Desk review

Functionality of wastewater treatment plants in low- and middle-income countries

WaterAid

Key messages

Official development assistance (ODA) for wastewater treatment plants (WWTPs)

ODA disbursement on WWTPs (and large sanitation systems in general) is estimated at over 1 billion USD a year, and increasing. That is 22% of total ODA for water, sanitation and hygiene (WASH), and more than twice what is spent on basic sanitation. The top six donors are: the World Bank, France, Japan, the European Union, the Asian Development Bank and the United States. Over half of the funding goes to lower-middle-income countries.

Evidence on functionality rates

There is little detailed evidence published on the sustainability and functionality of WWTPs in low- and middle-income countries. This brief literature review revealed many examples of WWTPs being built but never commissioned, taken off-line, and continually overloaded or underloaded. It is difficult to assess how prevalent the problem is. The multi-plant studies reviewed – which are of mixed quality and often dated – present a wide range of situations. In Mexico, 95% (of 194) WWTPs studied were not working. In Ghana, 80% (of 44) WWTPs were not working. In India, 54% (of 84) WWTPs were operating poorly or very poorly. In Vietnam, around 33% (of 17) WWTPs were substantially underloaded. In Brazil, most plants met effluent standards.

The causes

Poor functionality of WWTPs can be caused by inappropriate technology choices and poor design, but also by inadequate operations and maintenance (O&M). The first can lead to the latter, as inadequate technology or design can make O&M more difficult to carry out. A critical underlying cause is the institutional weaknesses and constraints to manage WWTPs sustainably, including low political priority; lack of recurrent finance for O&M; and inadequate knowledge, skills and systems for O&M. The donors' default approach is to fund the construction of facilities and their rehabilitation only, which is not sufficient in addressing existing institutional constraints and weaknesses. These can be overlooked when plans and designs are developed (often by foreign consultants).

Response needed

Existing efforts to address these issues need to be strengthened and mainstreamed, such as developing human resources capacity, establishing water operator partnerships (WOPs) and strengthening regulators. Moreover, governments and donors need to approach urban sanitation in a more integrated way that does not view sewered centralised sanitation as the only option. Technology choices for WWTPs should be based on multiple factors, with a central emphasis given to O&M and sustainability. Strengthening the capacity of local and municipal institutions is critical, along with wider institutional reform to create a more enabling environment. Bilateral donors and development banks need to improve on the gathering and sharing of evidence on the sustainability of the WWTPs they fund. This will enable better-informed decision making from countries and contribute towards ensuring these operations are based on and address the underlying causes of the persistent poor functionality of WWTPs.

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Definitions

Term	Defined as
Centralised systems	Large-scale systems that gather wastewater from many users for treatment at one or a number of sites (UN Water, 2015)
Decentralised systems	Dealing with wastewater from institutions and small clusters of users at the neighbourhood or small community level (UN Water, 2015)
On-site systems	Some institutions treat wastewater on-site in treatment plants
Domestic wastewater/ sewage	Wastewater from households and services (e.g. commercial premises and institutions) – collected in sewers and treated at WWTPs – collected on site and transported and treated off site – collected and treated in situ (JMP washdata.org)
Industrial wastewater	Collected in sewers and treated at WWTPs or collected and treated (if needed) on site and discharged into the environment (JMP washdata.org)
Untreated wastewater	Discharges not meeting national standards for release into the environment or next use (JMP washdata.org)
Sewage treatment options	Sewage treatment options can be divided into three broad categories: **– 'Conventional' aerobic treatment** – including conventional and high-rate trickling filters, aeration lagoons, activated sludge, extended aeration (including oxidation ditches) and some others. **– Anaerobic systems** – septic tanks, anaerobic waste stabilisation ponds, Imhoff tanks, baffled reactors, upward flow anaerobic filters, upward flow anaerobic sludge blanket reactors. **– 'Extensive' systems** – facultative and maturation ponds and constructed wetlands (reed beds), which rely on natural, mainly aerobic, processes.
Wastewater management	Provision and management of facilities to collect and treat wastewater to allow its safe disposal to the environment
Functional	Operating as intended in design and producing an effluent that meets effluent discharge/end-use standards as appropriate

Acronyms

ADB	Asian Development Bank
AFD	Agence française de développement
BORDA	Bremen Overseas Research and Development Association
CRS	Creditor reporting system
DAC	Development Assistance Committee
DEWATS	Decentralised wastewater treatment systems
DFID	Department for International Development
DGIS	Directorate-General for International Cooperation
EU	European Union
FSTP	Faecal sludge treatment plant
GIZ	German Association of International Cooperation
GLAAS	Global Analysis and Assessment of Sanitation and Drinking-Water
IBNET	International Benchmarking Network for Water and Sanitation Utilities
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme
NGO	Non-governmental organisation
O&M	Operations and maintenance
ODA	Official development assistance
OECD	Organisation for Economic Co-operation and Development
PPPs	Public-private partnerships
SDG	Sustainable Development Goals
SFD	Shit flow diagram
SIDA	Swedish International Development Cooperation Agency
SWA	Sanitation and Water for All
UASB	Upflow anaerobic sludge blanket
UN	United Nations
USAID	United States Agency for International Development
WASH	Water, sanitation and hygiene
WOP	Water operators partnership
WSP	Water and Sanitation Program (World Bank)
WSUP	Water and Sanitation for the Urban Poor
WWTP	Wastewater treatment plant

1 Introduction

Background

Sustainable Development Goal (SDG) 6 includes a target (6.2) to achieve universal access to safely managed sanitation and a target (6.3) to halve the proportion of untreated wastewater, and substantially increase recycling and safe reuse globally by 2030. Wastewater and faecal sludge may remain untreated due to the lack of treatment facilities, or the fact that the existing facilities are not functioning as intended. A World Bank report[1] on infrastructure in Latin America highlights wastewater as one the sectors lagging, stating that 'the dismal wastewater performance is a real emergency'. In certain contexts, poor functionality and sustainability of wastewater treatment plants (WWTPs) are recurring issues – the result of a lack of monitoring data and poor transparency and accountability.

While many countries keep records of installed treatment capacity, less information is available on the performance of treatment plants. The SDG 6 global monitoring mechanism has developed some preliminary estimates for the proportion of domestic wastewater that is treated (6.3.1a). However, the data comes from 79 mostly high- and middle-income countries, excluding much of Asia and Africa, and does not take account of the effects of poor WWTP functionality. Few countries systematically collect or publish this data at city, regional or national level. One exception is India, which commissions studies on WWTP functionality.

Despite the limited data,[2,3,4] one study[5] indicates variability across different regions, with countries in Europe and North America, the Middle East and North Africa, and Latin America more likely to treat wastewater than those in South Asia and Sub-Saharan Africa. A report from 2000 suggested that only 2% of cities in Sub-Saharan Africa have sewage treatment (partly because many cities have no sewerage networks), and only 30% of that small number of WWTPs are operating satisfactorily.[6]

The purpose of this review is to set out and synthesise what has been documented on the functionality of WWTPs, as well as the current levels of investment. It is mainly concerned with large sanitation systems – primarily centralised WWTPs – which receive most of the resources and has a focus on low- and middle-income countries. Faecal sludge treatment plants (FSTPs) are considered where appropriate, given the increasing attention to such facilities due to their key role in serving the many urban areas that rely on-site sanitation.

This quick desk review was commissioned by WaterAid as a preliminary exploration of the sustainability of WWTPs, to inform further exploration and engagement in the topic.

Methodology

This desk-based review brings together evidence from donor reports, academic papers, and WASH practitioner literature (conference papers, trade reports). Information for the review was gathered through internet searches using the following search engines to locate documents: Google Scholar, WEDC, IRC WASH, SuSanA (including the mini-site on shit flow diagrams). The following major academic databases were searched: JSTOR, EBSCO, SCOPUS, PubMed, and Elsevier/Science Direct. Trade magazines and professional associations were also searched, along with the following databases and document repositories: WASHwatch, Waterlines, the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS), Organisation for Economic Co-operation and Development (OECD)'s CRS (creditor reporting system), JMP (the WHO/UNICEF Joint Monitoring Programme), IBNET (the International Benchmarking Network for Water and Sanitation Utilities) and WSP (the Water and Sanitation Program), as well as donor project databases (the World Bank, DFID, Millennium Challenge Corporation, AFD, JICA, ADB, USAID). A combination of search terms was used: wastewater treatment plant + sewage treatment plant + sustainability + functionality + Africa + Asia + South America + Middle East. The search was conducted in English, with priority given to WaterAid's focus countries and regions.

Key sector review reports were searched to find country-level information on WWTPs (WASH Poverty Diagnostics and the Country Status Overviews/WSP Pathways to Progress reports). The UN Water and SWA (Sanitation and Water for All) websites were searched for country commitments on WWTPs. The reports of the Special Rapporteur on the Human Rights to Safe Drinking Water and Sanitation and Country Mission Statements were searched for their observations/recommendations on WWTPs. Finally, a small number of key informants were interviewed, including WaterAid staff and eight external experts.

In the analysis, examples are discussed by income-level categories of the countries, based on the per capita Gross National Income:[7] low-income countries (<995 USD), lower-middle income (996-3,895 USD), upper-middle income (3,896-12,055 USD), and high-income (>12,055 USD) – although the latter are not a focus of this assessment. The stable/fragile country[8] status of the country is also considered.

Limitations

There is limited availability of data on WWTPs (especially on functionality) in donor project databases, websites and other reports, and the reporting quality is sometimes low. Donor investment is more important in some countries than in others (for example, in India most investment comes through government programmes, whereas African countries, except for South Africa are often dependent on external aid). This report, based on the limited published evidence, offers an incomplete snapshot and a rough approximation to functionality rates. This in itself indicates the subject is under-researched and under-documented and belies a serious neglect of an expensive and vital industry.

Information on donor investment in WWTP is also limited, which required us to make rule-of-thumb estimations, the rationale of which is made clear throughout the document.

Structure

The document is structured as follows:

- Section 2 presents the scale of investment in WWTPs, including the latest trends and standards.
- Section 3 outlines the functionality of WWTPs, with reference to a range of practical experience with WWTPs. Country examples are presented according to a typology for Gross National Income and fragility.
- Section 4 summarises successes and failures in the functionality of WWTPs.
- Section 5 provides considerations for future development.
- A set of annexes supports the main document. These are referred to throughout.

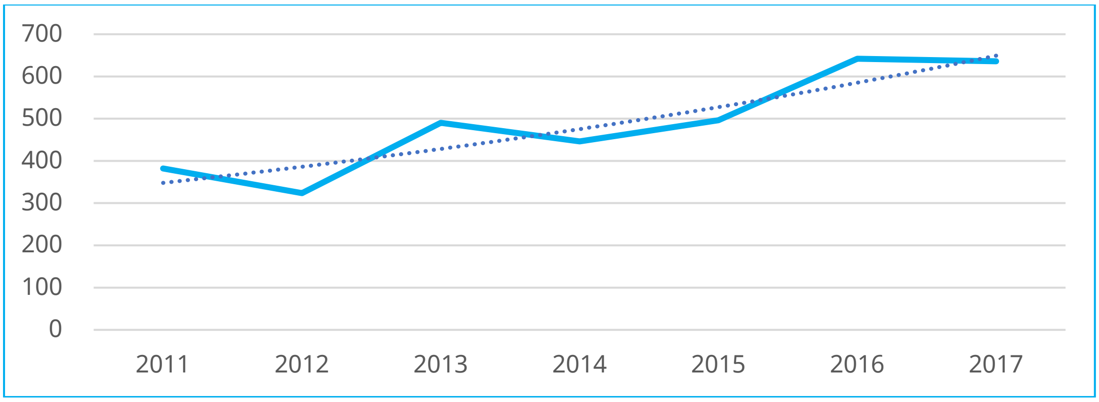
2 The scale of investment in large sanitation systems

A scan of the scale of investment began with a review of donor involvement and focus on WWTPs. This was done in two steps: the first step was to identify the donors with the largest disbursement on large sanitation systems on the CRS database, and the second step involved deeper examination of individual donor project databases/reports/websites to see if their support included WWTPs. The following section presents the limited information found.

