What do we require from water biotechnologies in Africa?

This paper shows requirements and obstacles towards sustainable biological wastewater treatment in Algeria, Bourkina Faso, Egypt, Ghana, Morocco, Senegal and Tunesia.

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Abstract

When discussing water and sanitation issues, technology is often seen as the key element by many stakeholders. Within a multinational project, the opportunity was taken to analyse the experiences with the existing water infrastructure to look behind this assumption and – if not working satisfactory – to identify the key requirements that obviously have not been met. Following this, it should be possible to prepare a set of requirements to learn from this. A three stage questionnaire for different stakeholder level (authorities, operators and end users) has been launched in Algeria, Burkina Faso, Egypt, Ghana, Morocco, Senegal and Tunisia. Some main obstacles towards sustainable biological wastewater treatment could then be identified. The reader expecting specific technical suggestions might be disappointed but the key messages that are relevant for all the different conditions of the four North African and the three Sub Saharan countries are presented. The given requirements tackle issues that are unfortunately not only of technical nature and are (almost) all linked to each other.

Introduction

The survey conducted within the WATERBIOTECH project (www.waterbiotech.eu) showed that numerous technical and non-technical aspects can influence the success of system operation. The results also showed that there is a rather small number of different water biotechnologies applied in the partner countries involved in the project. Whereas the water supply side mainly relies only on physic-chemical methods, wastewater treatment seems to be dominated by the biological treatment methods of activated sludge systems (AS) and pond systems (PS). Despite some exceptions, the type of technology present

Key facts:

- Operation costs shall be as low as possible and maintenance requirements shall be in line with local capacities
- Technologies shall be insensitive to normal industrial inflows and load variations
- Technologies have to comply to effluent standards given

...but at the same time it has to be ensured that:

- Legal standards reflect a reasonable balance between risks minimization and feasibility
- Legal standards shall consider envisaged water reuse
- Legal standards have to be enforced in practice
- O&M requirements are met by appropriate organisation at any time
- Industrial impact is regulated and limited by appropriate means

The authors therefore conclude that in Africa a practice- and system-based approach is required for introduction of water biotechnologies (rather than following paper-based strategies prepared for other developed countries). Adapted legal frameworks with less stringent requirements could make it easier to reach scale and strengthen local economy at the same time.

could not directly be blamed for the failures – it is more the combination of the type of selected technology with the non-technical conditions present that do not work out.

Given many problems with external infrastructure (energy, materials and supplies), practice reflects that extensive/simple systems seem to have a higher probability of long term operation than intensive (technical) systems. But even for pond systems, the development of the associated catchment leads to significant problems. The background of the investigated regions shows different infrastructure conditions with significantly lower sanitation and wastewater coverage in the Sub-Saharan countries. On the other hand water reuse is a more pressing issue in North African countries given that wastewater is often the most reliable water source in dry climates. More details on the survey results and the methodology applied in the survey are described in Nikiema et al. (2013).

The objective of this paper is to summarize the most important requirements for local adaptation that have been extracted from the surveys and to discuss some issues that are linked to them.

Technical requirements

Many of the technical requirements given below should be common knowledge for planning engineers and also necessary aside the target regions of the project. Anyway, the summarized points below are directly tackled by the challenges reported in the survey and therefore worth to be repeated. Besides the bullet points of the requirements itself, some critical discussion points have been added to show the relevance of non-technical aspects that impact technology implementation and complicate engineer's life.

Treatment performance

Legal compliance and impacts on health and environment

The treatment capacity has to comply with regulations and has to ensure that no harm is posed to humans and the receiving environment (aquatic systems and water resources):

- Legal compliance specific to each country and area.
- Low toxicity of remaining pollutants on fish; e.g. low levels of ammonia.
- Low levels of N and P to avoid eutrophication.

