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COMPARATIVE PERFORMANCE EVALUATION OF WASTEWATER TREATMENT SYSTEMS FOR REUSE IN IRRIGATION

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ABSTRACT

In this study a comparative performance evaluation of existing wastewater treatment systems available in the Karachi city was carried out. The three options available are trickling filter, aerated lagoon and oxidation pond. The physical, chemical and biological parameters (SS, BOD_5, COD, ammonia nitrogen, phosphorous and fecal coliform) in the influent and effluent samples of each system were measured on weekly basis over a period of twelve months. Additionally, effects of temperature on different pollutants removal in oxidation pond were also studied. The result of sewage influent indicates that it is fairly strong and concentrated. However, the overall performance of oxidation pond has an edge over the other two systems on the basis of effluent quality, economics, operational and maintenance considerations. In view of the high fecal coliform count, chlorine treatment for disinfection would be mandatory. Due to prevailing conditions of developing countries, oxidation pond seems to be the viable option of wastewater treatment. It is therefore recommended, to have a number of oxidation ponds located along the periphery of the metropolis and surrounded by green belts to reuse the treated water. This may be helpful in saving large quantity of fresh water and also solving the unmanaged wastewater problem of the city.

Key words: Wastewater treatment, oxidation pond, fecal coliform, green belts.

INTRODUCTION

Karachi, a metropolitan city of Pakistan with population over 18 million is facing acute and chronicle shortage of potable water. Recycling and reuse of secondary treated wastewater for landscape and irrigation may be helpful in saving large quantity of fresh water and also solving the unmanaged wastewater problem of the city. At present, sewage generated in the city is about 435 MGD, out of which about 345 MGD is drained untreated into the coastal waters creating severe environmental problems. The three wastewater treatment plants (two trickling filter plants and an aerated lagoon) can treat less than 30% of the total wastewater generated, while an oxidation pond located in the Karachi University Campus on a pilot plant scale treated 52500 gallon/day. This is just a fraction of wastewater being produced by Karachi.

Karachi is supplied about 35 gcd against WHO standards of 60 gcd. Ten percent of this supply is used for irrigating city landscape and another 15% losses take place in transmission system, fulfilling only about 50% requirements of potable water. If recycled treated water, there will be direct saving of 10% of potable water now being used for irrigating city landscape. Moreover, the indirect benefit of recycling would be protecting the marine life, protecting the sea food from contamination, recovering precious water for industrial reuse, since all industries buying potable water for their use.

Many countries now consider wastewater reuse as a method to secure water resources (Shelef and Azov, 1996). In India, wastewater is currently being used for irrigation, gardening, flushing, cooling of air conditioning, as feed for boilers and as process water for industries (Chawathe and Kantawala, 1987). In China, national policy has been developed that promotes the development of water efficient technologies and encourages the reuse of reclaimed municipal wastewater in agriculture first and then for industrial and municipal uses (Zhongxiang and Yi, 1991).In Japan, reclaimed wastewater is used for toilet flushing, industry, stream restoration and flow augmentation to create “urban amenities” such as green space (Asano & Levine, 1996; Asano et al., 1996).Therefore, an appropriate wastewater treatment and management methods which are robust, easy to operate and suitable for environmental conditions are needed to be developed in the country. Likewise, appropriate reuse, recycling and disposal methods for treated effluents also needed to be investigated. In this study, the performance of the three existing wastewater treatment systems working in the city was evaluated from the recycling view point. The main objectives of the study was to find an environmentally sound wastewater treatment system that can work in urban environment.

METHODOLOGY

The source for collection of influent samples was at the inlet to the treatment plants and the effluent samples at outlet points of the following three systems on a weekly basis over a period of twelve months.

i) Trickling Filter Plants

ii) Aerated Lagoon

iii) Oxidation Ponds Systems

There are three Trickling filter Plants at different locations in the city, having a total treatment capacity of 151 MGD but actually treating about 90 MGD sewage. It consists of pumping station, screens, detritors, primary settling tanks, biological filters and final tanks. The aerated lagoon has a capacity of 5 MGD and is equipped with two aerated lanes each fitted with 4 numbers of 20HP horizontal shaft paddle aerators and having a retention period of 18 hours.

The domestic wastewater treatment facility through the pilot oxidation pond system has been provided at the Karachi University Campus. Four trapezoidal oxidation ponds of equal dimensions were constructed. The hydraulic load, the BOD load and the retention time respectively were 2,045,692 liters per ha day, 511 Kg/ha day, 3.4 days in each pond. This would mean that a total retention time of 6.8 days in P-1 and P-2 (connected in series) and again 6.8 days in P-3 and P-4 (connected in series) was kept constant through out the period of study.

