps, the two biggest hurdles to the implementation of appropriate wastewater management and there is a real need to cultivate political interest in this area. As noted by Ingram (2011), systems are biased towards "business as usual" and only if political leaders see either threats or opportunities, and/or have vision and passion are real changes likely to occur.

Laugesen *et al.* (2010) makes the gloomy prediction that "*despite the past failure of most centralized systems, it is likely that most new wastewater management systems in developing countries will continue to be advanced, centralized and with a continued high probability for failure*". He suggests a number of reasons for this, with the most important being the political preference for large, one-off investments (addressed in 7.1). Other reasons include inertia ("we've always done it this way"), the desire to have what seems to be an advanced, state-of-the-art system, and the education and experience of wastewater engineers. Hawkins *et al.* (2013), in their examination of poor-inclusive urban sanitation, also note the risk of considering sewerage as the only 'proper' form of urban sanitation, which can then lead government officials to choose that option even when it is not technically or financially viable. They also comment that "*perverse incentives around contracting*" may also reduce the motivation to develop more cost-effective and locally applicable solutions.

7.3.2 Regulations

Regulations are clearly vital (a point that was amply made in section 7.1), but it is important that they be well thought out and coherent across different areas as they have the potential to stifle innovation and lock countries into inappropriate solutions.

Brown and Farrelly (2009), in a review of 53 studies of innovation processes in water and wastewater management, found that the primary barriers to change are socio-institutional rather than technological and identified regulatory framework limitations along with limited community engagement, fragmented responsibilities and insufficient resources as problems.

Spiller *et al.* (2012) looked at how the European Water Framework Directive is stimulating change in water and wastewater management by water and sewerage

companies in England and Wales. They found that perceived water supply problems were (in some cases at least) met with novel solutions, particularly in relation to catchment-based rather than end-of-pipe management. The picture was, however, less reassuring in terms of wastewater management where there was almost no reference to decentralised stormwater harvesting, water-sensitive urban design or wastewater reuse technologies, which are standard practice in some areas of the world including Australia, despite their potential local benefits. It was felt that the national regulatory framework was not well-suited to wastewater management and that there were conflicts between, for example, UK climate change mitigation and carbon dioxide emission reduction regulations and demands within the Water Framework Directive for increased wastewater treatment processes. An additional explanation for lack of innovation in the wastewater sector was the financial constraints placed by previous capital investment made under the Urban Wastewater Treatment Directive.

7.3.3 Inadequate or deficient monitoring

The current monitoring in respect of progress towards the MDG target on sanitation is based on whether sanitation facilities are 'improved' or 'unimproved' (see Figure 1). Kvarnström *et al.* (2011) argue that the focus on specific technologies stifles creativity and innovation, locks people into predefined technologies and can lead to a 'tick box' mentality. Monitoring the user facility also means that no account is taken of the resulting wastewater and how this reaches the environment, and there is an urgent need to address this issue (see section 7.4 Data Needs).

Although (arguably) not a barrier to innovation, but to acceptability, the following case study illustrates the problems that can be caused by deficient monitoring.

Case study 8: Ecological sanitation and the Erdos eco-town project

This project introduced source-separation sanitation techniques in newly built four- and five-storey buildings in China. The ecological sanitation approach was considered ideal as, in this semi-arid region of China, there was pressure on water resources resulting in water rationing, the region has a long history of using human waste as fertilizer and a market for the product was identified. The approach used involved modern porcelain urine-diverting dry toilets connected by a chute to basement collection wheelie bins for faeces and sawdust (the compostable sorbent material) placed in ventilated sealed cabinets. The major problems with the project resulted largely from poor building but also a complete lack of building inspection. The project team expected that buildings would be inspected by the Construction Bureau and their designated inspection companies. This, however, did not happen and the buildings turned out to be very poorly constructed, with illegal pipe and electrical connections, buildings without drainage and pipes without insulation all resulting in the faulty functioning of the plumbing and ventilation systems. Because there were no inspections, problems weren't discovered until the tenants were living in their flats (Rosemarin *et al.,* 2012).

