Anaerobic waste stabilization ponds: a low-cost contribution to a sustainable wastewater reuse cycle

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Introduction

The increasing scarcity of water in the world along with rapid population increase in urban areas gives reason for concern and the need for appropriate water management practices. According to the World Bank, "The greatest challenge in the water and sanitation sector over the next two decades will be the implementation of low cost sewage treatment that will at the same time permit selective reuse of treated effluents for agricultural and industrial purposes" (Looker, 1998).

Wastewater is composed of over 99% water. In a developing urban society, the wastewater generation is usually approximately 30-70 m^3per people per year. In a city of one million people, the wastewater generated would be sufficient to irrigate approximately 1500-3500 hectare (SIDA, 2000). Innovative and appropriate technologies can contribute to urban wastewater treatment and reuse.

Water contaminated by human, chemical or industrial wastes can cause a number of diseases through ingestion or physical contact. Water-related diseases include dengue, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever. Consequently, no other type of intervention has greater impact upon a country's development and public health than the condition of clean drinking water and the appropriate disposal of human waste (SIDA, 2000).

One approach to sustainability is through decentralization of the wastewater management system and this approach leads to treatment and reuse of water, nutrients, and byproducts of the technology (i.e. energy, sludge, and mineralized nutrients) in the direct location of the settlement.

More emphasis is being placed on the need to separate domestic and industrial waste and to treat them individually to make recovery and reuse more sustainable. The system must be able to isolate industrial toxins, pathogens, carbon, and nutrients (Rose, 1999).

2. Methodology

2.1. Pond Design

Anaerobic Ponds Design: Anaerobic ponds can be satisfactorily designed, and without risk of odor nuisance, on the basis of volumetric BOD loading (l_v, g/m^3d), which is given by:

$l_v = L_i Q / V_a$

where L_i = influent BOD, mg/l (= g/m^3)

Q = flow, m^3/d

V_a = anaerobic pond volume, m^3

2.2 Anaerobic Digestion

Anaerobic bacteria degrade organic materials in the absence of oxygen and produce methane and carbon dioxide. The methane can be reused as an alternative energy source **(**biogas). Other benefits include a reduction of total bio-solids volume of up to 50-80% and a final waste sludge that is biologically stable can serve as rich humus for agriculture (Rose, 1999). Much advantage is noticed in this treatment. The Advantages of Anaerobic Digestion Treatment (Van Leir, 1998);No, or very low energy demand; Production of valuable energy in the form of methane; Low investment costs and low space requirement; Applicable at small as well as large scale; Low production of excess sludge, which is well stabilized; Low nitrogen and phosphorus requirements; High loading capacity (5-10 times that of aerobic treatment) ; High treatment efficiencies; Suitable for camps with long term periods without discharge of wastewater ;Effluents contain valuable fertilizers (ammonium salts) and the beauty of the anaerobic treatment technology is that it can be applied to a very small and very big scale. This makes it a sustainable option for a growing community.

2.3 Role of Anaerobic Ponds in wastewater treatment- Low cost technology

Anaerobic ponds are deep treatment ponds that exclude oxygen and encourage the growth of bacteria, which break down the effluent (Annexure1). It is in the anaerobic pond that the effluent begins breaking down in the absence of oxygen "anaerobically". The anaerobic pond acts like an uncovered septic tank. Anaerobic bacteria break down the organic matter in the effluent, releasing methane and carbon dioxide. Sludge is deposited on the bottom and a crust forms on the surface as shown in Fig. 2 in Annexure 1.

Anaerobic ponds are commonly 2-5 m deep and receive such a high organic loading (usually > 100 g BOD/m^3 d equivalent to > 3000 kg/ha/d for a depth of 3 m). They contain an organic loading that is very high relative to the amount of oxygen entering the pond, which maintains anaerobic conditions to the pond surface. Anaerobic ponds don't contain algae, although occasionally a thin film of mainly *Chlamydomonas* can be seen at the surface. They work extremely well in warm climate (can attain 60-85% BOD removal) and have relatively short retention time (for BOD of up to 300 mg/l, one day is sufficient at temperature > 20^{o}C).

