Wastewater treatment practices in Africa - Experiences from seven countries

This paper presents the treatment plants existing in Africa; it discusses the types of processes applied, the required treatment performance per country and the main challenges hindering their performance as well as the reuse of the treated wastewater.

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Abstract

In this paper, existing wastewater treatment practices in 7 African countries, i.e. Algeria, Burkina Faso, Egypt, Ghana, Morocco, Senegal and Tunisia, are reported. Data were collected by questioning wastewater treatment plants managers as well as treated wastewater users in 2012. This study showed that 0.2 to 63 L/d/person of wastewater are treated in these countries, with the higher levels obtained for North Africa. Technically, treatment plants (mostly activated sludge and waste stabilization ponds) deal with high organic loads, uncontrolled input, power cuts and increasing wastewater flow rates. Poor operation and maintenance (O&M), in part caused by the lack of funds, high energy costs and lack of re-investments, is also a serious reported issue. Consequently, treatment plants often deliver insufficient effluent quality, which negatively affects the environment and acceptability of stakeholders towards the treated water. Other challenges, such as water availability, long-term impacts, financial and social constraints, affecting the reuse, are also discussed.

Introduction

The coverage with improved sanitation in the different target countries is presented in Table 1. In the 3 Sub-Saharan African (SSA) countries (Burkina Faso, Ghana, Senegal), sanitation coverage ranges between 34 and 72 % for combined improved sanitation and shared/public toilets. This contrasts significantly with the situation in North Africa (Algeria, Egypt, Morocco and Tunisia) where levels are noticeably higher (70-100 %), with limited use of shared facilities. The other side of sanitation is to ensure a proper disposal of the wastewater (including faecal sludge) being generated. One objective of WATERBIOTECH project has been to evaluate the existing technologies for wastewater treatment in the target countries, looking at the types of processes implemented, their efficiency, compared with the standards values, and the current outcomes of the treated water.

Materials and Methods

On the course of this activity, three different questionnaires were prepared (in English, French and Arabic). This paper focusses on the data obtained through interviews in 2012 of key stakeholders, with Questionnaires 2 and 3. Q2 aimed at collecting information on the functionality

Key findings:

- At least 7 out of 10 wastewater treatment plants are either waste stabilization ponds or activated sludge. Treatment plants allowing simultaneous production of biogas are not common.
- The amount per inhabitant of wastewater entering a treatment plant ranges from less than 0.2 L/d/person in Ghana to 63.2 L /d/person in Tunisia.
- Treatment plants face challenges such as high organic loads, uncontrolled waste input, power cuts, increasing wastewater flow rates, poor O&M, high energy costs and lack of re-investments.
- Treatment performance expected from treatment plants in Africa is sometimes barely achievable technically (e.g. 0.05-0.1 mg/l of phosphorus in Tunisia).
- Poor treated wastewater quality, inadequate infrastructure, poor institutional linkages, stringent regulations, limited public/farmers acceptance and awareness and low willingness to pay for this resource are among the top challenges currently faced by target African countries in reuse of treated wastewater.

Table 1. Sanitation coverage in the different target countries[1]

	Burkina Faso	Ghana	Senegal	Algeria	Egypt	Morocco	Tunisia
Urban	*50* (37)	*19* (73)	*70* (19)	*98*	*97* (3) [85]	*83* (14)	*96*
Rural	*6* (10)	*8* (43)	*39* (10)	*88*	*93* (7)	*56* (6)	*52*
Average	*17* (17) [< 5]	*14* (58)	*52* (14)	*95* [86]	*95* (5)	*70* (11) [<60]	[82]

[1] The value in italic is the coverage with improved sanitation (i.e. toilet facility). Between parentheses is given the share of shared/public toilets; between brackets the percentage of households connected to the public sewer (when reported) is given, (JMP, 2012).

The values reported in Table 1 do not necessarily: 1) mean that the systems reported are operational; 2) imply proper treatment and disposal of the wastewater produced. Statistics do not reflect the real situation (which is expected to be much worse) (UN, 2006).