Official development assistance

In the CRS database, we first analysed OECD donors' official development assistance (ODA) disbursements in large sanitation systems, identified with the code 14022 and including large scale sewerage, including trunk sewers and sewage pumping stations, and domestic and industrial WWTPs. In 2017, the overall support from all official donors to large sanitation systems amounted to **636 million USD**. This amount, which has been increasing steadily, represents 13% of the total 4,967 million USD disbursed for WASH,[i] and more than three times the 217 million USD disbursed for basic sanitation (code 14032: latrines, on-site disposal).

Figure 1: ODA disbursement in large sanitation systems over time (million USD) [2017]



[i] This includes CRS codes 14020, 14021, 14022, 14030, 14031, 14032 and 14081.

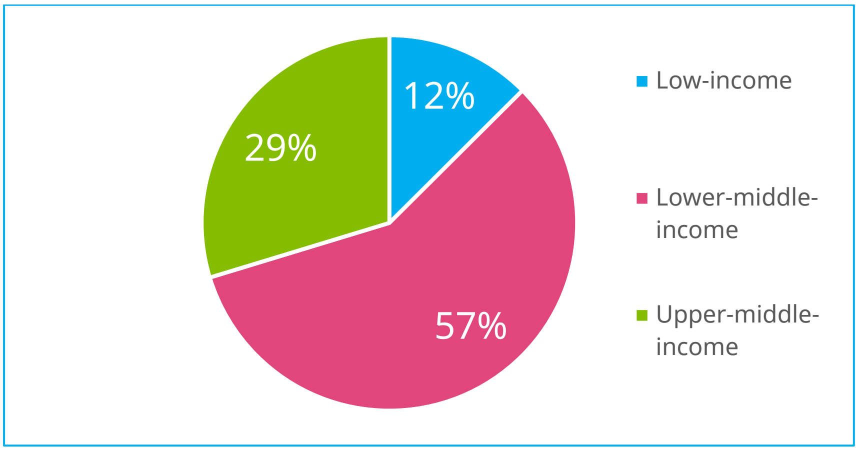
To reduce the bias from particular circumstances in a given year (for instance spiked expenditure due to project cycles), we looked at the average disbursement in the 2015–17 period. We found the yearly disbursement was 591 million USD.

However, a sizeable investment in large sanitation systems is conflated within the 14020 CRS code, which includes 1615 million USD for large WASH systems. These are operations that did not, or could not, identify separately what was for water and what was for sanitation. We roughly estimated that a about a third of that investment goes to large sanitation systems, that is 513 million USD. This is calculated by extrapolating the proportion of investment in large sanitation systems (code 14022) to large water systems (code 14021), which is 591 million USD to 1271 million USD, or 32%. This rough approximation brings the total disbursements for large sanitation systems to 1,104 million USD. That represents about 22% of the total disbursement for WASH, and more than twice the support to basic sanitation, estimated at 506 million USD using the same method.

Where the investment goes

Focusing again on the 591 million USD average disbursement (code 14022 only), most of it goes to lower-middle-income countries (57%), followed by upper-middle-income countries (29%) and low-income countries (12%).

Figure 2: ODA disbursement in large sanitation systems, by recipient country category



The most common recipient countries as per the CRS database (2015–17) are shown in Table 1.

Table 1: Countries receiving most ODA (2015–17) for large sanitation systems (fragile countries (2015) in italics and million USD received yearly in brackets)

Low-income countries	Uganda (18), Burkina Faso (16), Ethiopia (8), *Mali* (6), Nepal (5), Tanzania (5), Niger (4)
Lower-middle-income countries	Vietnam (81), Cameroon (36), Tunisia (30), Egypt (29), India (22), Uzbekistan (21), Kenya (17), Bangladesh (17), Morocco (15), *West Bank and Gaza Strip* (14), Sri Lanka (12)
Upper-middle-income countries	Jordan (37), Brazil (37), Turkey (19), China (13), Lebanon (12), Dominican Republic (11), Serbia (8)

Investment by donors

Looking at where the funding comes from and focusing again on the 591 million USD average disbursement (code 14022 only), 298 million USD comes from Development Assistance Committee (DAC) countries, 270 million USD from multilaterals and 23 million USD from non-DAC countries. In descending order, the biggest donors were the World Bank (137 million), France (110 million), Japan (100 million), EU institutions (64 million), the Asian Development Bank (41 million), the United States (38 million), the United Arab Emirates (22 million), the African Development Bank (20 million), Germany (18 million) and Switzerland (14 million) – see Table 4 in Annex.

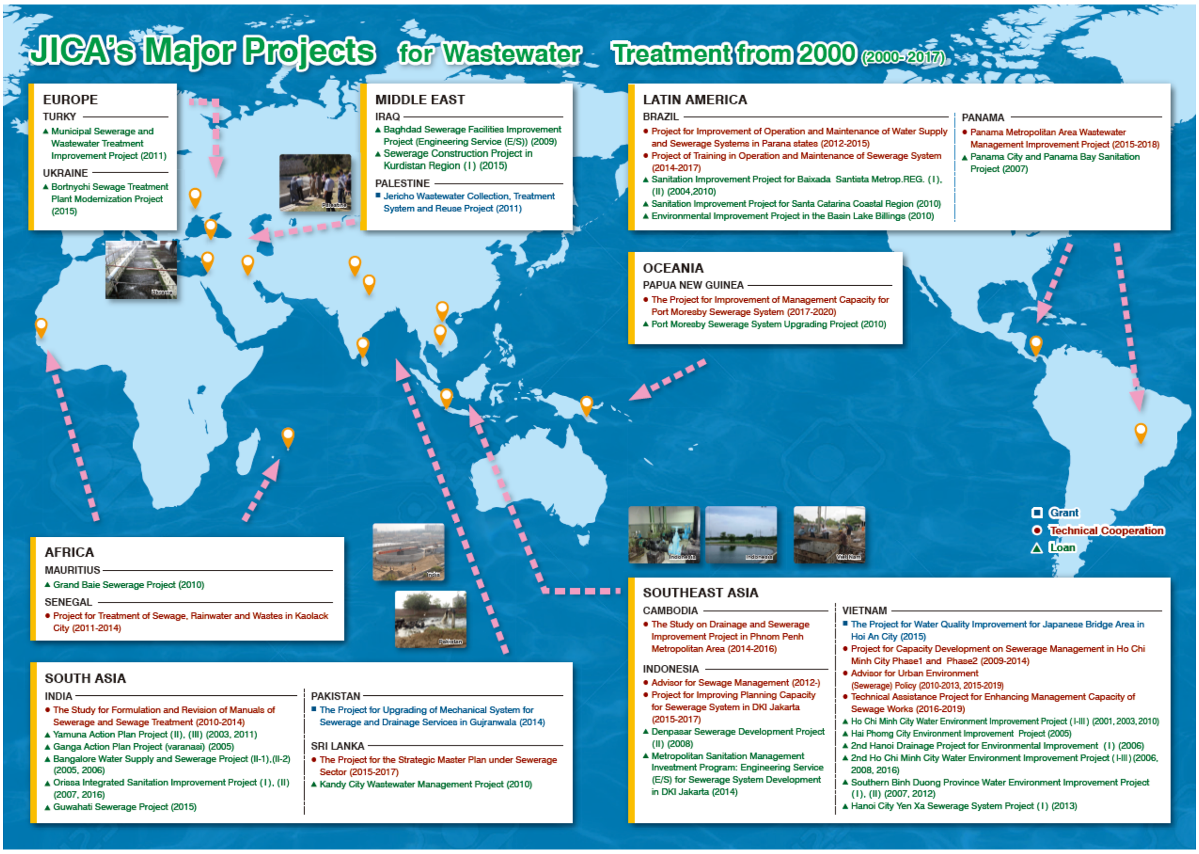
Given the limitations of CRS codes for distinguishing clearly between spending on large sanitation systems and large WASH systems in general, donor websites were also searched to understand the extent of their funding of wastewater treatment. Some donors have project databases that make it possible to view projects (past and present), but in general donor websites provide insufficient information to allow assessment of the extent to which they are investing in WWTPs. The numbers presented are likely to underestimate the actual investments from donors. For instance, there are investments in WWTPs in Cambodia from ADB, JICA, Korea International Cooperation Agency and AFD (as a key informant highlighted), but these did not show up in our search.

The **World Bank** is the donor with the most systematic reporting of its portfolio. A search in its projects database[9] revealed 478 projects on wastewater (346 completed and 126 ongoing), the majority in East Asia and the Pacific region (134 projects) followed by Latin America and the Caribbean (73 projects) and the Middle East and North Africa (104). The World Bank has only funded 54 projects in Sub-Saharan Africa. The World Bank has also been active in South Asia – for instance, there is an ongoing project in Dhaka, Bangladesh. Countries in Africa with World Bank-funded projects that include a wastewater component include Senegal, Kenya, Botswana, Tanzania, Zimbabwe and Ethiopia. The World Bank's top five focus countries for investments on wastewater treatment are China, the West Bank and Gaza, Vietnam, Brazil and Tunisia (in that order). The World Bank's investment in wastewater treatment projects has shown a slight upward trend in the period 1990–2019 but with large fluctuations year on year. A 2005 World Bank review of its own portfolio found that about 35% of its total sanitation-related commitments were allocated to wastewater treatment. Between 587 million USD and 949 million USD was spent on wastewater treatment in a sample of 47 projects.[10]

Projects listed on the **Agence Française de Développement** (AFD) website include the North Gaza Emergency Wastewater Treatment Plant grant in Palestine (19 million USD), the East Alexandria WWTP loan in Egypt (100 million USD), support to the Water and Sanitation Company of Santa Catarina (CASAN) in Brazil, and the Xiangyang wastewater collection and treatment system loan in China (33 million USD).

For **Japan International Cooperation Agency** (JICA), there is no searchable project database. They have developed a pamphlet illustrating its major projects on wastewater, shown below, indicating the type and location of investment,[11] but not the financial amount.

Figure 3: JICA's major projects on wastewater



For **EU institutions**, the European Commission International Cooperation and Development search engine[12] produced 49 recent items related to wastewater, of which 16 were relevant WWTP projects, spread across Egypt (four projects), French Polynesia, the Cook Islands (two projects), Kazakhstan, Tajikistan, the Kyrgyz Republic, Tanzania, Myanmar, Tunisia, Lebanon, the Dominican Republic and Peru. The

European Investment Bank's project database records 109 loans for WWTPs between 2000 and 2019, targeted primarily at Mediterranean countries (45 loans, 2,740 million EUR), followed by countries in Africa, the Caribbean, the Pacific and Overseas Countries and Territories (55 loans, 1,687 million EUR) and Asia and Latin American (19 loans, 942 million EUR).[13]

A search on the **Asian Development Bank** project database[14] reveals 22 projects with a component on WWTP, nine of which are closed (in Sri Lanka, Azerbaijan, Nepal and six in China). ADB have seven active projects in China and others underway in Indonesia, Myanmar, Vietnam, Georgia, Mongolia and Nepal.

For **United States Agency for International Development** (USAID), out of a total of 297 WWTP projects USAID supported over the 2008–18 period, only five projects were targeted at low-income countries, while upper-middle-income and lower-middle-income countries had 144 and 125 projects respectively, according to a search on the **USAID** project site.[15] It indicates around 12 WWTP projects between 2016 and 2018 in Jordan, Egypt and Lebanon. USAID has historically also supported wastewater treatment initiatives in Egypt (81), Jordan (59), the West Bank/Gaza (19) and the Philippines (11). The Millennium Challenge Corporation, linked to USAID, has provided finance for a number of projects in lower-middle-income countries, including Cabo Verde,[16] El Salvador and Mongolia.[17]

No detailed information relevant to the topic could be found on the **United Arab Emirates** Ministry of Foreign Affairs and International Cooperation site or the **African Development Bank** site.

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) project website reveals around ten recent and current projects on wastewater, a number of which are in Jordan, including on:
– decentralised wastewater management
– strengthening capacities (state supervision, training specialist staff)[18]
– introducing performance-based service[19]
– piloting co-digestion and reuse of sludge

GIZ has also advised on regulatory frameworks for wastewater disposal services in urban Bolivia.[20] In India, GIZ supported feasibility studies for wastewater treatment and recycling potential,[21] as well as a pilot on co-fermentation of septage and organic solid waste to produce clean energy.[22] KFW, the German development bank, has active projects in the West Bank and Gaza (rehabilitation and extension measures for existing sewage systems and a plant and construction of a WWTP), Yemen (rehabilitation of sewage and pumping systems and construction of a WWTP), Peru (collection and treatment of urban wastewater), Costa Rica (construction of sewage networks and WWTPs), Montenegro (infrastructure for wastewater discharge and treatment) and Kosovo (wastewater disposal and wastewater treatment).