3. Result and Discussion

Anaerobic ponds reduce N, P, K and pathogenic microorganisms by sludge formation and the release of ammonia into the air. As a complete process, the anaerobic pond serves to: Separate out solid from dissolved material as solids settle as bottom sludge. Dissolve further organic material; Break down biodegradable organic material; Store undigested material and non-degradable solids as bottom sludge; Allow partially treated effluent to pass out. This is a very cost-effective method of reducing BOD_5. Normally, a single anaerobic pond in each treatment train is sufficient if the strength of the influent wastewater is less than 1000 mg/l BOD_5((McGarry and Pescod, 1970). Designers have been in the past too afraid to incorporate anaerobic ponds in case they cause odor. However, results obtained from a more recent study in northern Brazil carried out by Pearson et al. (1996) suggest that maximum design volumetric loadings may increase to 350 g BOD_5/m^3d at 25°C rather that restricting it to 300 g BOD_5/m^3d at 20°C. Furthermore, Mara and Pearson (1986) propose a maximum sulphate volumetric loading rate of 500 g SO_4/m^3 d (equivalent to 170 g S/ m^3d) in order to avoid odor nuisance.

In anaerobic ponds, methane production increases sevenfold for every 5^{o}C rise in temperature. (Marais, 1970)

Table 1
BOD removals in Anaerobic Ponds loaded at 250 g BOD_5/m^3 d (Mara, 1976)

Retention Time (days)	BOD_5 removal %
1	50
2.5	60
5	70

Anaerobic ponds are normally designed on the basis of a temperature, pH and saline dependent PH maintenance through anaerobic pond. A study on anaerobic pond treatment of tapioca starch waste conducted by Uddin (1970) revealed that a volumetric BOD loading rate of around 750 $g/m^3 \cdot d$ resulted in a pond pH of 6.0. Fig. 3, which is based on Uddin's results shows that when the BOD loading rate was increased above this value, the volumetric BOD removal rate was reduced. Most likely, pond overloading impaired methanogenesis. Experiments conducted by Sergrist (1997) showed a 50% growth inhibition at a NH_3-N/l concentration of 25-30 mg/l. Strong ammonia inhibition in anaerobic ponds can occur at concentrations >80 mg NH_3-N/l and may reduce significantly COD elimination to as low as 10% in primary anaerobic ponds (Data is still scarce in this matter). Arridge et al. (1995) working on an experimental WSP complex in Northeast Brazil found a one log unit removal in the AP for each of the following indicators: faecal coliforms, faecal streptococci and Clostridium perfringens. Salmonellae were reduced from 130 to 70 MPN/100 ml and Vibrio cholerae 01 was reduced from 40 to 10 MPN/l respectively. Anaerobic ponds appear to be essential for high levels of V. cholerae removal.

3.2 New Techniques in Ponds

Two PC-based waste stabilization pond design procedures, based on parameter uncertainty and 10,000-trial Monte Carlo simulations, were developed for a series of anaerobic, facultative and maturation ponds to produce < or = 1000 E. coli per 100 ml for both 50% and 95% compliance.