Table 2: Treated wastewater amounts[1]

	Ghana	Burkina Faso	Senegal	Egypt	Algeria	Morocco	Tunisia
Wastewater treated [1000 m^3/day]	< 5 (2011)	< 5 (2011)	38 (2011)	Not reported	317 (2006)	485 (i.e. 25% of the wastewater) (2011)	658 (2010)
Ratio: treated wastewater/ inhabitant (L/ person/d)	<0.2	<0.3	3.2	-	9.6	14.3	63.2

[1] The treatment efficiency might be unsatisfactory

of water treatments units. It was mainly addressed to wastewater treatment plant (WWTP) managers and other specialists working on the ground, within the sanitation sector. Q3 aimed at gathering information on the reuse of the treated wastewater. It was addressed to users of treated or untreated wastewater.

The identification of key stakeholders per country was done by the national partners. In many cases, the operators/technicians in charge of the O&M of WWTPs were not fully aware of the specificities of the technologies, leading to incomplete data collection. On the other hand, given the high number of TPs in some countries, only selected WWTPs were investigated in detail.

Results and Discussion

Wastewater treatment plants

Amount of wastewater

Total amounts of wastewater treated in each target country are presented in Table 2. As a general observation, a sewer system provides the core of the wastewater inflow to WWTPs. Additional septage transport by trucks is also present, especially in some SSA cases. In the 3 SSA countries, less than 5 L/d/person of wastewater are treated. The situation is significantly different in North Africa where ratio reaches 63 L/d/person in Tunisia. The sewerage network is also quite well developed, with e.g. over 80% of households connected to sewer in Algeria and Tunisia. On the other hand, given the relatively low per capita water consumption, all plant types deal with high organics and nutrient concentrations, compared to WWTPs in developed countries. The specific flow rates of wastewater being treated in one WWTP are also highly variable over the continent. While there are below 200 m^3/h per WWTP in SSA (except for one WWTP in Dakar having 1,200 m^3/h of hydraulic flow rate), many WWTPs have some 3,000 to 5,000 m^3/h of hydraulic flow rate in North Africa.

Treatment processes in use

Table 3 presents an overview of the most used technologies. Activated sludge (AS) and stabilization ponds (either aerated or not) are the most used technologies in Africa (Figures 1-4). In all target countries, both technologies represented 68-100% of all implemented units still in operation. In Ghana, AS systems are applied mostly by private entities (industry, hotels) while ponds are preferred by public entities. But, as shown in Figure 5, a wide range of treatment processes are also being operated. Trickling filters were popular some years ago while ponds have now the preference. Many WWTPs are also in disrepair (Figure 6). In Burkina Faso, only ponds are used. However, the remaining five countries show a wider application range at large scale of AS or ponds (Figures 2,4). Combinations of treatment systems for polishing and tertiary treatment rarely exist. It is to be noted that many of the described plants are aged.

Table 3: Overview of the WWTPs in operation.

Country	Total number	1st most used technology	2nd most used technology	3rd most used technology	Feed flow rate (m^3/h)
Burkina Faso	2	100% of ponds	N/A	N/A	96 (for the largest)
Ghana	19[1] (4 ponds under construction)	42% of ponds	26% of AS or aerated tank	16% of anaerobic digesters, etc.	1 - 25
Senegal	9	56% of ponds	44% of AS	N/A	28 - 1,200
Algeria	123 (96 under construction[2])	55% of ponds	45% of AS	N/A	8 - 2,750
Egypt	> 99	Between 65 and 85% of AS	About 10% of ponds	Others	-
Morocco	> 100	>77% of ponds	5% of AS	Trickling filters, etc.	12 – 4,914
Tunisia	109	82% of AS	13% of ponds	Trickling filters and wetlands	4 - 3,250

[1] 6 WWTPs that are only partially functioning (likely with low performance) and are not considered in the total number.
[2] Among plants under construction, 60 are AS and 36 are ponds.

Anaerobic digestion for wastewater and/or sludge treatment allows biogas production and electricity generation. But this is very rarely found although the potential might be high. A lack of understanding of the requirements in AS plants for biogas production might be a reason. AS plants with energy generation have been reported from North Africa (Figure 2) and Senegal while 3 cases of anaerobic digestion of liquid waste exist in Ghana. However, willingness to produce biogas is low in countries with significant energy resources such as Algeria.