7.4 Data needs

There is a pervasive lack of data relating to virtually all aspects of water quality and wastewater management (particularly in developing countries). UNEP (2010) summarizes the resulting issues as follows: "*A key to understanding water quality challenges and solutions is collecting, storing, analysing and sharing water quality data. Without adequate data, serious water quality challenges are unlikely to be identified and managed adequately to protect human and ecosystem health. Conversely, by monitoring water quality and collecting and sharing water quality data, it is possible to determine if water quality in lakes, reservoirs, rivers and groundwater is improving or deteriorating and to identify growing problems and potential solutions that require prompt action. Despite the importance of good data, there are currently large gaps in monitoring efforts and data related to water quality, especially at the global scale.*"

A brief examination of the wastewater management literature reveals data gaps relating to:

- Information on the physical, chemical and biological characteristics of many surface- and ground-waters (UNEP, 2010);
- Information on water-storage capacities of river basins (UNEP, 2011);
- Empirical information on which latrine siting guidelines (which vary widely) are based (Graham and Polizzotto, 2013);
- Information on the condition of built wastewater infrastructure (UNEP, 2011);
- Performance of treatment works (Oliveira and von Sperling, 2011);
- City-based information on the fate of faecal sludge (Peal *et al.,* in press a);
- Information on generation, treatment and use of wastewater (Sato *et al.,* 2013);
- Information on the volume, quality and location of wastewater used in irrigation (Qadir *et al.,* 2010);
- Information on the impact of agriculture on water quality (UNEP, 2011); and
- Information on industrial discharges or a register of industries (UNESCO, 2009).

These are some of the gaps that have been identified; clearly data availability will vary by location, with some cities and countries having more abundant data than others. Even where data exist, however, they may not be comparable between locations and times and, as an extra note of caution, it has been observed "*that many water quality programs, especially in developing countries, collect the wrong parameters, from the wrong places, using the wrong substrates and at inappropriate sampling frequencies and produce data that are often quite unreliable*" (FAO, 1996).

One of the gaps highlighted above is the amount of wastewater generated and treated. Sato *et al. (*2013), for example, found from a search of data published in 181 countries that only 55 countries had data available on all three aspects of wastewater (i.e. generation, treatment and use) and that much of this was very dated (pre-2008). The Green Drop programme in South Africa (Case Study 9) goes some way to addressing this question in a local context and, as well as addressing data needs, it also illustrates strong governance and the effective use of regulations.

Case study 9: Wastewater management monitoring in South Africa

The Green Drop certification programme, launched in South Africa in 2008, is an incentive-based wastewater quality management regulation that supports progressive implementation and improvement in wastewater management. The Green Drop process examines the performance of wastewater treatment works against specified standards and requirements and has acted to raise the profile of wastewater treatment in the consciousness of local governments, the media and the public.

The strategy is based on the identification of poorly performing municipalities who consequently correct the identified shortcomings, along with the introduction of competition between municipalities and the use of benchmarking in a market where competition is difficult to implement. The programme has been described as informative and educational by design and, as such, has inherent capacity building characteristics (DWA, 2011). Consideration of a number of performance areas gives an overall wastewater system score, which leads to the system being ascribed to one of five categories ranging from 'critical' to 'excellent'. Those systems achieving excellence are awarded 'Green Drop' status. In 2010/11 data was received from all 821 municipal wastewater collector and treatment systems in the country, representing a total wastewater flow of 5258 Ml/day. The average score increased from 37% in 2009 to 45% in 2010/11, but 56% of the systems were classed as unacceptable, so there is clear room for improvement.

