Comparative Study of Wastewater Treatment Technologies for a Township

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Abstract— The paper presents comparison among the most frequently used waste water systems in developing countries. Various physico-chemical and biological techniques have been used for the treatment of domestic wastewater. The wastewater is conventionally treated either by suspended growth system, by attached growth system or combined suspended and attached growth system. The system studied were oxidation pond, activated sludge, upflow anaerobic sludge blanket, trickling filter and constructed wetland. All the above systems were designed and analysed based upon the various factors such as BOD removal efficiency, land required, power required, HRT, quantity of sludge to be handled, initial, operational & maintenance cost. The main summary table for quantitative analysis is prepared based on per capita values. It also includes the advantages and disadvantages of the treatment processes.

Key words: attached growth system, suspended growth system, removal efficiency, sludge handling

I. INTRODUCTION

The community waste water carries organic as well as inorganic impurities. Direct discharge of waste water into the river or any fresh water source leads to its pollution. Inappropriate use of water resources and poor management of waste water has an increasingly negative effect on economic growth on social welfare and on the world's eco-systems. Nowadays there is a wide variety of systems which can be applied for wastewater treatment. In developed countries the number of alternatives may be somewhat more limited due to the more stringent effluent quality standards usually applicable, while in developing countries as a whole the breadth of choices to be analysed may be higher. This fact stems from the diversity of effluent standards encountered throughout these countries. Also the cost component and the operational requirements, while important in the industrialised countries, play a much more decisive role in the developing countries. All these points make the preliminary selection of the more appropriate systems for the intended application a critical step, many times overlooked in less careful designs.

In developed countries, critical items which are to taken into consideration are efficiency, reliability, sludge disposal aspects and land requirements, environmental impact, etc. Where as in developing countries, these parameters have secondary importance, but have a smaller magnitude, compared to developed countries.

In developing countries, critical parameters for selection of treatment system are cost of construction, cost of operation, sustainability, simplicity, etc. These items are also important for developed countries, but cannot be considered to be critical.

The objective of the paper is to present elements for a preliminary comparison among the systems most frequently used for treatment of domestic wastewater, with a particular view to developing countries, under different conditions. The items analysed should help the consultant or even members of the organised community to make a first evaluation and preliminary selection of the treatment systems which could present a higher potential applicability for each case under consideration.

For this some applicable systems were designed for next three decades and analysed for various parameters for the township generating 3500 m3/day of sewage (peak flow).

II. THE SYSTEMS ANALYSED

- Oxidation Pond (OP)
- Activated Sludge Process (ASP)
- Trickling Filter (TF)
- Upflow Anaerobic Sludge Blanket (UASB)
- Constructed Wetland (CW)

All the above systems are analysed based upon the various factors such as BOD removal efficiency, land required, power required, HRT, quantity of sludge to be handled, initial, operational & maintenance cost.

A. Oxidation Pond

Waste stabilization ponds are biological treatment systems, which processes and operations are highly dependent on the environmental conditions such as temperature, wind speeds and light intensity which highly variable and any given combination of these environmental parameters is usually unique to a given location.

An oxidation pond is a shallow pond designed specifically to treat sewage by natural purification processes under the influence of air and sunlight. The stabilization process consists largely of the interactions of bacteria and algae. Bacteria digest and oxidize the constituents of sewage and render it harmless and odor free. Algae utilize carbon dioxide and other substances resulting from bacterial action and through photosynthesis produce the oxygen needed to sustain the bacteria in the treatment process. During the detention period, the objectionable characteristics of the sewage largely disappear.

Wastewater is first subjected to preliminary treatment (screening and grit removal) to remove large and heavy solids. Basically, primary treatment is carried out in anaerobic ponds, secondary treatment in facultative ponds, and tertiary treatment in maturation ponds. Anaerobic and facultative ponds are for the removal of organic matter and maturation ponds for the removal of faecal viruses, faecal bacteria.

There are many advantages of using this kind of biological treatment like easy to operate, low energy required, less equipment maintenance, and better sludge thickening. However, the effluent quality from fixed- film system are relatively poorer than other conventional systems.