Numerous problems arise with the issue of legal compliance. A legal framework should cover the risk management of wastewater treatment, disposal and reuse for the conditions where it is applied. Under this assumption, the durable compliance of a system keeps health risks and environmental risks at an exactable level. As basis, the thresholds given for the effluent has to be achievable by a system. In many cases, developing countries copy requirements from others (developed countries) or even worse: They set more stringent thresholds. It is not to be forgotten that, in developed countries, the current legal framework reflects the status of a (costly) system development and upgrade over decades. This development followed a stepwise improvement - from mechanical treatment, carbon removal up to tertiary treatment (where necessary).

For example, economically and technically feasible technologies cannot meet the stringent P requirements given in Tunisia (P levels below 0.1 mg/L!). Also, since many projects are funded externally and national and international tender procedures apply, intensive (technical) systems get favoured over extensive ones as a consequence. The dependence on foreign technology import is prolonged when the offered solutions have to comply with strict effluent requirements.

As second aspect, compliance requires the knowledge on system performance and its control. As first part of this, the operator has to be able to measure something and, as a consequence, to react according to the results. This implies costs on analytical materials and equipment but also sufficiently trained personnel. Both efforts are dependent on the number and nature of parameters to be covered. Secondly, regulators have to be aware of the operation results and have to verify them externally. Again, time and resources are needed. Practice shows that capacities on both sides do not meet these requirements in many cases.

Reuse

In case of water reuse, the effluent quality has to prevent adverse impacts on humans, the receiving environment and agricultural production (but to keep beneficial nutrients for plant uptake):

- No further contamination of groundwater, e.g. with pathogens.
- Low salinity.
- Possibly high nutrient (N and P) levels.
- Low pathogen contamination.
- Low suspended solids (to avoid sedimentation in the irrigation devices).

Legal compliance issues apply in the same way for reuse purposes as stated earlier. Since reuse of treated water may be an input to the food chain, this is even more important. But frameworks have to consider the nature of the reuse envisaged. This means that nutrients shall not be removed since they are needed. Hence, treatment costs can be reduced and the market position of the reuse water strengthened. In some North African countries, water subsidies for irrigation water (from public water supply) counteract water reuse from wastewater treatment by reducing its market value. Considering the important aspect of hygienic risks, wastewater treatment is only one step in the reuse chain. Selection of crops, transport, irrigation system and other aspects contribute to a successful reuse system (see WHO guidelines; WHO, 2006). Studies revealed that even the handling of the crops during transport and market are more relevant for hygienic contamination than the treatment of the used wastewater itself (Ensink, 2010). Discussing safety issues and having in mind that at many places of the investigated regions informal use of (untreated) wastewater is in place, practicable solutions for reuse are urgently needed. Figure 1 shows the effluent of a pond system for agricultural reuse. Here, farmers reduced the use since adverse impacts on crops have been observed (and not because some parameter thresholds where not met). The plant suffers from adverse industrial impacts (see also next chapter and Nikiema et al., 2013).

Plant size

Catchment development

The system size has to be designed to cope with the amount of current connection load including a certain (estimated) future increase.

- Selection of technology according to level of centralisation needed.
- System must be able to cope with anticipated changes of settlement structure (urbanization).
- Size must take into account the estimated future increase of inhabitants.

Currently, many systems suffer from overload conditions with the consequence that wastewater can only be partly treated. One reason is that the treatment capacities have not been planned accordingly or been increased in parallel to the collection systems or that a significant input comes from informal connections. As population is rapidly increasing in many peri-urban and urban areas in Africa, the systems have to cope with increased loadings as well with changed wastewater quality (impact of industry and businesses, see below). A transition of infrastructure with increasing level of centralisation has to be considered. Decentralized systems might be appropriate for a certain time period, and then sewer connection might be necessary to cover increased settlement density. Hence, the suitability of technologies might change with such considerations.

Local capacities

The management and O&M requirements related to the plant size shall be in line with local capacities.

- Complexity has to be appropriate for expertise available.
- Capacity building to increase and regularly adapt human resources shall be possible.

Generally, small systems with responsibilities of the end-user for operation require low complexity. For larger scale and technical systems, the operator is a key element. Often the resources for personnel are limited or redirected from their designation to finance other community issues. This leads to failure in many cases. Also the lack of internal and external monitoring contributes to a low awareness on capacity building within operating institutions (see also section on O&M).