The **UK's Department for International Development** (DFID) has had limited involvement in wastewater treatment. A search on DFID's Development Tracker[23] revealed two recent projects in Brazil funded by the Foreign and Commonwealth Office, although no project documentation is available. One historical example was the financing of work to complete a scheme in Faisalabad, which begun under ADB funding during the late 1980s and was completed with DFID funding as a component of the Faisalabad Area Upgrading Project in the 1990s. In the 1980s, the UK ODA provided funding for wastewater treatment improvements in Cairo.

Other investments in wastewater treatment

Together with donors, the private sector also has an interest in WWTPs. On their website, the International Federation of Private Water Operators AquaFed states that 'SDG target 6.3 presents a clear business opportunity for companies around water quality and wastewater treatment'. The sector has seen a range of Build-Operate-Transfer concession projects on WWTPs, starting in 1999 with the plant in Durban (South Africa) and more recently with a WWTP project in New Cairo (Egypt). In Egypt, the Public-Private Infrastructure Advisory Facility[24,25] provided support to two public-private partnership (PPP) transactions for the wastewater sector and the Government is pursuing several other PPPs in line with its Rural Sanitation Strategy, which allocates 20 billion EGP (over 2 billion EUR (2013)) for increasing wastewater service coverage.

There are also examples of the use of blended finance to support WWTPs; that is, the use of development finance to mobilise additional finance, such as commercial loans – see the example of the Amman[26] project in Figure 5 in the Annex.

Other countries have experience of domestic private sector engagement in wastewater treatment. In China, the great majority – over 80% – of WWTPs have been developed by municipalities through PPPs with local public sector companies. These companies, usually municipally owned, are able to borrow, which municipalities cannot do, so their key role is to provide investment finance as well as expertise.[27] This model is also found in Pakistan, where the Urban Services Corporations (government-owned companies) were set up, as part of the ADB-funded Sindh Cities Improvement Project.[28]

NGOs rarely support WWTPs, but there are some examples of support for smaller-scale FSTPs from WSUP, SNV, WaterAid, BORDA and Practical Action, in cities across countries including Bangladesh, India, Zambia and Madagascar.

This review shows it is difficult to find accurate information on the financing of WWTP. This section has principally looked at capital financing, but one of the main drivers of poor functionality is the lack of recurrent funding, which will be discussed in more detail in Section 4.

3 Studies on the functionality of WWTPs

This desk review identified a range of recent experiences with WWTPs. The following country or city examples were found and are discussed in this section, trying to balance regionally and across income levels.

Table 2: Country examples included

	Stable	Fragile
Low-income	Tajikistan, Ethiopia, Niger, Tanzania, Uganda, Nepal	Zimbabwe, Mali, DRC, Afghanistan, Haiti
Lower-middle income	India, Pakistan, Kenya, Bangladesh, Ghana, Vietnam, Egypt, Indonesia	Myanmar, the West Bank and Gaza
Upper-middle income	Jordan, Namibia, South Africa, Brazil, Mexico	

Low-income countries

Few donors or governments appear to invest in WWTPs in low-income countries. **Niger** is a typical example in that there is no wastewater treatment system, either in Niamey or the other urban centres, except for a few systems managed by commercial operators (hotels, some industries). In some countries, for instance Niger, Ethiopia and South Sudan, this is because limited water availability and the predominance of on-site sanitation. On-site sanitation creates a need for faecal sludge disposal, but FSTPs are usually either absent or poorly maintained.

Existing WWTPs (and FSTPs where present) in low-income countries face a range of issues in operations and maintenance (O&M) and management, as the following examples illustrate.

In **Nepal**, four WWTPs were built in Kathmandu Valley in the 1980s but none are effectively operating today.[29,30,31] In 2002, another WWTP was constructed in Kathmandu Valley but is only partially functioning as the cost of operation is very high.

Elsewhere, WWTPs have been built but never fully commissioned. In Bulawayo, **Zimbabwe**, two WWTPs (Sast 1 and 2) were built adjacent to each other along Khami Prison Road. Sast 1 was built in 1981 but is currently decommissioned. Sast 2 was built in 2002 but never fully commissioned because the firm doing the work pulled out during the country's hyper-inflationary period.

Other low-income countries report malfunctioning technologies. In Dar es Salaam, **Tanzania**, recent reports[32] found that five out of seven wastewater stabilisation ponds were malfunctioning; sewage discharges directly into the Indian Ocean and the Msimbazi River. Reasons for this situation include the selection of technologies, such as activated sludge, that have high operational costs and require a reliable electricity supply, and lack of adequate institutional provision for O&M.

In cities with a high proportion of on-site sanitation, treatment plants may not have the capacity to deal with the over-loading produced by a high volume of high-strength faecal sludge. The National Water and Sewage Corporation (NWSC) of **Uganda** operates 25 treatment plants nationwide; however, overloading of the plants reduces effectiveness and reduces their compliance with national biological oxygen demand (BOD) standards for effluent. The big issue with waste stabilisation ponds (particularly anaerobic ponds) is desludging. As a relatively large task, required at infrequent intervals, this requires organisation to ensure that the financial and human resources needed to undertake it are available. There is anecdotal evidence that difficulties in ensuring the availability of these resources lead to indefinite delays in desludging, with the result that plants eventually fail. In **Ethiopia**, Addis Ababa treatment plants in Kaliti and Kotebe do not have enough capacity to process the city's sludge; a further 15 decentralised WWTPs will come online in 2018.[33] Nevertheless, Ethiopia's 2017 Integrated Urban Sanitation and Hygiene Strategy emphasises the need for safe wastewater management, investment in more decentralised WWTPs, and the introduction of wastewater reuse.[34] The Ethiopian city of Mekelle does have a simple FSTP based on basins that act first as holding ponds and then, when drained, as drying beds, but there is no operator on site and excess liquid overflows from the ponds and is discharged to the environment. Despite these limitations, the system appears to achieve some improvement in sludge quality (observation by author).

Steep declines in gross national income affect the functionality of WWTPs. Harare in **Zimbabwe**, now with poorly functioning systems, was once known to have spent more on sewage treatment than on the sewerage reticulation system.[35] The effluent from Harare's treatment plant irrigated grassland on which cattle were reared and there were functioning treatment plants serving the surrounding 'townships' in 1983. **Tajikistan**,[36] once a middle-income country, has an advanced WWTP in Dushanbe, but O&M has not been conducted over the past 20 years. Limited resources available for the rehabilitation of sewerage and WWTPs has resulted in reduced effectiveness of wastewater treatment.

The fragility of a country is a predictor of the absence of treatment facilities and poor functionality of WWTPs. For instance, many fragile and conflict-affected low-income countries have no centralised WWTPs.

Despite an Integrated Water and Wastewater Sector Policy (2014), **Afghanistan** has no functioning WWTP, and existing septage management systems are informal.[37] In **DRC**, the few historic wastewater networks in cities have not been maintained and are no longer operational, with virtually all treatment plants out of service.[38] The lack of a centralised WWTP in Port-au-Prince, **Haiti**, was one contributor to the cholera outbreak after the 2010 earthquake. As part of reconstruction, the Titanyen WWTP opened in May 2012, with funds from the Spanish Cooperation Agency for International Development (AECID). However, malfunction (huge bubbles in the lining of the second waste treatment pool)[39] meant the facility closed after 18 months.[40] **Mali** might be an exception among fragile countries: Bamako's first WWTP was constructed in 2006 with financing from the Netherlands, although it is not used for domestic wastewater.

Managed by a state-owned company, ANGESEM (Agence Nationale de Gestion des Stations d'Épuration du Mali), the plant treats wastewater from the Sotuba industrial zone.[41]

Lower-middle-income countries

There are more examples of WWTPs in stable lower-middle-income countries, either in their capital city or main cities. Nevertheless, issues with functionality are common, such as insufficient sewerage systems, non-functioning pumping stations, and underloading or overloading the capacity of the plant.

A 2012 report stated that of the 388 cities of **Pakistan**,[42] only eight had wastewater treatment facilities and very little wastewater was treated. Lahore, the second biggest city, has never provided any treatment for municipal wastewater. Prior to 2005, the two activated sludge plants in Islamabad, the capital, were in poor condition. With financial support from the French Government, the French company Veolia refurbished them and built a fourth plant, under a design and build contract, completing the work in 2007.[43] However, it appears that only one plant continued to operate after this date and that this had ceased to operate effectively by 2016.[44,45] The situation in Karachi, Pakistan's largest city, is similar. The city originally had three WWTPs, with a combined capacity of about 680,000m^3/day. By 2005, the capacity had reduced to a third of this figure and by 2015 the plants were not providing any treatment.[46] The waste stabilisation pond system in Faisalabad, Pakistan's third city, should treat around 20% of its wastewater, but a recent document from the Danish Ministry of Foreign Affairs states that the plant is malfunctioning and can only treat 10% of Faisalabad's domestic wastewater.[47] The most likely reason for malfunctioning is failure to desludge the plant's large anaerobic ponds. Sambrial has a small functioning plant based on waste stabilisation ponds, which was provided under the World Bank-funded Punjab Municipal Services Improvement Project; otherwise, there are currently no operational municipal WWTPs in Punjab (observation by author). A WWTP was proposed for Rawalpindi with ADB support, but late land acquisition and other problems meant that the plant was never built.[48] Elsewhere in Pakistan, plants have been designed and built but never used; for example, waste stabilisation pond systems serving Kohat and other plants in Peshawar. The reason seems to have been that effective institutions for ensuring sound operation of the plants were not in place when they were built. In Jatoi, there is a WWTP with treatment in an aerated lagoon, constructed with World Bank funding in 2008. Only 29% of the city's faecal waste reaches the WWTP because almost half of the wastewater in the sewer pipes leaks – this is a result of residents damaging sewers in an attempt to clear blockages. In turn, the treatment plant is only able to treat 40% of the wastewater it receives.[49] In Thatta, there is a WWTP that receives 20% and treats 9% of the city's faecal waste.[50]

In **India**, a 2015 study[51] estimates that only one-third of total wastewater generated in Class I and Class II cities is collected. Another concludes that treatment capacity in those cities stands at only 30% of that required, while an inspection of 115 WWTPs found they were using 72% of their installed capacity.[52,53,54,55] Taken together, these figures suggest that the proportion of wastewater treated in Class I and Class II cities may be as low as 22%. A 2007 Central Pollution Control Board review of the operation of 84 WWTPs in nine states concluded that the operation of 54% of the WWTPs was poor or very poor, with 36% satisfactory and only 10% good.[56] Analysis of the information contained in the review suggests that performance is influenced more by location than type of technology. Performance of most WWTPs in Bihar and Uttar Pradesh was rated poor or very poor, while that of most in Maharashtra and Goa was rated either satisfactory or good. While the reasons for this disparity are unclear, it is significant that the states with poorly performing plants also rate poorly in the governance rankings produced by India's Public Affairs Index.[57]

Much of the effluent from the Jajmau tanneries in Kanpur, Uttar Pradesh, is treated in the city's common effluent treatment plants, sometimes (but not always) after initial treatment at individual tanneries. The National Mission for Clean Ganga is implementing plans to reduce discharge of untreated wastewater, including untreated industrial effluent, to the Ganga river and to treat effluent from tanneries separately from domestic wastewater. Treatment facilities are being financed using a 'hybrid annuity model', where the Government pays 40% of the project cost linked to construction milestones. The remaining 60% is paid over 15 years as annuities to the private concessionaire, along with O&M expenses. The intention is that performance-linked payments will both enhance project viability for the concessionaire and ensure longevity of wastewater assets. Contracts are in place for treatment plants to serve Mathura, Haridwar and Varanasi, with finance provided by the IFC and the World Bank. In all three cases, the contract will be undertaken by an Indian company. A further contract, for a WWTP to serve Howrah in West Bengal, was awarded in early 2019.[58] One of the authors assessed the existing wastewater collection and treatment system in Howrah in the late 1990s. At that time, there were virtually no tertiary sewers and the main pumping station lifting wastewater into the outfall sewer leading to the WWTP was not operational. Later investigations in other cities along the Ganga showed that tertiary sewer networks were by no means complete. A visit to Dehradun, Uttarakhand, in January 2017 revealed that the recently constructed 68,000m^3/day capacity treatment plant was receiving less than 7,000m^3/day of low-strength sewage. These examples show that it is not unusual for WWTPs in India to be initially underloaded, hydraulically, organically or both.