Figure 1. A WWTP (activated sludge) being operated in Accra, Ghana [From left to right; Stabilization tank, Aerated reactor, Settling tank and treated water tank, reused for lawns irrigation. Real flow rates: about 25 m^3/h].

1.

Figure 2. The Choutrana wastewater treatment complex (activated sludge + anaerobic digestion of excess sludge) in Tunisia. The 2 WWTPs, designed for a total of 1,300,000 population equivalent. Real flow rates: 3,250 m^3/h for the oldest, 1,667 m^3/h for the most recent (Al Ayni, 2012)

Figure 3. A faecal sludge treatment plant (pond system) in Sekondi-Takorady, Ghana. From left to right; Faecal sludge discharge area (from trucks); Series of ponds. Treats about 100 m^3/d of faecal sludge.

Figure 4. The Mahdia WWTP (aerated pond system), in Tunisia. It is designed for 150,000 population equivalent (Real flow rate: 426 m^3/h). Treated water is UV-disinfected before discharge (Al Ayni, 2012).

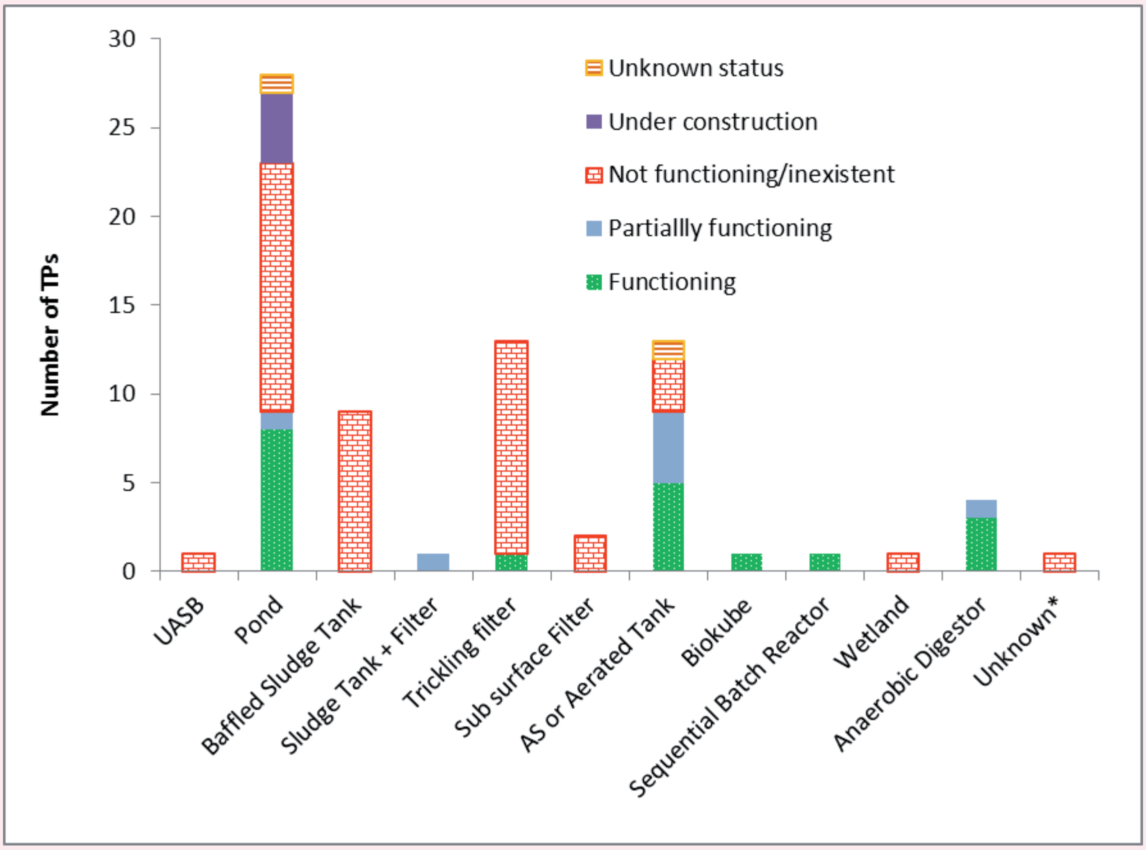

Figure 5: Distribution of technologies in Ghana (UASB: Upflow anaerobic sludge blanket, Adapted from Murray and Drechsel, 2011).

