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PEOPLE AND SYSTEMS FOR WATER, SANITATION AND HEALTH

Obstructions in waste sabilization pond use in Uganda

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STABILIZATION POND SYSTEMS often referred to as lagoons or oxidation ponds are holding basins where natural processes involving bacteria and algae stabilise the waste and pathogen die-off occurs. Sewage from water-borne sanitation systems must be treated before disposal or reuse to reduce the organic matter from the sewage, which in turn reduces on the risk of pollution and removes pathogenic (disease causing) organisms which may cause serious health risks.

In developing countries, such as Uganda, Kenya and Zambia, sewage treatment by stabilization ponds has been effective and an ideal way of using natural processes that take place. The tropical and equatorial climate that is experienced by these regions has contributed greatly to this. Further to this WSPs are cost effective, they are easily maintained, are not energy intensive, no complex machinery (if any) is required during operation, and there is no need for a supply of spare parts let alone having to generate revenue in order to acquire them.

However, to achieve high standards of effluent quality and higher efficiencies it's very important to carry out routine operation and maintenance of the system. Hence the need to revisit factors that affect the performance of the system, so that we can have improved treatment standards and mitigation of any possible dangers that may result due to these factors. This is what sparked my interest in having both NHCC and UNISE stabilization ponds as my case studies in order to identify possible improvements into the performance of this kind of wastewater treatment.

Study Objectives

The main objective of the study was to investigate into the obstructions in use of Waste stabilization ponds and suggest possible improvement measures. Specifically the study was aimed at:

- Reviewing the coverage and performance of wastewater stabilization pond systems
- Evaluating the performance of the NHCC and UNISE stabilization pond system through a seasonal evaluation of the influent, in-pond processes and the quality of the effluent.
- Identifying the causes of poor performance of these systems
- Proposing possible remedial measures to overcome the problems identified above.
- Implementing proposed measures in collaboration with Stakeholders.
- Monitoring and evaluating the effects of the implementation/modification.

Methodology

The approach to achieving the study objectives involved: An assessment of ponds in Uganda - through literature reviews; Selection of study sites; Monitoring the performance of the case studies; Data collection and analysis.

Table 1. Historical performance of wastewater stabilization ponds- depending of the influent strength

Pond system	Location	Raw Influent BOD_5	Effluent BOD_5	BOD Removal (%)
Mbale pond	Mbale	250	38	84
Gulu pond	Gulu	295	42	86
Lira pond	Lira	330	52	85
Kirinya pond	Jinja	330	34	90
Kimaka left pond	Jinja	389	34	85
Kimaka right pond	Jinja	389	57	86
Tororo ponds	Tororo	550	77	86
Kizungu ponds	Mbarara	512	61	89
Kitoro ponds	Entebbe	550	49	92
Doko left ponds	Mbale	452	28	94
Doko right ponds	Mbale	452	29	94

Source Obura A 1999

Table 2. Percentages removal for different parameters

POND	NHCC				UNISE				Ugandan Standard
Season	Dry season		Wet season		Dry season		Wet Season		
Nutrient	RE%	Effluent	RE%	Effluent	RE%	Effluent	RE%	Effluent	(NEMA)
Nitrates	73	20	58	14	64	30	41	17	45mg/l
Ammonia	47	**8***	90	**2***	5	**15***	59	**4***	1mg/l
Ortho-P	68	1.5	88	1.3	20	4.5	51	1.9	5mg/l
BOD5	52	50	56	56	66	38	50	**60***	40mg/l
COD	84	93	75	**128***	30	**130***	64	**101***	100mg/l
FC/100ml	>99	**2E4***	>99	800	>99	4000	>99	5000	10000

*Values above the required National Effluent standard (National Environmental Management Authority, NEMA).