Similar underloading issues can be found in **Egypt**, as illustrated in the images below. In the Orasqulia WWTP (left), located in New Cairo, several of the clarifiers are empty, which suggests underloading. This is consistent with the fact that the populations of the Egyptian new cities are only a small fraction of their design populations. The remaining trees in the image of el Tor plant (right), in Sinai, show that the extent of the irrigation has decreased over the years, perhaps due to reducing wastewater flow to the treatment plant.

Figure 4: Google Earth image of Orasqulia WWTP (left) and El Tor in Sinai WWTP (right)

These two cases, along with the examples in India, highlight a key aspect to consider in PPPs: the need to ensure that the contract with the private sector party is based on a realistic assessment of the likely initial load on the treatment plant and the way in which that load will increase over time. Failure to do so may result in the payments by the public sector partner being higher than is justified by the volume and strength of wastewater treated.

Bangladesh, like Pakistan, has very little wastewater treatment services. The Pagla Treatment Plant, the only WWTP in Dhaka, comprises of sedimentation tanks and waste stabilisation ponds. It was designed to treat sewage from the southern part of the capital city – although its restricted drainage area, limited capacity and inadequate maintenance has meant that only an estimated 2% of human excreta in Dhaka is effectively treated.[59] In recent years, the situation has worsened because the trunk sewer to the plant was severed during road works. A scheme to replace the severed sewer and upgrade the Pagla works was produced under the World Bank-funded Dhaka Water Supply and Sanitation Project (DWSSP). The project ended before implementation could start but the intention is that the works will be executed under the Dhaka Sanitation Improvement Project, which includes upgrading the Pagla WWTP under a design-build-operate contract. The Dhaka Water and Sewerage Authority (DWASA) is seeking funds for five new WWTPs in Dhaka, two of which are currently under consideration for construction.

In Dhaka, there is limited demand for FSM because many people connect toilets to the drainage system, much of which consists of pipes. In this respect, the often-quoted assumption that 20% of Dhaka's population has access to sewerage while the remainder uses on-site facilities is inaccurate. As with other towns in South Asia, the high population density, access to water in or close to the house, high water table and poorly draining soils mean that on-site sanitation is not viable. The existence of wastewater collection facilities, provided more or less informally by municipalities, landlords and residents, needs to be considered when designing new wastewater collection and treatment systems.

In the meantime, municipalities along with numerous agencies (including WSUP, UNICEF, Practical Action and WaterAid) have been testing approaches for improved

FSM[60] throughout the country. Funded by the ADB's Second Urban Governance and Infrastructure Improvement Project, FSTPs using planted drying beds were built in 11 municipalities. FSTPs are not immune to the problems observed in WWTPs: only five of the 11 plants are reportedly functional in 2019. A recent study visited four of these municipalities and found that the Jhenaidah FSTP had to be rehabilitated four years after construction and is now managed by an NGO, the plant in Chowmuhani started operation four years late, the Lakshimpur FSTP has been functioning continuously, and the Narsingdi plant has never been functional.[61] Equally, a separate inspection to another of the Sirajganj FSTPs, suggested that the facilities had never been used.[62]

Kenya's National Sanitation and Hygiene Strategy includes a commitment to ensure that all solid and liquid waste is properly managed by 2020. Although it is estimated that 20% of urban Kenyans have sewerage connections, only 3–4% of urban wastewater receives treatment.[63] Many existing WWTPs are said to be operating well below design capacity (15–20% on average).[64]

Ghana has a total of 44 WWTPs, but only 20% of these are working, and most of these are below their design loading, according to a 2008 study.[65] The two main conventional WWTPs in Kumasi are at KNUST University and Asafo (completed in the mid-1990s). Both have been decommissioned at various points; for instance, the university plant has needed rehabilitation and enlargement as the student population has increased. The Asafo plant is operating below capacity, since only 60% of the intended population is connected. Reasons for the lack of connections include: the cost of water for flushing, the unreliability of the water supply, the charges for using the plant (the sewerage charge – which should in theory cover at least the operational costs of the plant), and the difficulties in making connections. The upflow anaerobic sludge blanket plant near the Korle lagoon in Accra has similar problems and receives only about one-third of its designated capacity.[66]

In **Vietnam**, less than 10% of the wastewater in the country is treated, according to a 2013 review.[67] There were 17 centralised WWTPs in six cities, with total capacity of 565,000m^3/day, many of which were funded by the World Bank. Effluent standards were mostly being achieved. Around two thirds of the plants were operating relatively close to their design capacity, the overall range being 18% to 128%.[68] The plant operating at 18% of its design capacity, in Hanoi city, was only receiving wastewater from a nearby industrial zone and not from the proposed residential service area. There were 31 more plants under design or construction, and the country plans that by 2025, 70–80% of municipal wastewater will be collected and treated properly.[69]

In **Indonesia**, around 90% of the 150 sludge treatment facilities constructed in the 1990s were either closed or barely operational by 2009 and a recent estimate suggests that less than 4% of Indonesia's septage is treated at a treatment plant.[70]

In **Myanmar,** a fragile lower-middle-income country, WWTPs are concentrated in Nay Pyi Taw and Yangon.[71] DFID has recently funded technical advice and recommendations for the rehabilitation of the WWTP in Yangon,[72] while ADB is supporting the development of the country's wastewater quality standard. Japan's Kubota Group intends to build a US$108 million plant in Thilawa Special Economic Zone. Mandalay City Development Committee has partnered with the Thai-based Hydrotek Public Company to build a plant and collection system there.

In Palestine, **the West Bank and the Gaza Strip** have received substantial donor support to address wastewater treatment. JICA supported a WWTP in Jericho that opened in 2014, as well as the sewerage network in Aqbat Jabr refugee camp in 2017 that connects to that WWTP. The World Bank, AFD, Belgian and Swedish cooperation and the European Commission funded the North Gaza Emergency Wastewater Treatment Plant, which took 13 years to build.[73] In the West Bank, estimates suggest only one-quarter of wastewater is treated. Jericho has five major WWTPs, 13 smaller WWTPs, and more than 700 small-scale on-site WWTPs. Some wastewater flows into Israel, where it is treated and reused in agriculture. Israel charges the Palestinian Authority for treating this wastewater (more than 26 million USD in 2016). In the Gaza Strip, about 90% of wastewater is collected and partially treated. Treatment plants are overloaded and function poorly, partly because of underfunding and partly because of Israeli restrictions on the entry to the Gaza Strip of energy and materials. Israeli bombing has affected one of the Gaza Strip's treatment plants.[74] Partly treated wastewater is discharged into wadis[ii] and directly into the sea.

Upper-middle-income countries

There are more examples of WWTPs in upper-middle-income countries, particularly in Central and South America. However, in Latin America,[75] only about a third of wastewater is treated, the proportion varying from 4% in Costa Rica to 99% in Chile.[76] Although less frequent, there are also examples in upper-middle income countries of poorly maintained and non-operational WWTPs.

Brazil's SNIS (National System for Information on Sanitation), produces yearly reports on sewage collection and treatment. The reports are based on the response of service providers to questionnaires – in 2013, it was filled in by 67% of the municipalities, containing 91% of the urban population. More detailed information on performance is contained in the 'Sewage Atlas' produced by Brazil's National Water Agency (ANA), which showed that in 2015, half the population was connected to sewerage and about 70% of the sewage collected was treated.[77] Around 1,900 (34%) municipalities were served by a total of around 2,800 treatment plants. Ponds and upflow anaerobic sludge blanket systems (UASBs) were the most common treatment technologies, with a much smaller proportion of activated sludge systems and aerated lagoon systems.[78] A similar split is common elsewhere in Latin America – ponds being the most common technology, followed by activated sludge and UASBs.[79] A 2011 study assessing the performance of 166 plants[80] found that across all technologies, biological and chemical oxygen demand effluent concentrations were higher than predicted in the literature, but still close to design values (anomaly explained by low influent concentrations). UASBs followed by post treatment were closest to achieving the predicted

[ii] A valley, ravine or channel that is dry, except in the rainy season.

performance. Removal of faecal coliforms was better than expected for most technologies, the exception being UASBs, which also performed poorly in removing total suspended solids.

In **Mexico**, despite the national water programme including 100% treatment goals for municipal wastewater by 2030, there are many accounts of poorly maintained and non-operational WWTPs. The Special Rapporteur on the Human Rights to Water and Sanitation, after a visit to the states of Chiapas and Mexico in 2017, reported that expensive WWTPs were standing useless as a result of lack of maintenance. Only 12 out of 194 plants in Chiapas were functioning; in its capital, a tourism hub, San Cristobal de las Casas, wastewater flows untreated into water sources.[81] The social accountability initiative ControlaTuGobierno[82] has been monitoring wastewater treatment performance in Mexico. In visits to ten WWTPs they found three cases of reportedly operational plants for which construction was incomplete, one non-functioning plant, four partially functioning plants, and one with good functionality. The partially functioning plants presented a variety of issues. In one case, only parts of the plant are functioning, so the wastewater is effectively not being treated. Another suffers intermittent functioning, while a third has high levels of deterioration and abandonment. The fourth treats the wastewater, but there are overflows at the intake and faecal sludge is disposed of untreated. Development of new wastewater plants, as well as upgrades to existing wastewater plants, is planned, financed through PPPs, a model recently adopted through the Public and Private Partnership Law.

South Africa has also taken steps to monitor the state of the nation's wastewater infrastructure; the South African Institute of Civil Engineers reports in 2017[83] that 30% of the country's water treatment and wastewater treatment works are in critical condition, discharging increasing quantities of untreated waste into streams. 66% of all WWTPs require short- to medium-term intervention, 35% require capacity upgrades and 56% require additional skilled O&M staff.[84]

Reclaimed wastewater has been used in many countries to improve the financial sustainability of WWTPs. For instance, in Windhoek, **Namibia**, a water reclamation plant was established in 1969, in response to a prolonged drought. The Wastewater Reclamation Strategy assigns a role to the Government in reclaiming and treating wastewater to the standard of drinking water.[85] More recent experiences of reuse of wastewater and other treatment products in Bolivia, Brazil, Mexico and South Africa have been documented by the World Bank.[86]

Jordan currently has 28 WWTPs treating 98% of collected water.[87] The Jordanian National Strategic Wastewater Master Plan of 2014 calls for all cities and small towns in Jordan to have adequate wastewater collection and treatment facilities by 2035. Jordan's Water and Wastewater Infrastructure Project[88] has the objective of improving the management of wastewater facilities over the next 25 years through provision of improved wastewater infrastructure facilities, training and capacity building. USAID has expansion and upgrade plans for WWTPs in refugee-hosting communities, as there are reports of overloading.

Summary of existing evidence on functionality

The literature illustrates the multiple challenges centralised sanitation systems face. There are various accounts of WWTPs not fully built or built but never commissioned. Where they exist, many WWTPs face a range of functionality issues in O&M and management. They range from malfunctioning technologies, problems in the sewerage systems, underloading (for example, insufficient wastewater reaching the plant) and overloading (for example, a high proportion of sludge from on-site sanitation). While these issues seem most frequent in low-income countries and to a lesser extent in lower-middle-income countries, they are not uncommon in upper-middle-income countries, as Table 3 shows. Fragility also seems to increase the incidence of these problems.