Figure 6. A WWTP in disrepair in Accra, Ghana. From left to right; pump, aerated reactors, settling tank, weedy drying bed.

Challenges in the operation of treatment plants

The survey showed that several challenges influence the operation of WWTPs (Table 4). Among technical challenges, insufficient capacity to cope with increasing wastewater load (e.g. because of population increase) is a commonly reported problem. In case of strong deviation between wastewater collection and treatment capacity, a substantial part of sewage is released untreated (e.g. for Camberene WWTP, Senegal). Another key challenge WWTPs in Africa have to cope with is the pollution load variation, caused by uncontrolled discharges into the sewage network (e.g. from industrial discharge), a result of non-enforced regulations. Power cuts are a severe issue where processes with energy demand take place. Poor O&M, leading to inappropriate sludge disposal and odour generation and lack of re-investments are also reported.

Financial problem arises in all countries, negatively affecting the O&M, the construction (e.g. unfinished WWTPs in Morocco) or the upgrading of WWTPs. High energy costs are also cited as key constraint in all countries. In terms of management, differences can be observed, depending on the nature (public, private) of the operators. In the public sector, many WWTPs suffer from heavy administrative procedure for O&M and lack of short-term maintenance planning. Workers in charge of treatment plants often lack the full capacity to maintain them and are not motivated/encouraged to maintain treatment plants.

As a result, WWTPs often deliver insufficient effluent quality, causing complaints from stakeholders. Release of insufficiently treated wastewater into the environment is also observed where treatment plants are dysfunctional or temporarily disconnected (common in Ghana).

Quality requirement applied to treated effluents

Table 5 presents selected quality requirements for WWTPs in Africa. These values are compared with their European counterpart found in the Urban Wastewater Treatment Directive of the European Union. This table reveals that regulations on treatment standards and effluent requirements differ over the case study countries. In the 3 SSA countries, the standards to be achieved by treated effluents mostly rely on the WHO guidelines. But it is essential to emphasize the fact that regulation is not always enforced on a regular basis. Upstream enforcement of regulation (e.g. for the industries connected to the sewerage) is almost inexistent in all 3

Table 5: Selected parameters requirements for WWTP effluents in Africa and the European Union

Location	COD (mg/l)	BOD (mg/l)	Total N (mg/l)	Total P (mg/l)	Hygiene CFU/100ml
EU[1]	125	25	-	-	-
EU[2]	125	25	15 [3] or 10 [4]	2 [3] or 1 [4]	-
Burkina Faso	150	50	-	-	FC: 1,000
Ghana	250-400	50	-	-	TC: 400
Senegal	100-200	40-80	30	10	FC: 2,000
Algeria	90	30	51.5	10	FC: 2,000
Egypt	40-80	20-40	-	-	EC: 100
Morocco	250	120	-	-	-
Tunisia	90	30	1-30	0.05-0.1	FC: 2,000

[1] For non-sensitive areas and all plant sizes.

[2] For sensitive areas and plant size >10,000 population equivalent (PE).

[3] For plant size < 100,000 PE.

[4] For plant size >100,000 PE.

Table 4. Summary of the reported challenges (top 4 challenges per country are numbered).