The types of waste stabilization pond are :-

- Aerobic ponds
- Aerobic-anaerobic (facultative) ponds
- Maturation ponds
- Anaerobic ponds
- Controlled discharge ponds
- Complete retention ponds

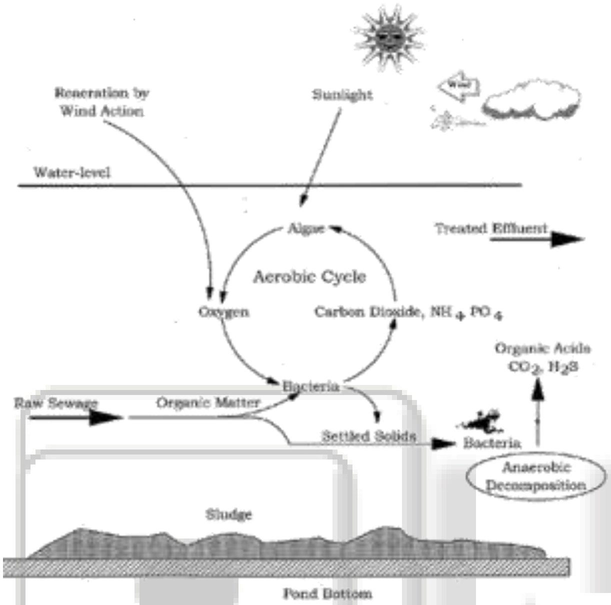

Fig. 1: Mechanism of Oxidation Pond

B. *Activated Sludge Process (ASP)*

Activated sludge systems encompass biodegradation and sedimentation processes which take place in the aeration and sedimentation tanks, respectively. The performance of the activated sludge process is, however, to a large extent dictated by the ability of the sedimentation tank to separate and concentrate the biomass from the treated effluent. Since the effluent from the secondary clarifier is most often not treated any further, a good separation in the settler is critical for the whole plant to meet the effluent standards.

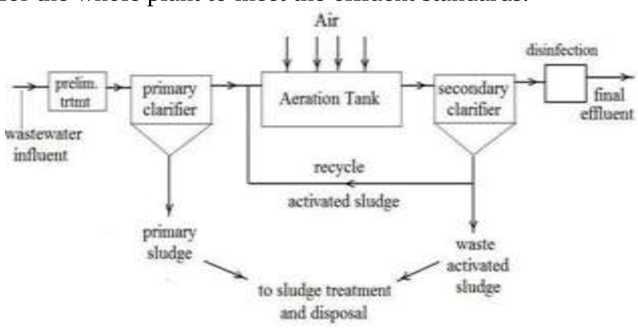

Fig. 2: Flow Diagram for Activated Sludge Process

Activated sludge process is a common method of aerobic wastewater treatment. These system originated in England in the early 1900's and earned their name because of sludge is produced which aerobically degrades and stabilizes the organic load of wastewater. The purpose of the process is to reduce amount of dissolved organic matter from wastewater, using microorganisms growing in aeration tanks. Microorganisms convert dissolved organic matter into their own biomass, oxidizing carbonaceous matter, oxidizing nitrogenous matter and removing phosphates.

C. *Trickling Filter*

It consists of a fixed bed of rocks, lava, coke, gravel, slag, polyurethane foam, sphagnum peat moss, ceramic, or plastic media over which sewage or other wastewater flows downward and causes a layer of microbial slime (biofilm) to grow, covering the bed of media. Aerobic conditions are maintained by splashing, diffusion, and either by forced air flowing through the bed or natural convection of air if the filter medium is porous.