Table 3: Summary of the status of the plants in the studies reviewed

	Location	Never functioned	Stopped functioning	Malfunction / partially functioning	Functioning well
Low-income	**Kathmandu Valley, Nepal**		4 plants (1980s) not operating today	Plant (2002) partially functioning	
	Bulawayo, Zimbabwe	Plant built but not commissioned	Plant decommis-sioned (1981)		
	Dar es Salaam, Tanzania			5 plants (of 7) malfunctionin g	
	Uganda			25 plants with overloading	
	Addis Ababa, Ethiopia			2 plants overloaded	
	Mekelle, Ethiopia			FSTP has overflowing ponds	
	DRC		Virtually all plants out of service		
	Port-au-Prince, Haiti		Plant (2012) closed after 18 months		
	Bamako, Mali				Plant (2006) functioning well
Lower-middle-income	**Islamabad, Pakistan**		2 plants stopped functioning	Plant functioning partially	
	Karachi, Pakistan			3 plants not providing any treatment	

	Faisalabad, Pakistan		Plant not functioning		
	Sambrial, Pakistan				Plant operational
	Rawalpindi, Pakistan	Plant never fully built			
	Kohat, Pakistan	Plant built but never used			
	Peshawar, Pakistan	Plant built but never used			
	Jatoi, Pakistan			Plant functioning partially	
	Thatta, Pakistan			Plant functioning partially	
	India			115 plants at 72% capacity	
	India			Poor/very poor operation of 54% plants (of 84)	36% plants satisfactory and 10% good operation (of 84)
	Egypt			Two plants underloaded	
	Dhaka, Bangladesh			Plant partially functioning	
	Kenya			Many plants below capacity (15–20%)	
	Ghana		80% plants (of 44) not functioning	Most of the 20% plants in operation are below design loading	
	Asafo, Ghana			Plant operating below capacity	
	Accra, Ghana			Plant operating below capacity	

	Vietnam			About a third of plants operating substantially over or under capacity	Most of 17 plants meeting effluent standards and working close to capacity
	Gaza Strip, Palestine			Plants are overloaded and function poorly	
Upper-middle-income	**2 states, Brazil**				166 plants mostly meeting effluent standards
	Chiapas state, Mexico		182 (of 194) plants not functioning		
	Mexico state and Mexico DF, Mexico	3 plants (of 10) not fully built	1 plant (of 10) not functioning	4 plants (of 10) partially functioning	1 plant (of 10) with good functionality
	South Africa			30% plants discharging increasing quantities of untreated wastewater	

4 Experiences

This section presents the common challenges and barriers to the performance of WWTPs, highlights promising practices, and considers priority actions moving forward.

Challenges to functionality

One 2013 review of wastewater treatment practices in seven African countries identified the main challenges hindering the performance of WWTPs.[89] The most frequent challenge was high O&M costs (especially power costs), which were not matched by sustainable funding. Other frequent issues included power cuts, pump failure, overloading, compliance with regulation, complaints (odour, mosquitoes), capacity of workers, industrial wastewater inputs, and presence of solid waste (more details in Table 5 in the Annex). A World Bank report focusing on Latin America highlighted four challenges: (1) disconnect between central government agencies funding the plants and local governments running them with scarce skills and resources, (2) overly ambitious 'imported' regulations that leave no room for gradualism, (3) limitations on resource recovery from treatment end products, (4) infrastructure not adapted for poor people (for example, expensive connections).[90] The most common challenges identified from the case studies and in the literature are presented in this section.

Technical and capacity issues

Technology choice and technical capacity

It is important to ensure the technical capacity – management systems, skills and supply chains – required to manage the chosen technology are in place. Otherwise, the technical choice must be categorised as inappropriate.

Inappropriate technology selection and inadequate process design and detailed design

Technology selection might be inappropriate for the operational environment, common when attention is not paid to life cycle costs. In particular, the high costs of energy-intensive technology might affect operation. However, there are also instances of simple technology and cost-effective solutions (like facultative lagoons) not being maintained.

Operation not matching design criteria, breakdown of equipment and inadequate technical back-up

Sometimes poor operation is inevitable because of poor design:

- Hydraulic loading may be lower than the design loading, because of lack of demand for pit-emptying services in the case of septage treatment plants and a lack of sewer connections in the case of WWTPs.
- Change in raw wastewater quality, caused by uncontrolled discharges into the sewage network (for example, from industrial discharge or other illegal connections).
- Frequent electricity outages disrupt treatment processes/pumping. A report on Kanpur in India prepared by a local NGO provides detailed information on pumping station operational procedures during power outages, identifying the fact that, while diesel generators were provided, they were often not used because of the high cost of diesel.[91]
- Flows into the works that are larger than included in the design.
- Volume of sewage received at the plant is less than intended because of breaks in the sewerage system.
- Use of combined sewers for sewerage and storm water can reduce the effectiveness of treatment during the rainy season, leading to WWTPs receiving more inflow than they can cope with. The absence of adequate storm drainage systems often makes treatment plants inoperable during extreme rainfall events.[92] Worldwide, the normal response is to provide overflows, storage in the system, or a combination of the two.

Workers' capacity and incentives may be inadequate to plan operations or maintain plants
The skills required to operate and manage WWTPs and FSTPs are often scarce. The problem is exacerbated because plant operatives are often low in the staff hierarchy, with limited decision-making powers and no prospect of promotion. Technology choice is directly affected by utility/service provider capacity – if those making the decisions about technology choice do not understand the implications of choosing certain technologies regarding their ease of operation, energy requirements, and so on, unmanageable WWTPs is the most likely result.

Financial considerations

Insufficient domestic investment
Most countries experience financial shortfalls that can affect construction, O&M or upgrading of WWTPs. Underloading has an impact on finances when the operator is paid based on the amount of wastewater treated. Brazil, where service providers aim to cover the investment costs via the tariffs, seems to be an exception.

Inadequate analysis or consideration of operational expenditure
There tends to be more emphasis on capital expenditure of WWTPs rather than planning whether operators can afford to run or pay for the plants in the long run, and whether operators have the ability and willingness to hire and train appropriately qualified staff. Those preparing cost estimates for construction may underestimate the full costs of operational expenditure (unintentionally or otherwise).

Lack of household connections
Without household connections, the health, environmental and convenience benefits of sewerage are not realised for the residents and the larger community. If residents do not connect to the network, the WWTPs are under-used leading to poor performance of treatment facilities, and the service provider does not get the planned return on investment. Reasons for the lack of connections vary from place to place. They may include a lack of incentives for the household to connect, including a lack of enforceable legal sanctions against those who do not connect. In some cases, for instance the Howrah case already mentioned, the problem is not so much households not connecting, but a lack of tertiary sewers. Where existing sewers are deep, the cost of connection may be high, and in many countries this cost must be met in its entirety by the connecting household, creating a powerful disincentive for connections. In some cities, many households discharge wastewater to existing informal drainage systems, resulting in another disincentive to connect.

The case of Sihanoukville in Cambodia is a good example. A WWTP was constructed with an ADB loan and completed in 2005. The investment cost (11 million USD) was paid by the government. In the years after its construction, only around 20% of the households have connected (this requires a one-off connection fee and a monthly wastewater fee). It cost almost 5,500 USD per connected household based on its expected operating capacity (or 544 USD per year, based on a 20-year lifespan and discount rate of 8%). The actual construction cost of 27,500 USD per household is five times the planned cost per household (according to a report produced ten years after the plant was constructed).[93]

Operational costs and tariffs
While construction costs are often met by higher levels of government, operational costs are usually the responsibility of local service providers. Tariffs are typically the main funding mechanism for WWTPs to cover O&M costs. User charges for wastewater are generally tied to piped water consumption, at least for those users that discharge into publicly provided sewerage systems.

A common problem in Africa and Asia is that the wastewater tariff charged to customers is insufficient to cover the full costs of the operation of WWTPs. In many cases, the wastewater tariff is lower than the water tariff, although wastewater removal services normally cost more than water supply services. Where tariffs are insufficient to cover operational costs, providers have the option of subsidising from other sources of income or reducing operational costs below the levels required for sustainable operation. Reducing operational costs will usually result in a reduction in service level, possibly leading to poor effluent quality or, in extreme cases, no treatment.

In Jordan, the Government is considering a revision of water tariffs to ensure that O&M costs of municipal water and wastewater services are covered by around 2020.[94] There are places where wastewater tariffs have even been used to provide funds for expansion, maintenance and operation of the existing systems. In Thailand, each household is charged 60 baht (2 USD) per month and hotels or other business entities are charged a higher tariff. In Zambia, the Lusaka Water Company has begun a sanitation surcharge to fund the extension of a piped wastewater collection system.[95] In China, the 13th Five-Year Plan required an increase in wastewater tariffs across the country to cover sludge treatment costs.

Institutional blockages

Weak management
This relates to the way in which service provision is organised. Management covers complaints response, performance management and financial management systems, IT training and planning. Management structures require skilled staff, and financing for administrative capabilities. In many countries wastewater treatment is a municipal responsibility, but municipal authorities, and even specialist water and sanitation providers, do not see treatment as a priority. Also, recruiting systems and salary structures often mean that it is impossible to employ and retain staff with the skills needed for effective management and operation. It is difficult to find middle-level managers with experience of working in a well-managed utility. Senior officials may be responsible for operation of services, but lack knowledge of and interest in operational issues. In certain instances, WWTP operators receive no formal training but learn on-the-job, meaning their technical knowledge is incomplete.

Failure of procurement systems
Often, there are no spare parts and the process of getting them replaced can be a time consuming and expensive process, for example, if regulation means that every supplier in the country must be checked before they can be ordered from abroad. Payment to external equipment suppliers may require hard currency, particularly when those suppliers do not have agents in-country.

Inadequate policies
A review of the GLAAS Country Highlights[96] (see Annex, Tables 6 and 7) reveals that nearly all participating countries include provision for municipal wastewater collection/treatment in their national sanitation policies and plans. However, only a few low- or middle-income countries report they have a plan for their WWTPs and are implementing it. Middle-income countries are more likely to have a plan and report high-moderate implementation. The review also indicates that low- or lower-middle-income countries are less likely to have a plan to maintain sewer systems and treatment facilities. The Country Highlights for Mozambique, Pakistan and Tanzania, however, do not include a reference to FSM, while others fail to refer to the safe use of wastewater in their plan/policy – for example in South Sudan, Bangladesh, Timor Leste, Zambia and Kenya. Yet, there are inconsistencies in the available data. For instance, not all the participating countries that reported implementing a wastewater treatment plan in their GLAAS country submissions, appear to monitor indicators for wastewater treatment according to the JMP records – for example, wastewater treatment data is missing on the JMP database for Botswana, Thailand, Nigeria and Kenya. As might be expected, there is a gap between self-reporting and what happens on the ground.

Policies not translated to action
Some countries include wastewater treatment in their national sanitation policies. However, few of these policies and strategies have been formally adopted and implemented. Lack of implementation of national policies is linked to the lack of clearly defined responsibilities and a lack of budget. Examples include Benin, which adopted a National Strategy for Wastewater Management in 2008, the same year Burkina Faso validated an Implementation Strategy for the treatment of wastewater and excreta in rural areas. Some countries included wastewater treatment in their country commitments at the SWA High Level Meetings. For example, in 2017 Tanzania committed to ‘give greater attention to on-site sanitation as well as wastewater treatment and faecal sludge management and implementation of promotional and regulatory measures to encourage private sector participation’.[97] The extent to which this has been followed through is not known.

There are many wastewater master plans that have never been implemented or only partially implemented. The reasons for the gap include that policies and strategies are often produced by consultants that are foreign to the country where the WWTP is based and not familiar with local context. But the more important reason is that these strategies pay insufficient attention to the institutional systems that need to be in place if they are to be successfully implemented. There is also a widespread failure to review policies and strategies, to find out how they worked out in practice and to rectify weaknesses.

On the other hand, there may be political will without capacity. In Cambodia, one minister recently stated that ‘not one more drop of wastewater will enter the sea’ – because the sea and beach are turning black and tourists are staying away. This resulted in all wastewater being pumped to the city’s one WWTP that was already over capacity (serving the local beer factory) and not functioning to design. Engineers were designing ad hoc upgrades to the WWTP with no realistic possibility of providing adequate treatment for the increased load.[98]

Regulation

Information on the actual performance of WWTPs and their compliance with environmental and public health effluent standards is limited. It is possible for WWTPs to deal with their design hydraulic load but fail to achieve their design performance in terms of effluent quality. Poor design and poor maintenance can result in rapid failure, which is likely to be ignored if regulatory systems are weak or absent, as is often the case. Untreated or partly treated effluent may then be used to irrigate crops, either directly or after being pumped out of the agricultural drains to which it is discharged. If discharged to watercourses, poorly treated effluent reduces the receiving water quality.