It was found out that the by-pass to the facultative pond of NHCC was opened by the wetland users in the receiving environment to allow for irrigation

Results of Case Studies

Sampling and analysis of parameters was done during the dry (September to December 1999) and the wet (Jan to Feb 2000) seasons. Table 2 gives the removal percentages that were obtained for tested parameters

General observations

Nutrient Removal

Nitrate: Despite the low levels of oxygen in these ponds, the required effluent value of 45mg/l (Ugandan standards) was never consistently achieved. Levels of nitrates are usually low in wastewater due to low oxygen levels and denitrification, as nitrification decreases with acidity and is slow at lower temperatures (Keney, 1973).

Nitrite: Due to lack of effective screening, the movement of floating materials in successive units causes sludge accumulation in these units. This contributed to the organic pollution hence the increased effect on the denitrification processes. Lack of flow from the NHCC second unit may have limited the reduction of nitrate concentrations. However despite the low removals, at all times the effluents met the minimum expected effluent quality of 2mg/l (Ugandan standards).

Ammonia: The expected total removal, which should be 40-60% (Vladirmir Norvotny / Harvey Olem, 1993), was rarely attained. In colder seasons (dormant seasons), nutrient accumulation in the substrate (sludge) usually occurs and the lagoon itself may be a source of nutrients. This could have been due to the unfavourable anaerobic conditions brought about by sludge accumulation in both ponds causing additional pollution to systems. In addition to causing low retention times, they may also contribute to the ammonia concentration. Lack of flow to the third pond also caused a reduction in the efficiencies. In addition, low pH values contributed to reduction in ammonia stripping in these lagoons. Nitrogen fixing algae (e.g. blue green algae) and some photosynthetic bacteria (e.g. Ozobacter bacteria) could also have affected fixing of limited quantities of N_2 in the dark (Harne, 1979).

Phosphorous: The effluent concentrations met the recommended limiting value of 5mg/l (Ugandan standards). Phosphorous removal was within the expected ranges of 4 - 100% (Reed,1993, Bhamidimari, 1991). However effluent concentrations were high compared to the low concentrations of the influent wastewater. The reason could possibly have been due to the sorption capacity of the material (gravel and soil), which decreases substantially within a limited number of years. (Lijklema, 1990). Phosphorous removal in ponds (just as in wetlands) could not have been effective due to the limited ability of phosphate to interact with soil and other adsorbing media (Novotny / Olem, 1993). However the efficiency of lagoons, in removing phosphate, is generally lower than that for nitrogen (Novotny and Olem, 1993).

Upon duckweed decay, all the phosphorus taken up by duckweed was recycled back into the system due to lack of periodic harvesting. An increased production of algae was an indication of phosphorous. Bacteria metabolism of organic matter may have converted organic phosphorous to phosphate in sludge, thereby creating the reducing condition required for phosphorous release to water. If organic substrates for bacteria growth are high, algal growth may be seriously impeded.

However, the removal efficiency for nutrients indicates that these lagoons can effect a higher nutrient removal rate, given that the required conditions are achieved, and also increased retention times by desludging, good pond site management and duckweed harvesting.

Biological parameters

Biological Oxygen Demand: The low removals and poor effluent were probably due to high levels of sludge in the anaerobic pond and the short-circuiting of wastewater through the bypass to the facultative pond of NHCC which reduced the retention time of the wastewater. After simple modification (by blocking the bypass) the effluent quality of 21 - 25 mg/l was obtained which met the required Ugandan standards.

In general both systems were capable of providing a monthly average BOD_5 concentration of less than 40mg/l during the major portions of the year, provided there was adequate contact time. These results are indicative of better removals, given increased retention time-reduced organic loads at present.

Chemical Oxygen Demand: Poor results could be due to the rising levels of sludge in the facultative pond unit, and the possibilities of short-circuiting in the pond, caused by dead points along the pond boundaries. For the NHCC system the hydraulics of flow in the maturation pond, due to lack of flow into the last pond unit, must have had a great influence on the poor performance of the system.