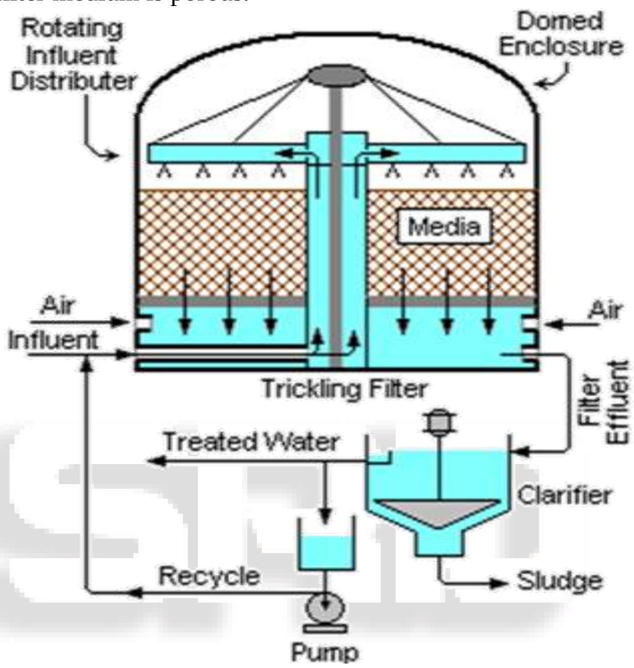

Fig. 3: Diagram of Trickling Filter

During operation, the organic material present in the wastewater is metabolized by the biomass attached to the medium. The biological slime grows in thickness as the organic matter abstracted from the flowing wastewater is synthesized into new cellular material.

D. *Upflow Anaerobic Sludge Blanket (UASB)*

Anaerobic digestion has become the most frequently used method for the treatment of medium to high- concentration effluents, due to the economy of the process, and the low generation of surplus sludge. Among the various configurations, the upflow anaerobic sludge blanket (UASB) reactor is the most frequently used reactor in full-scale installations for the anaerobic treatment of domestic wastewaters, being restricted mainly to countries with a warm climate.

In the UASB process, the wastewater flows through a granular or flocculent sludge bed, where different physical and biochemical mechanisms act in order to retain and biodegrade organic substances. Readily biodegradable substances are quickly acidified and then converted into methane and other biogas components, and, with the growth that usually arises, the reactions progress in general according to the empirical Monod equation.

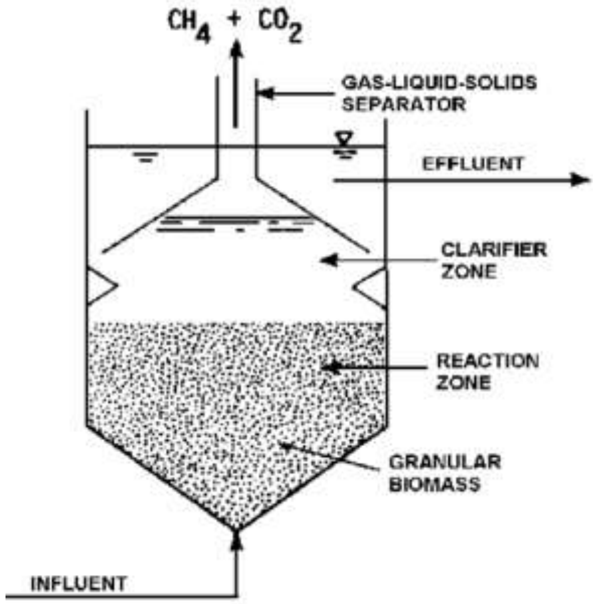

Fig. 4: Upflow Anaerobic Sludge Blanket

E. Constructed Wetland (CW)

A constructed wetland is an artificial wetland created as a new or restored habitat for native and migratory wildlife, for anthropogenic discharge such as wastewater, storm water runoff, or sewage treatment, for land reclamation after mining, refineries, or other ecological disturbances such as required mitigation for natural areas lost to a development. Natural wetland act as a biofilter, removing sediments and pollutants such as heavy metals from the water, and constructed wetlands can be designed to emulate these features. Wetlands are some of the most biologically diverse and productive natural ecosystems in the world. Constructed wetlands can also be a cost-effective and technically feasible approach to treating wastewater. Wetlands are often less expensive to build than traditional wastewater treatment options, have low operating and maintenance expenses and can handle fluctuating water levels. Additionally, they are aesthetically pleasing and can reduce or eliminate odors associated with wastewater. They are mainly classified into surface flow and subsurface flow constructed wetland. Out of which subsurface flow wetland is most commonly adopted.