	Burkina Faso	Ghana	Senegal	Algeria	Egypt	Morocco	Tunisia
Technical	3. No control over industrial disposals 4. Power cuts • Limited removal of nitrate or iron 2. Lack of compliance with the regulations	1. Pump failure 4. Power cuts • Overloading	3. No control over industrial disposals 4. Power cuts • Limited removal of nitrate or iron 2. Lack of compliance with the regulations	1. Power cuts 2. Industrial wastewater inputs (e.g. presence of oil) 3. Sludge discharge	• High loading rates • Lack of spare parts • Limited infrastructure for biogas reuse	4. Pump failure • Power cuts • Lack of control over wastewater feed • Foaming in activated sludge WWTPs • Poor management of sludge produced	2. Sludge elimination
Social	• Solid waste disposed in the collection network • Robbery • Vandalism	• Waste thrown in sludge • Complaints about odour and breeding of mosquitoes	1. Pump failure 4. Power cuts • Overloading	• Need of capacity building for sludge management	• Need of capacity building for sludge management • Low wages of workers causing lack of motivation	3. Limited qualified personnel Inadequate standards and regulations	-
Economic	1. High O&M costs	1. Lack of funds for O&M or rehabilitation 3. High O&M costs	1. Non-sustainable funding sources (charge fees are not sufficient) • Lack of funds for O&M (e.g. fuel for generator)	4. Outdated equipment	• High O&M costs • High cost of WWTP	1. Inadequate infrastructure 2. High O&M costs of treatment systems and sewerage networks	1. High energy consumption
Environmental	.	• Odour affecting locals in the vicinity	4. Deterioration of living conditions of populations • Groundwater pollution • Ecosystem disturbance	-	• Water reuse should be optimized at least for forest trees	• Air pollution (e.g. release of odours)	-

Table 6: Summary of main challenges (top 3 challenges per country are numbered) in reuse of water (user and WWTP manager perspective)

	Burkina Faso	Ghana[a]	Senegal	Algeria	Egypt	Morocco	Tunisia
Supply	1. Unsuitable Water quality 3. Odour in the water	1. Shortages of water supply (seasonal and intermittent) 2. Odour and filth in the water 3. Poor water quality	1. Inadequate infrastructure (e.g. for transport of treated sewerage to re-users)	1. Unsuitable quality of treated water • High water availability	-	1. Inadequate infrastructure • Bad water quality (salinity, pathogens)	1. Poor water quality due to high levels of pathogens and salinity
Social	2. Lack of supervision of treated wastewater users	-	2. Lack of potential users for treated water (given the location of the WWTP)	2. Lack of synergy between ministry of agriculture and ministry of water resources 3. Stringent regulation	• Lack of political will • Strict standards and regulations	2. Limited public/ farmers acceptance and awareness • Institutional set-up not allowing proper coordination • Lack of political will • Strict standards and regulations	-
Financial	-	-	-	• Low willingness to pay for treated water (prices must be subsidized)	• High O&M costs of networksP	3. Low willingness to pay for treated water High O&M costs of networks	2. No willingness to pay for the treated water
Long-term Impacts	• Reduction in soil fertility	-	-	-	• Deterioration of soil structure (due to salinity)	• Negative impacts of nitrogen excess • Deterioration of soil structure (due to salinity)	-

[a] In many areas in Ghana, farmers use mostly untreated wastewater, which is diluted to different degrees.

countries while quality of final WWTP effluent remains unsatisfactory and rarely controlled in many cases.

In North Africa, strict emission thresholds can be found, especially regarding COD (all countries, except Morocco) and phosphorus (Tunisia). For these parameters and countries, the national standards are even stricter than for the European Union (UWWTD, 1991). Such situation should result in the need of implementing highly effective WWTPs in order to match the regulation, which therefore would reveal expensive to operate. On the other hand, it is important to highlight that limitations of nutrient levels in treated effluents to be reused in agriculture, can be contra-productive. In some countries, some specific standards have been adopted for treated water to be reused in agriculture (e.g. Tunisia).

For all countries but Morocco, thresholds for hygienic parameter for treated domestic effluents are fixed, whether expressed in terms of faecal coliforms (FC), total coliforms (TC) or E. Coli (EC). However, such limitation could only be justified when the treated water is reused or discharged to sensitive receiving areas (e.g. with nearby DW resources). Likewise, this requirement only implies further treatment costs but does not support environmental conservation.