Figure 1: Effluent for reuse: wastewater treatment plant (WWTP) in Ouagadougou, Burkina Faso.

Figure 2: Decentralized system for rural community: Constructed wetland system in Tunisia.

Land and space requirements

The applied technology shall ensure the required performance at a minimal aerial footprint in cases where land availability is low (and land is expensive). Further, the technology selected shall consider other topographical limitations (e.g. steep hills, mountainous regions) and shall be appropriate for the local soil properties. If the location enables the application of sanitation by-products (e.g. compost), this should be considered in the technology selection. Extensive systems like ponds and wetlands generally require relatively large space for implementation whereas the high temperatures in African regions lead to reduction of the required area due to the higher microbial activity compared to temperate climates. Technical systems concentrate the biological turnover on smaller footprint but that leads automatically to higher complexity of the system. Figure 3 shows the impressive surface area of a pond system.

Treatment versatility

The biological treatment system has to be adaptable to cope with pollution characteristics (composition, toxic content) originating from industrial discharges.

- The WWTP shall be able to treat wastewater generated by local industries to a certain extend (depending on the type of industries).
- Technology shall allow flexible control of the process, in case of a variation in the industrial waste composition.

As already mentioned, settlement development and economic growth is often way faster than the infrastructure development in the investigated areas leading to significant impact on public treatment facilities. System failures are reported from simple overload condition due to (often informal) industrial input but also from direct system inhibition from toxic industrial wastes. Biological treatment systems can only cope with industrial inputs to a certain extend. Buffer volumes may help but, in case of strong toxic impacts, the microorganisms allowing pollution removal in the treating system are simply killed and the facility loses its whole capacity. In that case, a strict diversion of the toxic wastewater is the only way to go. Industries achieve the capacity to operate special treatment for their wastes easier than communities where technical capacities are normally limited (it is also easer to treat small amounts of strong toxic wastewater than large amounts of diluted toxic effluents). Even ‘high tech’ systems like MBR are not insensitive to industrial impacts. The potentially higher sludge age allows the adaptation of the biomass to hardly biodegradable matter to some extent but not to toxic constituents. Figure 4 shows a plant that suffers from seasonal impact of the olive oil production wastewaters – a problem that is encountered in many Mediterranean countries.

The second requirement for flexible control to cope with changing conditions will remain a wish - especially in the target regions. Even in Europe this poses a problem to AS plants which are connected to industries. Inflow monitoring connected to forecast for the indolent biological community are a matter of ongoing research and far from practical implementation.

Further, diurnal variations have to be considered:

- WWTPs must be insensitive to usual daily load variations.
- WWTPs must be insensitive to normal seasonal load variations.

Proper system design normally accounts for inflow variations by the introduction of safety factors (e.g. the German DWA A 131 guidelines for activated sludge

Figure 3: Large space requirement for pond systems: Ouagadougou WWTP (Burkina Faso); Treating 96 m³/h of domestic and industrial wastewater.

Figure 4: Domestic MBR plant with impact from olive oil production wastewater (inhibition due to phenolic compounds; Israel).

systems). However, critical operation conditions (and load peaks) have to be defined as input for system design. Influent equalization using buffer volumes helps in most cases to achieve a more or less constant effluent quality. This is especially important for small systems where the diurnal variations are pronounced.
Since domestic water use is relatively low in the concerned regions, the pollutant concentrations are relatively high which also has to be considered in the system selection and design.

Climate impact

Where the effluent shall be reused, evaporation shall not significantly impact the effluent discharge volume. Temperatures have to be a variable input parameter for system design to ensure optimal lay out for the local climate conditions. In general, biological systems are positively impacted by the higher temperatures in dry and tropical climates – an advantage that can be utilised in reducing the plant dimensions accordingly (to reduce costs).

Excess sludge

The wastewater treatment selection has to consider the amount of excess sludge produced and the connected de-sludging frequency that is needed. It has to include a sufficiently dimensioned sludge treatment and disposal mechanism that prevents any severe nuisance or adverse impact on the surrounding environment. Sludge treatment shall provide a sufficient quality for further use, with adequate chemical composition and low pathogen levels. In case no further use of bio solids is foreseen, the volume of produced excess sludge shall be kept as low as possible.