Section 8

Conclusions

Adopting a strategic approach to all stages of wastewater management

Current management approaches in many countries do not consider all elements of the wastewater cycle, from production to final disposal to a receiving water (or reuse). The different technologies are not always designed together, are often an attempt to retrofit or add to an existing system, or individual component design relies on poor data. This results in sewers running below or above capacity, wastewater streams being combined (which should not be the case), and treatment plants receiving too little or too much wastewater. In many cases, population statistics are used for designs, even when large parts of the community are not connected to a sewerage network. It is inevitable that in most environments, a mixed- system is the norm, resulting in a limited sewerage network, with some combined storm-water flows and a proportion of the community who use on-site facilities. In some situations, stormwater flows must be considered in the equation.

In any given setting, developing an overall wastewater management plan, encompassing where possible all wastewater components, should be undertaken based on appropriate boundaries. This may be a city or urban area, or conurbation. In any event, an appropriate administrative unit is needed to ensure effective oversight in design and operation. The systems must be flexible to accommodate new populations and sources, and indeed allow communities to have access to an improved level of service.

Optimizing the re-use of wastewater

Wastewater, in many cases, is rich in recoverable materials. This may be the nutrient value of domestic wastewater or indeed a particular fraction of an industrial discharge. In many regions the use of wastewater in agriculture is well-understood, albeit in a way that carries significant health risks. What is needed is a better matching of what is available to the needed reuse applications. For example, it may make better economic sense to reuse wastewater for fuel-wood production, rather than treating to a level good enough to irrigate food crops. The 2006 WHO Guidelines also offer a range of treatment and non-treatment options and a risk management approach for progressive improvement that is more achievable in low income settings. In addition to agricultural reuse for food production (both crop irrigation and fisheries), other opportunities are available such as energy recovery and reuse in process water. Technologies are now available which can extract resources from low-strength wastes, which previously would have been uneconomical.

Wastewater can be reused to augment scarce supplies and delay future investments in water supply infrastructure. Indeed, reuse should be seen as a critical component of water demand management plans when implemented together with health and environmental risk management.

Improving the fragmented institutional responsibility for wastewater

One of the main reasons why wastewater has been so much neglected is that it often lacks an institutional home. The drive to commercialize drinking water production and supply has resulted in neglect for wastewater management. Many reformed utilities do not see value in investing in wastewater infrastructure. Until this changes, it will be difficult to apportion responsibility for the impacts on health and the environment. Large polluters, particularly industries, can be policed. However unmanaged wastewater flows from unplanned areas and illegal discharge into storm drains etc. must be a municipal responsibility. Improved capacity is therefore needed. Wastewater can be a good business opportunity for utilities and systems developed for billing and revenue collection can be readily adapted for wastewater. At the regional level, mechanisms must be adopted to ensure neighbouring authorities agree on standards for monitoring and enforcement. In local communities there is clearly a role for environmental health professionals to assist in the management of wastewater discharges. With respect to wastewater production, some effort on minimization will be required. Non-point sources of agricultural run-off are a good example. It may be concluded that a combined approach of minimization and effective treatment will be needed.

Stimulating political will and the critical role of improved monitoring of wastewater

At the conclusion of the MDG period, water sector monitoring is uncertain and fragmented. Wastewater is the most neglected of all components of water monitoring. The model of the WHO/UNICEF Joint Monitoring Programme (JMP) has shown how good monitoring focused global attention and significantly contributed to the achievement of the water and sanitation MGD target while leading to significant progress on sanitation.

Although fragmented, water resources monitoring approaches have been developed, driven by national priorities. Water is critical to many other development challenges and a more holistic water agenda, including water resources and wastewater management, is needed.

Regardless of the outcome of the post-2015 process, water, at large, requires a coherent monitoring framework with improved data acquisition and analysis to track progress and provide a credible platform for action. Credible data will underpin sector advocacy, stimulate political commitment and trigger well-placed investment towards optimum health, environment and economic gains. The SDG debates are now focusing on a dedicated water goal and provide a great opportunity to also address inequalities.