The influent from trickling filter plant and aerated lagoon was collected from the grit chamber soon after it passes through the screen, which removes large suspended material. The treated effluent samples were collected at the outlet point of the three systems. The samples were collected in the morning hours on weekly basis and transported to the laboratory immediately in tightly sealed large plastic containers for physical and chemical analysis. Where as sterilized reagent bottle of 200ml capacity were used for taking out samples for bacteriological examination. During collection every attempt was made to avoid the collection of debris, paper, twigs as well as silt. These samples were kept at 4 ^{o}C and were analyzed within 24 hours.

All parameters (pH, Alkalinity, suspended solids, total dissolved solids, BOD, COD, ammonia nitrogen, phosphate phosphorus and fecal coliform) were determined according to the procedure laid down in (APHA, 1989), during 12 months period.

RESULTS AND DISCUSSION

For the three types of treatment under investigation the best choice shall be based on the comparative treatment efficiency of suspended solids, BOD, ammonia nitrogen, phosphate phosphorus and fecal coliform. Other parameters like toxic elements etc. are also important in agriculture reuse, but not discussed here since the above treatment methods hardly contribute to their removal.

The results of the influent sample (data not shown) indicate that the sewage under treatment is fairly strong with BOD ranging from 165 mg/L in case of oxidation pond to 360 mg/L in aerated lagoon. Suspended solids vary from 181 mg/L in trickling filter to 1244 mg/L in aerated lagoon. Ammonia nitrogen is 39 mg/L in oxidation pond to 64 mg/L in aerated lagoon and the fecal coliform varies from 210x10^6 MPN/100ml in trickling filter to 2400x10^6 MPN/100ml in aerated lagoon.

Table 1. Comparative performance efficiency of the three treatment systems (yearly average)

Parameter	Trickling Filter	Aerated Lagoon	Oxidation Pond
Suspended solids	(88-98) 93	(77-91) 85	(77-97) 92
Biochemical Oxygen Demand	(64-81) 72	(65-92) 80	(60-96) 79
Ammonia Nitrogen	(13-23) 17	(3.6-50) 22	(19-60) 37
Phosphate Phosphorus	(7-20) 13	(4-50) 22	(6-82) 41
Fecal Coliform	(76-93) 85	(96-99.99) 99.96	(91-99.80) 97.60

The removal efficiencies for the three treatments for suspended solids, BOD, ammonia nitrogen, phosphate phosphorus and fecal coliform are presented in Table 1. The yearly average value provided in the table is estimated as an average of weekly data. Figure 1 and 2 present the seasonal variation based on the monthly averages, for BOD and fecal coliform removals. As expected the performance of the oxidation pond (without mechanical aerators) is lowest for the two winter months but comparable and even better during rest of the year, (95% removal for BOD in July). During 10 months of the year, performance of oxidation pond was found excellent keeping in view that the hydraulic retention time, which was of very short duration, i.e. 3.4 days and at a depth of 1.04 m. It will be noted that the effluent quality from the oxidation pond and aerated lagoons meets the standards for irrigation reuse as far as suspended solids, ammonia nitrogen and BOD are concerned. In contrast, the performance of the trickling filters was less due to its operational and maintenance problems, so typical with developing countries. The result of the analysis indicate that none of the effluent meets the microbiological quality criteria for the agriculture reuse as the fecal coliform count were found in the range of 10^6 MPN/100ml. In Pakistan untreated and primary treated wastewater is generally used in agriculture since decades. As no much attention has been given to microbiological criterion for irrigation reuse, therefore no data is available on the vegetable grown by secondary treated and untreated wastewater. However, the data collected for similar conditions of other countries are available and can serve as guidelines. Shuval *et al*., (1986) has reviewed all the available epidemiological studies conducted on wastewater reuse for crop irrigation.

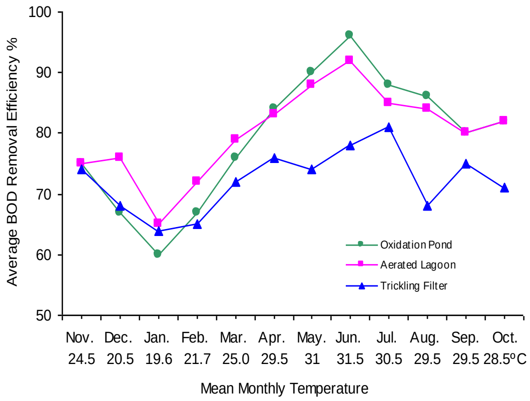

Fig 1. Seasonal Variation of BOD Removal Efficiency

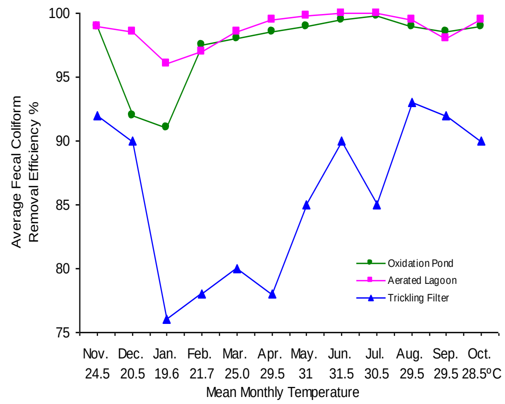

Fig.2 Seasonal Variation of Fecal Coliform Removal Efficiency

Table 2. Engelberg Guidelines for wastewater reuse in agriculture (IRCWD, 1985).