Bacteria and Viruses

Faecal Coliforms: Stressful conditions in the pond must have caused coliform die off. There was no removal by the maturation pond, which had been due to lack of wastewater reaching this pond (caused by the short-circuiting of all the wastewater through the bypass of the facultative pond), demeriting the main function of the maturation pond. For both pond systems, effluent values of less than 10000 FC/ 100 ml were achieved which meets the required effluent recommendations (NEMA standards)

Limitations in WSPs use in Uganda

Causes of inadequacy in the treatment of wastewater by WSP treatment are not unique for each pond. The treatment efficiency and effluent quality for the two pond systems varied due the lack of effective operation and maintenance. Lack of screens, irregular and poor disposal of screenings and poor embankment management adversely affected treatment efficiencies. Sludge and sediment has accumulated beyond required levels so that the retention times are too low to effect the design reduction for the quality parameters.

The lack of duckweed harvesting has also contributed to the poor effluents, and unless this activity is carried out periodically the effluent will continue to be of low quality, hence a source of nutrients to the receiving environment. Additionally the differences in the design of the pond systems (lack of some elements like screens, grit removal chambers) significantly contribute to poor treatment. This often leads to solids bypassing screens (if any), leading to a high level of floating solids, and therefore lowering the quality of the influent.

Conclusion

From both historical and current test results for the case studies, it can be noted that according to the Ugandan standards, the treatment efficiencies are relatively high. Low BOD of the final effluent of well-designed WSP could be due to the algae, which it contains (this causes 'algal BOD' which is different in nature to the 'sewage BOD').

Flow of sewage through the bypass of the NHCC pond system caused deterioration in the performance of the system before the modification. After the modification (January 12, 2000), flow through the bypass was prevented and this visibly improved the performance of the system.

The NHCC pond system has never had any desludging since the commencement of operation (about 20 years ago). This is well above the recommended time for desludging and has led to deposition of sludge in the first pond, causing a deterioration in the performance of the system due to reduced retention times in the ponds and increased BOD concentration.

It was also evident that there is no systematic chemical; biological and physical water quality analysis for routine evaluation of the performance of the waste stabilization system. The two pond systems did not have records of the influent raw sewage and the treatment efficiencies, giving no opportunity for evaluation of the performance of the systems.

The trends of physical parameters indicated lack of adequate plug flow in the system. However with adequate operation and maintenance, this can be improved and will greatly increase the efficiencies of treatment.

Nevertheless WSPs have potential to be the most suitable means for treating both industrial and domestic wastewater especially in the tropics.

Challenges/lessons learned

To attain proper design, installation and adequate operation and maintenance routine activities, it's crucial to ensure appropriate measures for the successful operation of these systems in the field. This can done through:

- Careful design, planning and layout of WSPs (especially with embankments, scum guards, pond bases, pond inlets, interconnections & location)
- Alternatives for upgrading lagoon effluents, (upgrading existing lagoons and designing original systems to meet the water quality standards can be done in a number of different ways; for instance the incorporation of macrophytes in the system, growth of fish and bivores in pond units should be could be used to encourage algae control)

- Effective Operation and Maintenance routine activity programmes should incorporate - removal and burial of scum, grit and screenings, monitoring volumes and quality of influent and harvesting of macrophytes (biological and mechanical)
- Fencing should be erected with allowance for air exchange and efficiency in pond mixing
- Additional research on water quality based on effluent quality, hydraulics of flow and social and cultural values showing the proper way to operate and maintain WSPs should be done.

The way forward

To achieve the expected treatment standards, awareness, training and supervision is vital. The local authorities should have professional support to oversee the maintenance as well as training local people (in addition to those who generate the wastewater).

Despite the relatively good percentage of removal, this is not a good measure of effluent quality but gives a rough idea of how well the system might perform. The performance level may have to be established from continued monitoring of the effluent quality reached.

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Acronyms

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
FC	Faecal Coliforms
NEMA	National Environmental Management Authority
NHCC	National Housing and Construction Corporation
NWSC	National Water and Sewerage Corporation
O&M	Operation and Maintenance
UNISE	Uganda Institute of Special Education
RE%	Removal Efficiency

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