The capacity of regulatory authorities is critical to ensure treatment complies with national or regional standards, as well as to collect and publish WWTP performance data. In Thailand, the Enhancement and Conservation of National Environmental Quality Act (1992) allows for penalties in case of lack of treatment and disposal of untreated wastewater, but regulatory agencies may not have the capacity to police illegal disposal and enforce the penalty. Costa Rica’s Regulation on the Approval and Operation of Wastewater Treatment Systems ensures complaints on wastewater treatment can be sent to the Ombudsmen Office. However, the gap between regulatory standards, which most countries have, and ability to enforce discharge standards is a critical issue. For instance, in Panama, discharge standards are so strict that it almost verges on unsustainability. Environmental protection organisations often lack resources, and testing of effluents is either infrequent or non-existent.

Demographic trends

Most towns and cities in lower-income countries are experiencing large surges of population growth, resulting in increased wastewater generation. Financial constraints and failure to prioritise treatment mean that provision for treatment usually follows rather than precedes growth. The result is that WWTPs receive loads that exceed their capacity. Long periods of time between identification of the need and the plant commissioning contribute to this problem and are often associated with receiving approval to proceed with design and construction, and difficulties in acquiring land due to its high price and reluctance of people to live near a treatment plant. For instance, in Faisalabad, Pakistan, land theoretically reserved for treatment at the master planning stage had been encroached and surrounded by housing long before the funds to acquire it had become available.

In recent years, internal displacement of people in Angola, Iraq, Palestine and Syria, among others, has put more pressure on the operating capacity of wastewater facilities and damaged sewerage networks. Operating and maintaining WWTPs for refugees in camps and informal settlements as well as host communities is another challenge – for example, in Jordan and Lebanon.[iii]

Lack of information on wastewater quality and flow

Data is often not available from national authorities' statistical offices and sanitation regulators. International agencies, including the World Bank, and regional development banks, such as the ADB, promote the concept of benchmarking, using the methodologies developed by the International Benchmarking Network (IBNET). The IBNET database provides information on sewer coverage and overall revenue and cost information but does not cover wastewater quality and flow. There are few national – and virtually no regional – benchmarking associations dedicated to wastewater services in Africa, Asia or Latin America.[99] Examples of national and sub-national benchmarking initiatives include Brazil's National Sanitation Information System (SNIS), established in 1996. Tanzania has carried out performance benchmarking through Memorandums of Understanding (MoUs) with urban water supply and sewerage authorities (UWSAs), and established a computerised information system, Majls, in 2006. In 2009, India initiated the Service Level Benchmarking (SLB) for urban water supply and sanitation. This provides service level indicators for each sector along with guidelines on developing information system improvement plans and performance improvement plans for cities.[100] JMP found that data on wastewater treatment was available from 115 countries, representing 88% of the global population with sewer connections. See Figure 6 in the Annex for an IBNET global heatmap on wastewater treatment.

The problem is the lack of data on performance. Indian treatment plants normally have good records of influent and effluent quality, but many countries lack consistent (year-on-year) influent and effluent data. Some have performance indicators tracking the percentage of population benefitting from modern wastewater systems (Iran) or performance monitoring of utilities. Some countries, including Jordan and Brazil, collect data on wastewater at a decentralised level (focal points within communes are trained to collect data on wastewater treatment facilities in Burkina Faso).

[iii] Jordan hosts over 700,000 registered refugees from Iraq and Syria, of which 90% are living outside of camps; while in Lebanon, the water infrastructure is struggling to serve the 1.5 million refugees that represent the equivalent of one third of the Lebanese population.

Options for the ownership and provision of WWTPs

The main options for ownership and provision include:

- Public ownership and operation by enterprise or department
- Public ownership with operation contracted to the private sector
- Private ownership and operation, often with regulation
- Community and user provision

Public ownership and operation by enterprise or department

Effective public sector performance is possible where there is a strong organisational culture, good management practices, effective communication, rules and regulations, procedures, meaningful work, shared professional norms, teamwork, individual performance, promotion based on performance, training and skills. Achieving these conditions will often require substantial investment.

In China, projections for municipal water demand mean that current municipal wastewater treatment capacity will have to increase significantly. Many WWTPs are run as public companies in China under a system by which public agencies/utilities are transformed into independent corporations.[101] These enterprises keep separate accounts, take full responsibility for profits and losses and pay taxes. These models exist alongside other models, which involve the private sector. In Egypt, a public sector Holding Company (wholly owned by the Egyptian Government)[102] ensures the functioning of the water and sanitation sectors and covers the difference between operating costs and user charges.

Public ownership with operation contracted to the private sector

In the past, governments were often criticised because of their perceived inability to provide, operate and maintain the public services required to keep pace with rapid urbanisation and population growth. The deficiencies identified included inadequate accounting for costs and financial risks, lack of incentives to satisfy consumer demands, failure of the public sector to provide equitable access to public goods, user fees which did not reflect real costs, and the uneconomic use of resources. In light of these perceived weaknesses, since around 1990 international agencies and, to a lesser extent, governments of low-income countries have supported efforts to involve private sector actors in infrastructure and service provision. Private sector models have been advocated to bring the efficiency and user responsiveness of business practices into WWTPs/services. This is intended to achieve greater productivity, reduce O&M costs, counter a lack of accountability, mismanagement, corruption, bureaucracy, and a lack of incentives for local personnel, and curb political interference.

Since wastewater treatment is a public good, there are oversight issues where government is not strong. It is important to recognise that private sector involvement does not remove the need for effective government agencies to prepare, place and regulate contracts with the private sector. If government capacity to regulate is limited, private sector solutions will not work effectively.

Options for involvement in low-income countries range from simple lease and management contracts through to concessions, involving payment by the public service provider to the private sector contractor.

In Colombia, the Government is developing several new WWTPs to overcome a lack of government investment and cost overruns in municipal water treatment systems. Two cities in Colombia contracted operations out to 'mixed' companies, jointly owned by the municipality, a private operator and local private shareholders, with the city authorities retaining ownership of the infrastructure. Brazil has a similar experience. The Atotonilco de Tula plant in Mexico treats wastewater generated in the valley of Mexico. It is 54% funded by the private sector and operated by a private consortium. Other Latin American cities in Brazil, Colombia, Chile and Mexico have adopted a build-operate-transfer approach to WWTP construction.[103] The options for this involvement range from simple service contracts through various types of management contract to concession contracts, franchises and complete disinvestment.[104]

The experience of the UK with the Private Finance Initiative has raised the challenge to develop and monitor effective contracts that can be successfully implemented at justifiable prices. In doing so, it is important to consider the long-term implications of the contract. For instance, WWTPs often work in their first year since the first year's operating budget is included in the contract. This will not guarantee long-term operation where the technology selected has high power costs and/or sophisticated O&M needs. More recent experiences with design-build-operate contracts have been more successful (for example, with the World Bank in Vietnam and Tanzania) where the client finances the investment and a company operates a five-year contract. Longer contracts (10–15 years or even longer) avoid incentives to choose technologies that have lower capital costs and higher operational costs, and help the private sector develop the capacity to operate and maintain these facilities.

In India, the private sector provides services to public sector wastewater management entities. The scope of these services varies from design and construction through to plant operation, under service and management contracts. In some cases, contracts for design and construction include provision for a period of subsequent O&M. An example is the contract awarded to the Pune-based company Thermax to upgrade the Diggian plant, serving Chandigarh and the surrounding area. The contract involved installation of new units to double the plant's capacity, including moving bed biofilm reactors, and included ten years' subsequent operation, subject to a satisfactory performance over an initial six-month period. Construction was completed in 2008 and was achieving a satisfactory effluent in 2013.[105] More recently, as indicated elsewhere, Indian private sector companies are involved in the construction of new treatment plants as part of the Clean Ganga programme.

There have been mixed experiences in the past with concessions in the water sector. Concessions to a private company were typically structured so that the company would recover their costs of investment over a long period (for example, 30 years). However, in some settings, an unreliable political environment meant that companies wanted to recover their costs as soon as possible, with high tariffs leading to a public backlash against the company. Concessions were more successful in the Philippines, Brazil, Vietnam and Nicaragua.

Private ownership and operation

There are many examples of private sector involvement, both formal and informal, in water supply provision, while landlords and communities may fund the construction of sewerage. In contrast, there are very few examples of private sector ownership and operation in wastewater and faecal sludge treatment. The reason for this lies in the public good nature of treatment; it is very difficult to make a profit from treating wastewater and faecal sludge. One recent example was the Pivot Works faecal sludge treatment initiative in Kigali, Rwanda. The aim was to treat faecal sludge to the point where it could be sold to industry as a solid fuel. Unfortunately, the initiative proved to be financially unsustainable without continued donor support and the Pivot Works 'factory' closed after fewer than three years' operation. The key to success for exclusively private sector involvement in treatment would be end products that can be sold at a profit. If this becomes a reality in the future, it will be essential to ensure robust and functioning regulatory systems are in place.

Community and user provision

In many contexts, social enterprises are developing innovative technologies for small wastewater treatment systems, such as decentralised wastewater treatment systems (DEWATS) and working with the local government to scale them. One successful example is the AguaTuya community-run decentralised water supply and wastewater systems in Cochabamba, Bolivia.[106]

Other potential problems with community supply of water supply, sewerage and wastewater treatment include difficulties in sustaining services over time and problems with either duplicated provision or gaps in provision. The second is the more likely scenario in relation to wastewater treatment. Examples of lack of sustainability of sewerage projects include the complete disappearance of the initiative in Sukkur, Pakistan, inspired in the Orangi Pilot Project. This won an Agha Khan award in 1993 but there was no trace of the sewers constructed through the project when one of the authors visited the project area about 15 years later. Further research is needed, but it seems that, given the fact that unit costs decrease as the scale of production increases, community provision is unlikely to achieve results city-wide. There are, however, situations in which community-led provision may provide an option for areas that are difficult or expensive to serve by centralised provision, as is the case in Cochabamba, Bolivia.[107]

Sustainability

Sustainable operation of WWTPs requires attention to a range of factors, including human capacity (adequately trained staff and good management), appropriate technology, institutional capabilities, financial resources, and environmental sustainability. Promising practices that have the potential for sustainability of WWTPs include:

Human resources, skills and capacity
ADB has supported the Water Operators Partnerships (WOPs) programme, which includes twinning partnerships between mentor and recipient utilities, and master classes and executive courses on aspects of WWTP operations. In Myanmar,[108] the twinning agreement provided step-by-step training to improve the performance of the Yangon WWTP. In Indonesia,[109] the twinning focused on two cities where treatment plants that were built in 2015 but not commissioned or operational at the time, reportedly due to lack of operational capacity. There were twinning initiatives between Lahore Water and Sanitation Agency in Pakistan and North West Water in the UK in the 1980s, but it did not appear to resolve weaknesses in the management culture. Similar examples exist – including Severn Trent Water in the UK and the Water and Sewerage Authority in Chennai, India – and show that such initiatives can often be a 'sticking plaster' with limited impact if the institutions themselves are not willing to learn, change and develop. Twinning needs to be part of a more radical and comprehensive approach to institutional strengthening and/or changing institutional culture.

Since 2017, GIZ has supported vocational training for the wastewater sector in Vietnam, leading to people becoming accredited as a 'Skilled Employee for Wastewater Technology'.[110] Vietnamese instructors/teachers cover a curriculum including O&M of municipal and industrial WWTPs; wastewater and sludge treatment processes; management and documentation of plant O&M processes; safety in WWTPs and the basics of metalworking, electrical works and construction works. Such initiatives require the internal staffing structures and workplace culture to allow people to use the training they have received.