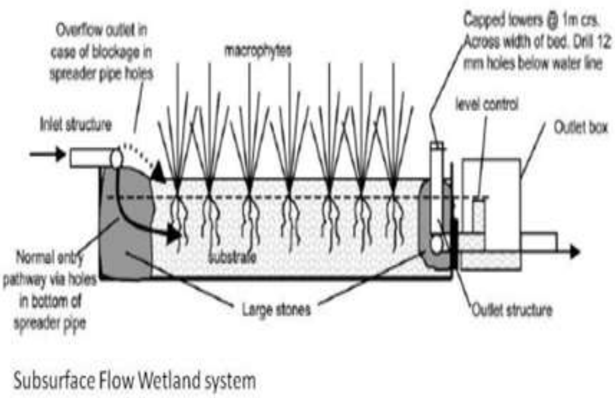

Fig. 5: Subsurface Flow Constructed Wetland

In subsurface flow constructed wetlands, the flow of wastewater occurs between the roots of the plants and there is no water surfacing (kept below gravel). As a result the system is more efficient, doesn't attract mosquitoes, is less odorous and less sensitive to winter conditions. Subsurface-flow wetlands can be further classified as horizontal flow and vertical flow constructed wetlands. In the vertical flow constructed wetland, the effluent moves vertically from the planted layer down through the substrate and out. In the horizontal flow CW the effluent moves horizontally, parallel to the surface.

III. CONCLUSIONS

From the study the comparison is tabulated in table no.1, from which it is concluded that

The oxidation pond system gives best results in BOD removal with zero energy consumption, also the initial, operation and maintenance cost was found very less as compared to the other systems. But the land requirement and hydraulic retention time for oxidation pond was found comparatively very much higher.

For the activated sludge process system the power consumption, initial cost, operation and maintenance cost were found very much high as compared to the other systems. But the land requirement and hydraulic retention time were found comparatively less than the oxidation pond.

For UASB system the land requirement was less than all the other systems. Also the power consumption, initial, operation and maintenance cost were found also less than activated sludge process and trickling filter system but more than the oxidation pond and constructed wetland system.

Trickling filter gives best results and very less land requirement and hydraulic retention time but the initial, operation and maintenance cost were found more than all the other systems except the activated sludge process system.

Constructed wetland requires very much land as compared to all the other systems. Also initial cost requirement was also found to be high than the oxidation pond. But the power requirement, operation and maintenance cost for constructed wetland were found very less than the other systems under consideration.

The overall analysis of various waste water treatment processes leads to the conclusion that there is no ideal system applicable to all the conditions. Before reaching to any decision the analysis of situation must be done individually. Depending upon the analysis of various aspects and site conditions one can give efficient, economical and adequate solution, not only for design but also throughout operational life of treatment plant.

It was concluded that UASB system will prove to be one of the demanded wastewater treatment option for the treatment of wastewater generated from the township, as it requires comparatively less land, power consumption, initial, operation and maintenance cost than activated sludge process and trickling filter. Though oxidation pond and constructed wetland systems requires less land, power consumption, initial, operation and maintenance cost than the UASB, they will not be preferred as they requires about 10% more land than the UASB system.

Treatment system	% BOD removal efficiency	Requirements		Cost (Rs./Capita/yr)			HRT (Hrs)	Quantity of sludge to be handled (m^3/capita/yr)
		Land (m^2/cap)	Power (KW/cap/yr)	Initial	Operation	Maintenance		
OP	75 - 90	2.23	-	335	30	9.45	240	-
ASP	85 - 93	0.57	8.63	1090	130.65	177.4	5.5	1.1 - 1.5
UASB	60 - 80	0.29	2.6	802	102	40	6	0.07 – 0.1
TF	85 - 93	0.35	2.6	864	102	95.8	-	0.4 – 0.6
CW	60 - 80	2.92	1.3	773	53	8	63	-

Table 1: Showing Comparison between Various Systems.

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