A new initiative will enable an analysis of wastewater, water quality and water resources management to provide global comparisons on progress. This can serve donors and Member States to target interventions in priority areas, in order to maximize health, environment and economic gains.

Key to the new approach is developing a monitoring framework that builds on the knowledge of existing monitoring efforts such as the JMP, GEMS-Water, Aquastat, UIS and others. The past decade has seen rapid changes in the way data is collected and analyzed. In response, the initiative will also need to incorporate new and novel sources of data including remote sensing and GIS. Critically, the framework must be grounded on what is measurable, affordable and applicable across a wide range of countries with differing capacities. The framework should be country-led as far as possible and avoid placing an unnecessary burden on Member States. The initiative will need to develop protocols to guide countries in their quest for useful water knowledge that enables them to better target action to where it is most needed.

Recognition of wastewater and its critical role in sustainable development

It is clear that wastewater needs to be more fully recognized within the overall water cycle, as one of the greatest untapped opportunities to enhance sustainable development. This is applicable in big cities, rural areas, and indeed anywhere in between. In terms of serving the poorest first, there is still a long way to go, both for basic water supply and sanitation. There is now a growing realization that the opportunities that effective wastewater treatment and reuse could bring to sustainable development could be achieved with a concerted effort and more political will.

Managing wastewater in a changing world

The world is undergoing significant demographic and social changes, with urbanization and migration being two of the most important issues. This will bring to bear increasing influences on the production of wastewater. The patterns of urbanization will see, in some areas, almost explosive growth in the secondary urban centres, in many countries in the south. Although, on the one hand, this may be seen as problematic, from the point of view of collection and treatment, it will pave the way for an exciting opportunity for decentralised collection and treatment and (as is the case with most forms of waste, collection, treatment and safe reuse as close as possible to the point of production) will be more economically attractive. On the negative side, if urban sprawl is allowed to encourage discharge of wastewater from small scale manufacturing enterprises, medical industries and unplanned settlements etc., this in itself will seriously affect local populations, their access to fragile water supplies and subsequently their health. In addition to wastewater from urban areas, agricultural sources, both point-source and diffuse, make a significant contribution. Although systems can be put in place to handle point sources through end-of–pipe solutions, reducing agricultural run-off will require minimization at source.

We will irreversibly damage the natural environment and miss cost effective opportunities to improve health if we fail to seize the opportunities that better wastewater management can bring.

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Appendix 1: Effluent quality parameters and wastewater treatment processes

The following is a list of parameters commonly used to assess effluent quality from plants treating essentially domestic and commercial wastewaters. When there is a substantial quantity of industrial wastewater discharged to a sewer other parameters may be necessary. For the control of industrial wastewaters discharging directly to a watercourse an entirely different set of parameters may be required.

Table A1: Selected effluent quality parameters

Measurement	Designation	Units	Comments
Biochemical Oxygen Demand (unsuppressed)	BOD_5	mg/l	BOD is normally measured over 5 days. The unsuppressed value measures oxygen demand from the oxidation of organic matter plus the oxidation of NH_4-N. It is measured at 20°C.
Biochemical Oxygen Demand (suppressed)	$BOD_{5.atu}$	mg/l	The suppressed value measures only the oxygen demand from the oxidation of organic matter. The oxidation of NH_4-N is suppressed by addition of allyl thiourea which kills the bacteria responsible for oxidation of NH_4-N.
Suspended solids	SS	mg/l	
Ammoniacal Nitrogen	NH_4-N	mg/l	
Nitrate Nitrogen	NO_3-N	mg/l	important nutrient measure
Total Nitrogen	N	mg/l	important nutrient measure
Total Phosphorous	P	mg/l	important nutrient measure
Faecal Coliforms		30-100	
Chemical Oxygen Demand	COD	mg/l	