3.3 Duckweed Based Wastewater Treatment System and Assessment of Nutritive Value and Economic Return

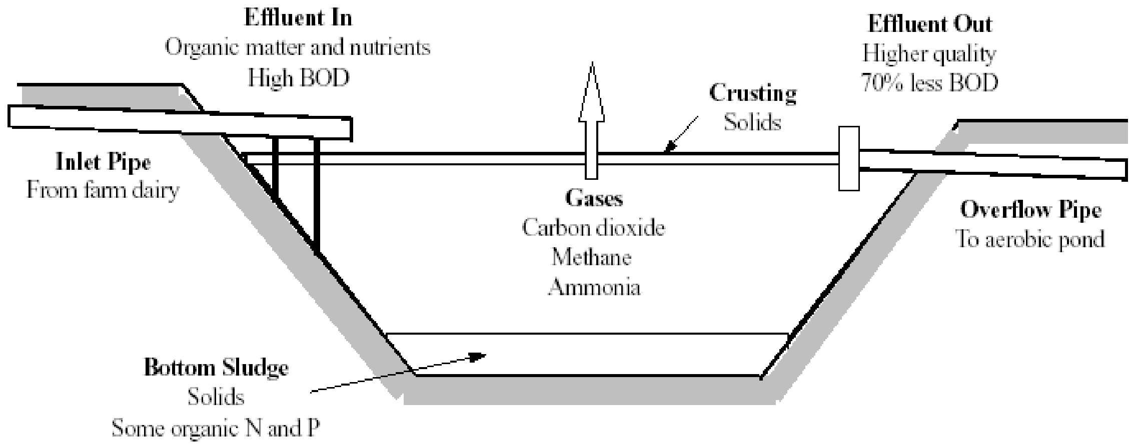
With the objective to evolve a low cost treatment technology, the project has been undertaken to study the efficacy of treatment of wastewater by duckweed, to assess the economic return from pisciculture (fed on duckweed) as well as evaluating the nutritive value of duckweed.

The duckweed based stabilization pond functions as anaerobic pond except at the top layer where aerobic condition prevails. The top aerobic zone effectively controls the odour problems of the pond. The capability of up taking nutrients and other substrate from wastewater has attributed this plant to be biological purifier. There is remarkable reduction of BOD, COD, Total Suspended Solid, Nitrogen, Phosphorus and Heavy metals from wastewater in duckweed based stabilization pond. Wastewater treatment by duckweed based stabilization pond provides the treatment at a low cost. This type of treatment system can therefore help in meeting the challenges posed in developing countries for environmental protection, due to resource recovery advantages over the conventional lagoon system.

Conclusion

The common characteristic of all of the described types is that they encourage “zero-discharge” technology. This cyclical, rather than linear approach includes the reuse of the treated effluent for agricultural reuse. The reuse of the wastewater decreases the money spent on fertilizers and it is considered safe, since it has been treated for pathogens.

Annex 1



Annex 2

References:

- Abis, Karen L. (2002). The performance of facultative waste stabilization ponds in the United Kingdom. Ph.D. thesis, U.K. University of Leeds.
- Arar A. (1988). Background to treatment and use of sewage effluent. Ch. 2, *Treatment and Use of Sewage Effluent for Irrigation*, M.B. Pescod and A. Arar (eds). Butterworths, Sevenoaks, Kent.
- Bartone, C. R. (1991). International perspective on water resources management and wastewater reuse - appropriate technologies. *Water, Science & Technology,* 23: 2039-2047.

based Activities (GPA) on Sewage, Developed by UNEP/GPA, UNEP/IETC & IHE in

- Boutin, P., Vachon, A. and Racault, Y. (1987). Waste stabilization ponds in France: an overall view. *Water Science and Technology*, 19 (12), pp.25-31.
- Bucksteeg, K. (1987). German experiences with sewage treatment ponds. *Water science and Technology*, 19 (12), pp.17-23.
- EPA (1983). Design Manual: Municipal Wastewater stabilization Ponds. Report No. EPA-625/1-83-015. Cincinnati: *Environmental Protection Agency*, Center for Environmental Research information.
- Mara D.D. (1976) Sewage Treatment in Hot Climates. John Wiley, London.
- Mara, D. D. and Pearson, H. (1986). Artificial Freshwater Environment: Waste Stabilisation Ponds. In: *Biotechnology* (Rehm and Reeds, eds.). VCH Verlagsgesellschaft, Weinheim, Germany.
- Mara, D. D. and Pearson, H. (1998). Design Manual for Waste Stabilization Ponds in Mediterranean Countries, Leeds: Lagoon Technology International Ltd.

- Mara, D. D., Alabaster, G.P., Pearson, H.W., Mills S.W. (1992). Waste Stabilisation Ponds - *A Design Manual for Eastern Africa*. Leeds: Lagoon Technology International Ltd.