Inclusive and appropriate technical design
For an 'all-city' solution, WWTPs need to be designed for extra load from faecal sludge collection, together with a receiving station that can provide robust technical pre-treatment with efficient screening to avoid overloading mechanical systems. Registers of private operators, records of loads delivered and charges for discharging at treatment facilities will improve effectiveness of treatment of loads delivered to the WWTP.[111]

Sophisticated WWTPs are not necessarily the most viable option in many low-income or fragile countries. For instance, in Moldova, the poorest country in Europe, a WWTP has a simple technical option – constructed wetlands with three to four operators. Simpler DEWATS have been pioneered by NGOs such as BORDA and IWMI. In South Sudan, USAID is supporting small-scale wastewater treatment (septic systems, small plants).[112] These might be appropriate for schools and other institutions, and perhaps some higher income and commercial areas. DRC has piloted decentralised WWTPs in peri-urban areas in collaboration with the Association of Drinking Water Networks Users. DEWATS have the potential to reduce the space required for treatment and the investment and O&M costs. The per-capita cost of small decentralised solutions like

DEWATS may be higher than that of centralised solutions because the facilities lose the benefits of economies of scale, or lower if they avoid the costs of long wastewater trunk mains. DEWATS mostly include anaerobic baffled reactors, which are relatively small and enclosed, avoiding smell problems. The challenge with these systems is desludging,[113] as shows a 2014 in-depth assessment of the performance of DEWATS systems in India and Indonesia.[114]

Financial sustainability
Several experiences illustrate efforts to ensure service providers/utilities responsible for the operation of WWTPs, and for cost recovery, do cover their operational costs.

In China, the national infrastructure bonds floated in 1998 and 1999 were partly used to underwrite municipal water-supply and wastewater. The World Bank has promoted the idea of **municipal bonds** in several countries but there are relatively few places where the conditions are right for it. Colombia has a wastewater pollution tax (tasa retributiva) that finances WWTPs.

Due to public finance constraints and the phasing out of official development assistance, Vietnam is seeking investment from the private sector to develop its wastewater collection and treatment systems. In Indonesia, the Central Government is aiming to develop mechanisms whereby local water authorities can enter into joint ventures and contractual arrangements with the private sector. The Ministry of Water Resources in India formulated a policy for PPP projects in the municipal wastewater sector through an innovative hybrid annuity model under the National Mission for Clean Ganga.

Various cost recovery models based on use or sale of the products of treatment have been trialled. In San Luis Potosí, Mexico, a power plant uses treated effluent from a nearby WWTP in its cooling towers. This wastewater is 33% cheaper than groundwater, resulting in savings of 18 million USD for the power utility over six years. The extra revenue covers almost all O&M costs of the WWTP. In Durban, South Africa, a WWTP provides tertiary treatment sufficient to render the effluent suitable for reuse in the paper industry.[115] Namibia has long pioneered sustainable wastewater management processes, with its first wastewater reclamation plant opening in 1968 in Windhoek in response to its arid climate. A second plant has promoted the use of biogas and sale of treated sludge as fertiliser. In Santiago de Chile, Chile, the WWTP treatment plant sells biogas. The WWTP in Santa Cruz de la Sierra, Bolivia, has anaerobic lagoons intended to generate biogas, which if converted into electricity would cover most of the utility's power demand, but regulations impede the transportation of electricity outside the WWTP.[116,117] Experience suggests biogas production is often much less than predicted and can't entirely cover the power demand. Dual fuel motors that can use biogas in a WWTP are an option that has, for instance, been used in Varanasi, India.[118]

Innovative approaches include Haya Water in Oman, which intends to register its sewage treatment systems for UN carbon credits, but it is unclear what percentage of the operational cost/energy can be recovered. In the Sanitation Challenge for Ghana, sponsored by DFID and the Bill and Melinda Gate Foundation, the Ministry of Sanitation and Water Resources awards municipalities with a prize for those that present the best sanitation strategies. In one example, Kumasi Metropolitan Assembly identified three WWTPs for rehabilitation and has secured partnership to rehabilitate two.[119] There are also examples of environmental agencies having been established.

Social accountability

Citizens and civil society groups have instigated activities to increase public participation in decision-making on WWTPs and improve transparency and accountability. In Mexico, ControlaTuGobierno[120] has been monitoring WWTPs, using the reports of the Superior Audit of the Federation. ControlaTuGobierno documents any problems with the plants, runs community training sessions and produces documentaries related to the management of water resources. In Kanpur, India, the NGO Eco Friends has also monitored the performance of wastewater collection and treatment systems for many years. And in Brazil, the NGO TrataBrasil was set up to draw attention to issues of wastewater treatment.

Promoting household connections

Household connections have been promoted through innovative finance, such as revolving funds; subsidising the connection (connection fee and/or tariff); behaviour change campaigns; and enforcement. A social assessment is often needed upfront to understand how best to increase household connections.

In Vietnam, revolving funds with social banks together with subsidised loans and grants for behaviour change outreach were used as part of a sewerage programme in coastal cities. In Brazil, the Companhia Espírito Santense de Saneamento uses a variety of participatory methods to communicate the importance of connecting to the sewer system to the citizens of Espírito Santo, while in São Paulo the Companhia Saneamento Básico do Estado de São Paulo subsidises connections to low-income households. Colombia’s Ministry of Housing administers the intra-household connections programme, which subsidises sewer connections and sanitary facilities for the nation’s most vulnerable families.[121] In Sri Lanka, an output-based programme supported the connections of low-income households to the sewer network through simplified sewers.[122] This and similar initiatives, such as the Brazilian condominial sewers and the Pakistani Orangi Pilot Project’s community-constructed sewers, have lower connection costs and deliver local sewers and house connections as an integrated package. A challenge in Pakistan was to get the sewerage service provider to accept community constructed sewers, built to standards different to official standards, as part of the formal sewer system.

5 Conclusion

The problem and its causes

Worldwide, the proportion of wastewater and faecal sludge that is treated is low. The problem is particularly acute in parts of Asia and Africa. Even if SDG 6.3 is achieved in 2030, 15% of wastewater in high-income countries, 31% in upper-middle-income countries, 36% in lower-middle-income countries, and 46% in low-income countries[123] will still be left untreated. Currently, much of this wastewater is used, untreated, to irrigate crops.[124] Wastewater (and faecal sludge) treatment is critical to protect the environment by reducing pollution loads to levels that do not lead to deterioration in the receiving environment and significant public health risks. As such, wastewater treatment has all the characteristics of a public good and, for this reason, ensuring the treatment of wastewater and faecal sludge is ultimately a public sector responsibility.

The poor levels of wastewater treatment in developing countries is caused not just by a lack of treatment facilities but also by the poor performance of the existing facilities. Indeed, some treatment facilities have never been used. Reasons for poor performance include inappropriate technology choice and poor design, including WWTP capacity being insufficient to deal with the wastewater and faecal sludge load generated in rapidly growing urban areas. But numerous apparently well-designed facilities perform poorly because of inadequate O&M, which in many cases is underfunded and lacking adequate institutional back up capability.

There is a dearth of evidence and attention to this topic, which makes it difficult to estimate how serious the problem is and for which countries. However, the few studies that analyse the functionality of more than ten plants show very poor functionality levels, although the data is quite old and not necessarily either comprehensive or rigorous. For example, in Mexico, 95% (of 194) WWTPs studied were not working. In Ghana, 80% (of 44) WWTPs were not working. In India, 54% (of 84) plants were operating poorly or very poorly. In Vietnam, around 33% (of 17) WWTPs were substantially underloaded. In Brazil, in contrast, most plants studied were meeting effluent standards.

One critical underlying reason for the poor functionality of WWTPs is perceived to be a lack of political will and the low priority given to sanitation and wastewater management by politicians and officials. This underlies more immediate causes, including a lack of finance and institutional systems that fail to provide the knowledge, skills and systems required for effective O&M. These problems cannot be dealt with solely at the municipal level. Rather, there is a need to ensure the incentives created and support provided by higher levels of government (the enabling environment) encourage and enable municipalities to take effective action on sanitation and wastewater management.[125]

The response

One way to develop a more integrated and 'technologically agnostic' approach to urban sanitation is to not assume sewered sanitation is the only way and **pay greater**

attention to non-sewered sanitation options. Separate provision for faecal sludge treatment will normally be required where most households rely on on-site sanitation (pit latrines, leach-pits and septic tanks) and may also be required to treat sludge from decentralised treatment facilities. This will entail an increase in efforts to develop effective systems for faecal sludge management, including faecal sludge and septage treatment, and thorough planning on how to integrate these with off-site systems.

For both sewered and non-sewered sanitation, it is important to always **consider the whole sanitation service chain**. For wastewater, this will require an assessment of systems for wastewater collection and transport (including informal systems discharging into drains). For faecal sludge, it will require an assessment of existing sanitation systems, emptying/desludging practices, and options for productive end use of the products of treatment.

A recent effort to contribute to these shifts is the concept of city-wide inclusive sanitation and the related call to action,[126] which are already starting to shape investments from development banks on urban sanitation. Proposed initially by the Bill & Melinda Gates Foundation, Emory University, Plan International, The University of Leeds, WaterAid and the World Bank, city-wide inclusive sanitation is based on four principles: the human right of all to sanitation, safe management along the sanitation service chain, the contribution of sanitation to the urban economy, and partnership among multiple actors.

Technology choice for WWTPs should be based on multiple factors, putting emphasis on operation and sustainability: operating costs (especially energy), reliability of power supply, supply chains for materials and spare parts, institutional capacity (in particular, the ability to recruit, train and retain staff with the knowledge and skills required). It is always worthwhile to consider anaerobic options – anaerobic ponds, UASBs and anaerobic baffled reactors – which reduce land and power requirements.

It is important to **strengthen the capacity** of local/municipal-level organisations to adequately manage wastewater and faecal sludge treatment facilities. There is a strong case for also exploring alternative arrangements, including specialist organisations, perhaps set up as public companies, as well as private sector management with public sector oversight. A wider **institutional reform agenda** needs to be considered, to address the environmental/institutional factors that explain why existing WWTPs perform poorly.

The role of bilateral donors and development banks

Governments, as duty bearers, have the responsibility to ensure adequate wastewater treatment services, and need to drive the responses highlighted above. However, most of the WWTPs in many developing countries are built with resources from ODA, which means bilateral donors and development banks also have some responsibility and the potential to leverage change. ODA to WWTPs (large sanitation systems in general) has been increasing steadily. It is roughly estimated at around 1 billion USD a year (2015–

17 average), which would represent 21% of total disbursement for WASH, and at least twice the disbursements for basic sanitation.

Despite emerging efforts to acknowledge and address the problems, many WWTP investments have failed to tackle the core functionality issues. There is an overwhelming case for donors and development partners to gather and share evidence on the sustainability of WWTPs in a systematic and rigorous way. This would be a first step towards understanding the issues and addressing the misalignment of incentives. Donor investments need to be based on more transparent and better-informed negotiations between governments and funders, and should include a broader set of stakeholders – CSOs, elected officials and pro-poor representatives. Central to this effort must be donors and development partners driving the political prioritisation of appropriate methods of treatment, along with a drive for improvements to the governance systems that can effectively deliver and sustain treatment services.