Reuse Process	Intestinal Nematodes Arithmetic Mean No. of viable Eggs/Liter	Fecal Coliforms Geometric Mean No. /100 ml
Restricted Irrigation (Trees, industrial crops, fodder crops, fruit trees and pasture)	< 1	Not Applicable
Unrestricted Irrigation (Irrigation of edible crops, Sports field and public parks)	< 1	< 1000

Current microbiological standards for wastewater reuse for crop irrigation vary from country to country and even from state to state in U.S., on the whole they are very strict (CSDPH, 1968; WRFA, 1977; Mara & Cairncross, 1989). However, Engelberg guidelines (Table 2) decided by a group of experts from WHO, World Bank, and International Reference Center for Waste Disposal (1985, 1989) are opposed to such stringent limits and conclude that risks of irrigations with well treated (secondary) wastewater were minimal and that the current bacterial standards are unjustifiably strict. In the light of above discussion, it can be concluded that from microbiological viewpoint the oxidation pond effluent can be used only after disinfections. The experience in Pakistan of wastewater reuse for irrigation justifies and supports Engelberg guidelines.

During study period it was observed that in oxidation pond and aerated lagoons, mosquito breeding, scum formation and odour problem were not existent for most of the months. However, in winter months with cloudy weather, the odour was noted. But, overall, the effluent quality was found positively better than the trickling filter except for few cloudy winter days in the whole year.

The economics of the above three systems have been the subject of research elsewhere and Table 3 give the relative costs and land requirements for various treatments (Alam, 1989). Based on the effluent quality (except for few days in winter months), capital, operational and maintenance cost, oxidation ponds as a system of treatment holds an edge over more sophisticated conventional methods particularly in arid and semiarid zones where inexpensive land is available. The only drawback would be the excessive requirement of land, in this case almost six times that of trickling filter and approximately twice as much as in aerated lagoon. Obviously it will not be suitable if built at one place for city like Karachi but may be suitable for small cities and towns. The odour problem in the system can be minimized if maintained the system properly.

Table 3. Estimated cost comparison per MGD for the three treatment systems (BOD removal efficiency 75%)

Cost (million US$)	Conventional Treatment (Trickling Filter)	Aerated Lagoon Systems	Oxidation Pond Systems
Capital	0.332	0.191	0.144
Operation & Maintenance (per year)	0.0069	0.014	0.014
Land area (ha)	0.041	0.086	0.232

This option of treatment would be feasible in Sindh and Baluchistan region, since large tract of arable lands are available. But in Punjab, most cities are located with the canal or tube well irrigated areas and oxidation pond treatment system can not be recommended. For such city/town aerated lagoon will be better choice since they occupy half the area as needed by oxidation ponds. Also in Northern Pakistan (including Punjab and NWFP) cold weather continue for five months, during which the efficiency of oxidation pond would be very low.

Based on the findings, it can be suggested that large cities like Karachi can be divided in small sectors and each sector to be provided its own oxidation pond on the outskirts along with the green belt. The decentralization of the system will minimize wastewater management problems, enhance community participation, reduce massive digging along road side for sewer lines and equally distribute wastewater along the periphery for irrigation.

A conceptual plan for Karachi need to be developed in which a number of oxidation ponds will receive wastewater from respective sectors and deliver the treated effluent to the green belt. The idea of green belt around city might have following benefits:

1. Minimize dust problem.
2. Reuse precious water now being drained into the sea.
3. Produced ornamental flower/vegetable, not only making Karachi self sufficient but leave enough for export.
4. Reduce poverty by providing job to the unemployed.
5. Once built, the oxidation pond can be operated and maintained on self help basis.

CONCLUSIONS

1. Oxidation ponds coupled with vegetable and fodder growing belts are the best solution to medium size and small towns in arid zones where inexpensive land is available.
2. A number of oxidation ponds on sector wise distribution with vegetable and fodder growing belts are recommended for large cities like Karachi.
3. Aerated lagoons are recommended for large and small towns of Punjab where cities are located within the irrigated and expensive agricultural lands.
4. The use of conventional type of treatment plants should be discouraged in the light of experience gained from the existing ones. Sophisticated operational problems, maintenance and spares are major factors against the conventional type of treatment plants i.e. trickling filter, activated sludge, biofilters, etc.

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