Challenges related to treated wastewater reuse

The situation of water reuse in Africa is highly variable. In some locations, water reuse is been practiced without much legal control. This is the case of Accra (Ghana) where water from drains is reused for growing a wide range of vegetables, even when it undergoes no proper treatment. In Burkina Faso, the government has agreed with the reuse of wastewater and has therefore developed areas for market gardening using this resource under some restrictions (only for selected vegetables). But in Senegal, water reuse is not always practiced even if a potential exist for that (current uses include gardening or livestock watering) for reasons including unsuitable location of the WWTP which causes the treated water not to be accessible to potential users.

The most important challenges with reuse acceptability in agriculture are observed in the case study countries of North Africa. While, on the one hand, Morocco significantly limits this practice for agriculture, Egypt on the other hand encourages it for selected farming activities. In practice, 45 % of the treated water in Morocco (25% of the wastewater undergoes any form of treatment) is reused, mainly for lawn irrigation, groundwater recharge and by industries. In Tunisia, it is used for golf courses and other green spaces' irrigation. In Algeria, the main uses include town road cleaning and for cooling fire engines. In all these 3 countries, the use in agriculture is limited. In Egypt, the permitted use of treated water depends on its quality.

Table 6 presents a summary of the challenges that water reuse faces in the target countries. Several reasons can justify the limited success of water reuse in agriculture for the concerned areas. Firstly, it shall be observed that water reuse is promoted in areas where access to water is scarce and no other water source (surface or groundwater) available at low cost (e.g. in SSA and Egypt). When there is competition with other water sources, treated water reuse is not successful. Under these circumstances, willingness to pay the water is also low, and it contributes to generating unfavourable conditions for water reuse. Low tariffs on fresh water (in Algeria, Morocco and Tunisia) also limit the possibility to sell treated water for irrigation and to generate significant income for WWTP operation. In general, cost recovery from reuse (if existent) is too low to cover even the operating costs of the added irrigation components, leading to dependency on foreign aid and governmental support. Exceptions can be treatment systems generating energy (Evans et al., 2012). Other socio-economic or political factors such as a lack of awareness, on both governance and user (e.g. farmers) sides, also impact willingness to pay.

Indeed, water reuse often suffers from bad perception from farmers (detrimental effect on soils and plants) and consumers.

Insufficient infrastructure and unsuitable treated water quality (high pathogen and salinity levels) are other factors that inhibit reuse. Specifically, insufficient pathogen removal in reuse water poses risks to health, especially if alternative risk reduction options are not in place, as advocated e.g. by WHO (2006).

Conclusion

This paper aimed at analysing the current experiences of 7 African countries in terms of wastewater management. It informed on some challenges and drivers for the current situation and confirmed the gap between North Africa and Sub-Saharan African countries. The study revealed that activated sludge and ponds systems are currently the top 2 technologies applied for wastewater treatment and overall represent over 70% of treatment units in the Region. But many WWTPs are subject to transition, especially in the fast growing urban centres of Africa. In addition, in most countries, not all wastewater is collected (e.g. through sewer systems) and not all collected wastewater is treated. This situation gives room for further diversification on existing systems as well as creating opportunities for new developments. Currently, in SSA, WWTPs are mostly expected to treat low flow rates effluents (< 200 m^3/h), but large systems with up to 5,000 m^3/h of flow rate, are also encountered in North Africa. The national standards in many African countries will benefit revisions to include achievable targets for essential parameters. Indeed, most entities in Africa cannot afford the high energy prices and operation costs of the systems, which require a trained and qualified staff as well, needed to be implemented in order to meet the current standards.

It is established that reuse of treated water, e.g. in agriculture, can help in reducing stress on valuable fresh water resources in two ways; avoiding their pollution and reducing their consumption, especially in urban and peri-urban areas. The lack of adequate infrastructure for water collection or treatment also causes the bulk of domestic and/or industrial wastewater to be discharged without any treatment, with damages health and environment. In principle, wastewater reuse provides a mean for income generation. However, in some countries, low quality of treated wastewater or restrictive legislation does not allow WWTPs and users to benefit from the reuse. Anyway, the complexity of the problem requires adapted approaches considering technical, organizational and governance aspects, like promoted by WHO (2006).

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