6 Annexes

Table 4: ODA disbursement for large sanitation systems in million USD (2017), from CRS database, code 14022

	2015	2016	2017	3-year average	Priority countries
World Bank Group	132.4	137.4	140.6	137	Burundi, Core D'Ivoire, Niger, Rwanda, Zambia, Vietnam, Tanzania, Ethiopia, Guinea, Kenya, Malawi, Bangladesh, Nepal, Kiribati, Uzbekistan
France	66.0	123.5	140.3	110	Cuba, Dominican Republic, El Salvador, El Salvador, Haiti, Kosovo, Benin, Honduras, Mexico, Saint Lucia, Bolivia, Ecuador, Cambodia, China, Lao, Philippines, Vietnam, Lebanon, West Bank and Gaza, Venezuela, Cabo Verde, Cameroon, Congo, Cote D'Ivoire, Guinea, Madagascar, Mali, Senegal, Egypt, Morocco, Tunisia, Togo, Burkina Faso, Niger,
Japan	68.9	87.5	142.8	100	Samoa, Papua New Guinea, Fiji, West Bank and Gaza, Iraq, Sri Lanka, Pakistan, Nepal, Myanmar, Maldives, India, Bhutan, Bangladesh, Vietnam, Thailand, Philippines, Mongolia, Malaysia, Indonesia, China, Cambodia, Peru, Guyana, Ecuador, Brazil, Albania, Kosovo, Serbia, Turkey, Ukraine, Algeria, Morocco, Tunisia, Ethiopia, Gabon, Kenya, Liberia, South Africa, Sudan, Tanzania, Zimbabwe, Costa Rica, Dominican Republic, Guatemala, Honduras, Jamaica, Mexico, Panama
EU Institutions	28.4	107.4	56.6	64	West Bank and Gaza, Lebanon, Jordan, Serbia, Morocco, Tunisia, Mali, Tanzania, Zambia
Asian Development Bank	44.4	39.2	40.2	41	Sri Lanka, Georgia, Bhutan, Tajikistan, Vietnam, Kiribati, Myanmar, Pakistan, India, China, Indonesia, Cambia, Mongolia,
United States	50.6	40.8	23.8	38	Jordan, sub-Saharan Africa, Egypt, India,
United Arab Emirates	38.7	27.5	0.0	22	Egypt
African Development Bank	9.8	27.4	22.2	20	Ghana and Mauritania
Germany	23.7	10.2	19.6	18	China, Jordan, West Bank and Gaza, Vietnam, Morocco, Mali, Belarus, Bosnia and Herzegovina, Kosovo,
Switzerland	16.5	12.4	12.7	14	Kosovo and Tunisia
Korea	1.6	1.6	16.4	7	Tanzania, Colombia
DAC countries, total	236.9	286.5	372.2	298	
Multilaterals,	220.0	325.6	263.6	270	

total					
Non-DAC countries, total	39.4	29.9	0.0	23	
Official donors, total	**496.3**	**642.0**	**635.8**	**591**	

Source: CRS database

Table 5: Summary of the reported WWTP challenges in seven Africa countries – technical/economic challenges more common

Burkina Faso	**Technical:** no control over industrial disposals; power costs; limited removal of nitrate or Iron; lack of compliance with regulations
	Social: solid waste disposal in the collection network; robbery; vandalism
	Economic: high O&M costs
	Environmental: n/a
Ghana	**Technical:** power cuts and overloading
	Social: pump failure; power cuts; overloading
	Economic: waste thrown in sludge; complaints about odour and breeding of mosquitoes
	Environmental: lack of funds for O&M or rehabilitation; high O&M costs
Senegal	**Technical:** limited removal of nitrate or iron; lack of compliance with regulations
	Social: pump failure; power cuts; overloading
	Economic: non-sustainable funding sources (charge fees are not sufficient); lack of funds for O&M (e.g. for fuel for generator)
	Environmental: deterioration of living conditions for population; groundwater pollution; ecosystem disturbance
Algeria	**Technical:** power cuts; industrial wastewater inputs (e.g. presence of oil); sludge discharge
	Social: need of capacity building for sludge management
	Economic: outdated equipment
	Environmental: n/a
Egypt	**Technical:** high loading rates; lack of spare parts; limited infrastructure for biogas reuse
	Social: need of capacity building for sludge management; low wages of workers causing lack of motivation
	Economic: high O&M costs; high cost of WWTPs
	Environmental: water reuse should be optimised at least for forest trees
Morocco	**Technical:** pump failure; power costs; lack of control over wastewater feed; foaming in the activated sludge WWTPs; poor management of sludge produced
	Social: limited qualified personnel; inadequate standards and regulations
	Economic: inadequate infrastructure; high O&M costs of treatment systems and sewerage networks
	Environmental: air pollution (e.g. release of odours)
Tunisia	**Technical:** sludge elimination
	Social: n/a
	Economic: high energy consumption
	Environmental: n/a

Source: Nikiema et al 2013

Table 6: Country highlights based on GLAAS 2016/2017 data

	Maintain sewer systems and treatment facilities			
	Plans with high implementation	Plans but moderate implementation	No plan/low implementation	Responsibility assigned
Afghanistan				Community development councils (CDCs)
Bangladesh				Yes
Benin				National Water Company of Benin (SONEB)
Burundi				Municipal sanitation services (SETEMU in Bujumbura, SETAG in Gitega)
Ethiopia				Ministry of Water, Irrigation and Electricity (MoWIE)
Georgia				?
Kyrgyzstan				Local government bodies, Municipal Enterprise of Water Supply and Wastewater Treatment
Liberia				No
Lithuania				Yes
Madagascar				Municipal services of large cities
Mozambique				Municipalities
Pakistan				Water and Sanitation Agency (WASA), town municipal authorities (TMAs), local government, and PHE in rural areas
Serbia				Yes
Timor Leste				National Directorate for Basic Sanitation (DNSB) and sanitation services at

				municipal level
Zimbabwe				Yes
Bosnia and Herzegovina				Public water utilities
Azerbaijan				JSC 'Azersu'
Botswana				Yes
Kenya				Water services providers
Nigeria				State/local government environmental protection agencies
Senegal				Yes
South Africa				Water Services Authority, local government (WSA)
South Sudan				MLPPUD Directorate of Urban Sanitation and local government
Tanzania				Ministry of Water and Irrigation (MoWI), urban water supply authorities (UWSAs)
Tajikistan				Yes
Ukraine				Municipal enterprises of water supply and wastewater treatment, local authorities
Uzbekistan				State unitary enterprises 'Suvokova'
West Bank and Gaza				Palestinian Water Authority (PWA), Ministry of Local Government (MOLG), service providers
Belarus				Yes
Burkina Faso				National Water and Sanitation Office (ONEA)

Cote d'Ivoire				National Office of Sanitation and Drainage (ONAD)
Kingdom of Eswatini				Swaziland Water Services Corporation (SWSC)
Thailand				Bangkok Metropolitan, municipalities, local administration offices
Zambia				Commercial utilities
Ghana				?

Source: GLAAS 2016/2017 data

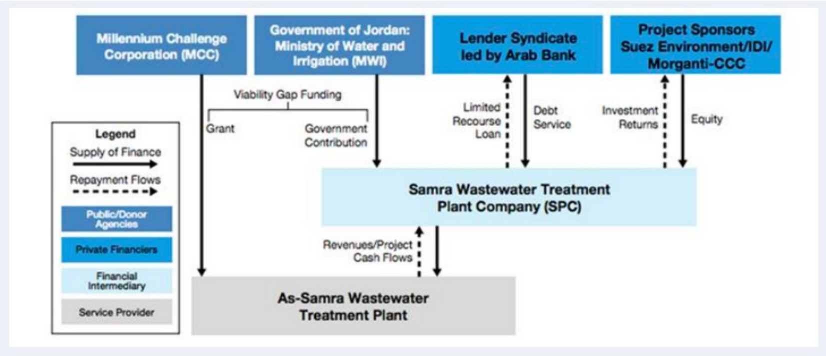
Table 7: Review of national sanitation policies for reference to municipal wastewater, faecal sludge collection and safe use of wastewater

Key: Reference included (green) | No reference (red)

	Municipal wastewater	Faecal sludge collection	Safe use of wastewater
Afghanistan	Reference included	Reference included	Reference included
Benin	Reference included	Reference included	Reference included
Botswana	Reference included	Reference included	Reference included
Burkina Faso	Reference included	Reference included	Reference included
Burundi	Reference included	Reference included	Reference included
Cote d'Ivoire	Reference included	Reference included	Reference included
Ethiopia	Reference included	Reference included	Reference included
Georgia	Reference included	Reference included	Reference included
Ghana	Reference included	Reference included	Reference included
Liberia	Reference included	Reference included	Reference included
Lithuania	Reference included	Reference included	Reference included
Madagascar	Reference included	Reference included	Reference included
Nigeria	Reference included	Reference included	Reference included
Senegal	Reference included	Reference included	Reference included
South Africa	Reference included	Reference included	Reference included
Thailand	Reference included	Reference included	Reference included
Zimbabwe	Reference included	Reference included	Reference included
Tajikistan	Reference included	Reference included	Reference included
West Bank and Gaza	Reference included	Reference included	Reference included
Azerbaijan	Reference included	Reference included	No reference
Bangladesh	Reference included	Reference included	No reference
Belarus	Reference included	Reference included	No reference
South Sudan	Reference included	Reference included	No reference
Timor Leste	Reference included	Reference included	No reference
Uzbekistan	Reference included	Reference included	No reference
Zambia	Reference included	Reference included	No reference
Kenya	Reference included	Reference included	No reference
Kyrgyzstan	Reference included	Reference included	No reference
Bosnia and Herzegovina	Reference included	No reference	No reference
Serbia	Reference included	No reference	No reference
Mozambique	Reference included	No reference	No reference
Pakistan	Reference included	No reference	No reference
Tanzania	Reference included	No reference	No reference
Ukraine	Reference included	No reference	No reference
Kingdom of Eswatini	No reference	No reference	No reference

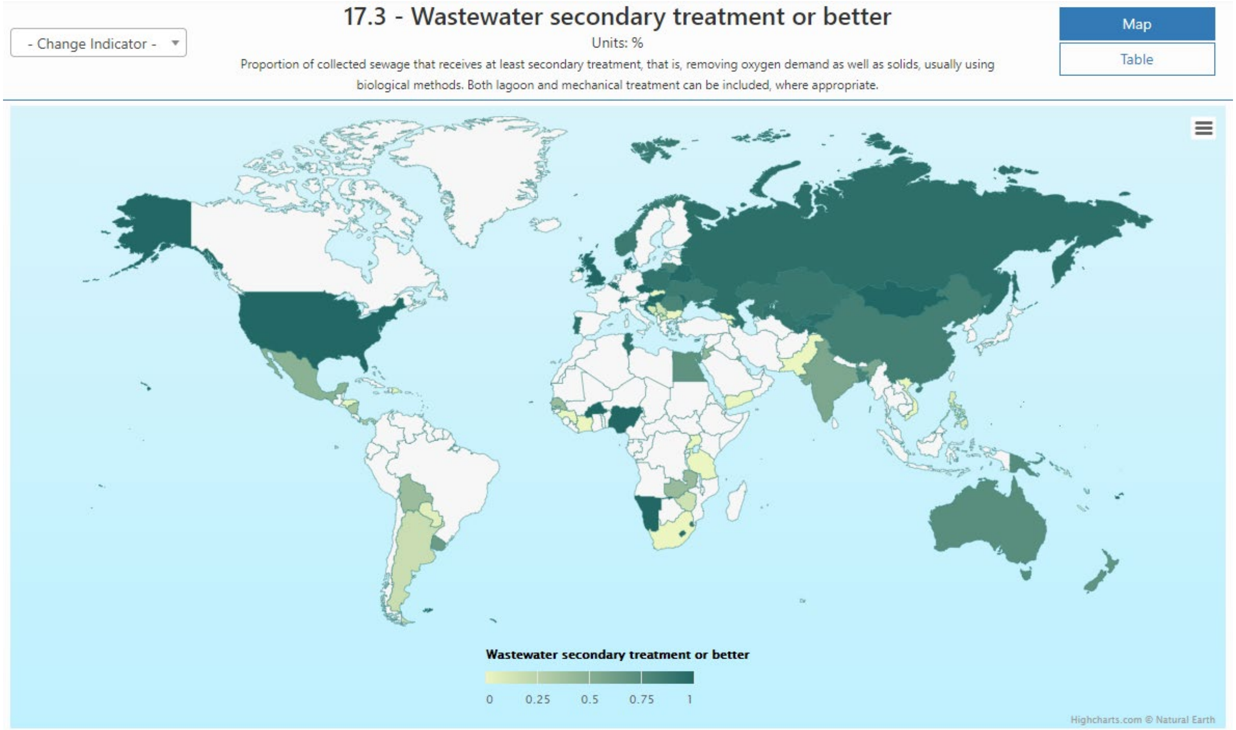
Source: GLAAS 2016/2017 data

Figure 5: Use of blended finance in the Amman Wastewater Treatment Plant project



Source: OECD (2018)[127]

Figure 6: IBNET heatmap of wastewater treatment



Source: IBNET[128]

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This desk review describes the flows of official development assistance to wastewater treatment plants and synthesises evidence on functionality. It analyses the causes of failure, highlights successes, and outlines the response needed from governments and donors.

WaterAid is an international not-for-profit, determined to make clean water, decent toilets and good hygiene normal for everyone, everywhere within a generation. Only by tackling these three essentials in ways that last can people change their lives for good.

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This review and other related resources can be accessed at:
washmatters.wateraid.org/wwtp-functionality

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Images:
Front, left: Wastewater treatment plant in Islamabad, Pakistan.
Front, right (top and bottom): Wastewater treatment plant in Siem Reap, Cambodia.
Back: above: Wastewater treatment plant in Siem Reap, Cambodia.
All images: WaterAid/Andrés Hueso.

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