Table A1: Selected effluent quality parameters

Treatment type	Brief Description	Quality achievable	Comments
Membrane Systems Microfiltration Ultrafiltration Nanofiltration Reverse Osmosis (RO)	Membrane Biological Reactors (MBRs) using micro or ultrafiltration membranes or additional advanced treatment after aerobic systems including RO.	Very high to extremely high. Micro and Ultra eliminate all biological agents and macro molecules. Nano removes simple organic molecules. RO removes inorganic ions.	Processes that close the water cycle and produce high purity water for reuse. Very high energy consumption.
Nutrient Removal Processes	Similar to nitrifying aerobic processes but modified to remove P either biologically or by addition of chemicals.	Very high quality effluents low in N and P.	Energy requirements and sludge similar to below.
Nitrifying Aerobic processes	Similar to below with longer sludge ages – retention times.	Very high carbonaceous removal with very low ammoniacal nitrogen and high nitrate. With tertiary treatment will produce very high quality effluents.	Can be modified to remove nitrate with overall reduction in nitrogen. Sludge similar to below. Recent concerns with the production of nitrous oxygen (very potent GHG).
Aerobic Processes - basic carbonaceous removal. Usually follows primary sedimentation. Relatively short sludge age.	Activated sludge and its many variants or biological 'filtration' and its variants. Effluent can be improved by tertiary treatment.	Carbonaceous removal wide range of quality down to (say 20mg/l BOD and 30mg/l SS). No reduction in ammoniacal nitrogen. Very little reduction in Faecal Coliforms.	Can be designed to produce a wide range of effluent quality. Relatively high energy consumption. Major sludge treatment requirements.
Stabilisation Ponds	Anaerobic, Facultative and Maturation ponds used in series, not always with separate Anaerobic pond.	Depends on combination of ponds and design. Can achieve low FC levels with Maturation Ponds. Sometimes high BOD and SS in effluent from algae but relatively harmless.	Land intensive. Good for small/medium sized towns. Need to be desludged at intervals – sometimes not done with serious consequences. Sometimes seen as warm weather process but can be used in moderate climates.
Anaerobic Treatment such as UASB systems	Simple anaerobic processes favourably used. Produces methane that can be used for power generation.	Carbonaceous removal only. No removal of nutrients and needs to be followed by an aerobic system to achieve high quality effluents.	Produce much less sludge than aerobic processes or Primary/Chemically assisted treatment. Not as robust as aerobic systems in coping with shock loads of industrial effluents. Widely used in Brazil, India and other countries.
Chemically assisted primary treatment	Uses ferric salts and/or lime sometimes with polyelectrolyte.	Depends on chemical dosage. Can remove 40% BOD and 80% SS. No removal of NH_4-N. Some removal of P depending on chemicals used. Essentially removal of suspended solids with some carbonaceous removal.	Compact treatment but generates lots of sludge; some may be difficult to treat. If lime used Health Hazard reduced. Sometimes used as pre-treatment for sea outfalls. Can be used as interim treatment in phased programme. Some reduction in FC.

Treatment type	Brief Description	Quality achievable	Comments
Primary sedimentation after screening		Can remove 20-30% BOD and 60-70% SS.	Generates sludge for disposal. Health Hazard if not treated adequately.
Screening /Fine Screening		Removal of Gross Materials. Improvement in aesthetics especially riverbanks. Can remove some BOD and SS, very little removal of FCs.	Can be used as first step in phased programme or adequate treatment if discharge is to large fast watercourse e.g. estuary. Relatively large screenings and grit for treatment and/or disposal – usually disposal to landfill Health Hazard.
Septic Tanks and Cesspits	A septic tank has an outlet and is a very basic process to store and treat solids anaerobically. The outlet often discharges partially treated wastewater to the ground and groundwater. A cesspit is a holding/storage tank without an outlet.	Properly operated septic tanks can reduce suspended solids considerably but the overflowing discharge is of relatively poor quality.	Septic Tanks and cesspits must have the contents removed at frequent intervals, a feature often neglected. In addition, in many places access is very difficult.