Resource orientation

The quality of available sanitation by products (compost, struvite etc.), if available, must allow safe handling and prevent adverse effects on health and environment from agricultural application.

- Good chemical and bacteriological properties of composts and other by-products.

Not only the generation of water for reuse but also the recovery of nutrients and organics opens the gate to the invisible benefits of the sanitation chain. The latter term 'chain' is the key to resource orientation since the production and application of e.g. composts and struvite needs the establishment of a service chain from collection over processing to marketing. This approach is subject of numerous projects especially in sub-Saharan Africa and has been already implemented at larger scale (Figure 5). Here economical feasibility strongly depends on the market generation. Besides the dry sanitation systems that are known as resource oriented, also the recovery of nutrients and the use of bio solids from wet systems is resource orientation. Wet and dry systems can be also combined to achieve resource efficiency (Masi, 2009).

Operation and maintenance

As central issue of wastewater treatment and sanitation, the survey revealed many challenges that are related to the O&M issues with the frequent statement that somebody is (officially) in charge but does not (or cannot or does not want to) do her or his job.

- Under limited local capacities extensive treatment systems with low O&M efforts shall be used.
- In case of complex systems under limited capacities, automation in combination with contractor's support shall provide proper operation.
- Consideration of locally available supplies shall be as high as possible.

In most cases reported, the lack of O&M is somehow related to the financial capacities. This starts with the lack of money for costly equipment replacements (mainly pumps), to the low motivation of personnel due to low remuneration and finally to the shutdown of important plant parts or whole plants because of their electricity consumption. Hence, in any case (also for large AS systems) it is demanded that the operation and maintenance efforts shall be as low as possible. The suggested use of automated control for operation is a future option for domestic systems and limited to industrial facilities at the time being. It remains to

Figure 5: Urine storage for agricultural application in Ouagadougou.

stress again that from experience the extensive systems can be trusted to achieve at least a certain degree of performance at limited O&M efforts (but not without O&M). On project level, O&M has to be incorporated as a long term component including external monitoring and backstopping for technical systems.

Energy demand

Energy demand is an issue repeatedly stated in the survey and in most cases related to costs or the impacts of an unstable public power supply on the system performance. Where pumping cannot be avoided, the selection of the technology has a clear impact on power consumption.

- Treatment process and control shall be as independent from powers supply as possible.
- If control systems require permanent power, uninterruptable (self sufficient) supply has to be provided.
- For systems with permanent power demand for processing the wastewater, energy production shall be available to cover as much as possible of the demand.

Low power demand allows the introduction of e.g. solar powered operation, an option for smaller systems and low hydraulic volumes to be pumped. The electricity generation from anaerobic treatment is sparsely introduced despite the huge potential for large systems. The high temperature conditions support the efficient operation of digesters in Africa – even for smaller scale units than applied in Europe. On the other hand anaerobic digestion increases the plant complexity and also safety issues have to be considered.

Recommendations and conclusion

The insight in the experiences of the investigated countries has shown that there is the need to simplify some aspects for the scale up of wastewater treatment biotechnologies. The legal framework plays a fundamental role to enable the potential of the full range of water biotechnologies that is often hindered by over regulation. This would allow stepwise infrastructure development at reduced costs and foster local businesses in this sector. The results showed that the industrial wastewater burden cannot be laid on technologies alone, this also needs an enforced regulatory framework.

The summarized requirements have to be considered during a sound system selection and design. The planning process itself therefore remains crucial. It has to consider costs and benefits, future developments and long term operation and maintenance. Therefore, knowledge on the various options of biological wastewater treatment has to be transported in a practicable form to the local engineer. Simplified tools for practical application are needed where the pool of technologies is the backbone.

The results also showed that water reuse and resource orientation are of increasing importance. The question is if these needs will enable sustainable wastewater treatment in future. As a question of economics, only a reasonable value of the marketable product will provide the necessary resources to do it as long as sufficient public subsidies are missing.

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