

Assessment of Wastewater Treatment Technologies Applied at Delta-Egypt (Case Study kafr Elshaikh Governorate)

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Abstract: Egypt is currently facing a huge problem in the wastewater treatment industry due to the rapid population growth, the extensive increase in waste water production and the great financial program requested to complete the full coverage of the country with waste water treatment plants. Optimization of the application of wastewater treatment techniques in their different categories primary, secondary and tertiary is highly recommended for the strategic planning of the country, future feasibility studies, design purposes and implementation. The main objective of this research is to assess the performance of five different waste water treatment processes applied in Kafr El-sheikh Governorate, Delta, Egypt. Conventional systems such as oxidation ditch, activated sludge, trickling filter and aerated lagoons were investigated under different hydraulic loading and influent quality. The activated sludge proved excellent removal efficiencies with high economic value for the treatment of capacities higher than 40000m³/day while oxidation ditches were highly recommended for treatment of discharges less than 12000 m³/day. The application of lagoons in either aerated or natural performance did not prove sustainable removal efficiencies after three years of continuous operation despite the disadvantage of the large area requirement in such a very high value of agricultural land in the Egyptian Delta.

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1. Introduction

Egypt is currently facing a big lack in the wastewater treatment facilities due to the rapid population growth, the optimization of wastewater treatment techniques with their different categories including primary, secondary and tertiary treatment is an urgent requirement to help the governmental strategic planning specially after the latest developments in this field, where quite large number of secondary treatment techniques have been applied all over the Egyptian territory including the delta area where land use is very precious. The main objective of this research is the assessment of the performance and economic requirement of five different treatment processes applied in Kafr El-sheikh Governorate, Egypt. Removal efficiency, comparison between operation requirements, power and labor cost will be the major assessment parameters. The principal objective of waste water treatment is generally to allow domestic and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Biological processes are used to convert the finely divided and dissolved organic matter in wastewater into flocculent settleable inorganic solids that can be removed in final sedimentation tanks. The biodegradable organic substances (colloidal or dissolved) are converted into gases that can escape to

the atmosphere and into biological cell tissue that can be removed by settling. Biological treatment is also used to remove nutrients (nitrogen and phosphorus) in wastewater [1].

The most commonly used biological processes are: The activated-sludge process, Aerated lagoons, trickling filters, Rotating biological contactors and Stabilization ponds. Mohamed [2], investigated the effect of the addition of fixed media on the performance of the conventional activated sludge. A pilot plant of activated sludge reactor was operated for two different methods of treatment. The first method was conventional activated sludge while the second was activated sludge with fixed media. In the conventional activated sludge method at a retention time of 10 hours, efficiency of COD removal up to 90% was obtained. In the second method of treatment same efficiency of COD removal was obtained at a retention time of 6 hours. According to the results of the pilot plant it was found that the addition of fixed media can reduce the volume of activated sludge tank by 64% consequently reduce the cost of the construction by 43% taking into consideration the cost of media.

Mohamed [3], studied the increasing demands for more stringent water quality effluent standards during the last decades in both developed and developing countries. The rehabilitation and/or

upgrading of many existing wastewater treatment plants in addition to increasing investments in constructing new plants is a must. In developing countries wastewater treatment is given high priority, to reduce the environmental pollution resulting from the discharge of untreated or inadequately treated wastewater into water streams. In the past few years, many efforts have been made to improve and enhance the efficiency of conventional biological processes dedicated for wastewater treatment coupled with trials to reduce reactor volume and land area requirements resulted in the development of the hybrid system.

In 2012 EIDosoky [4], showed that oxidation ponds were used widely in treating the waste water and sewage industry where the required capital and running cost is less than other treatment methods. The processes features easy operation and its ability to accommodate changes in organic and hydraulic loads without affecting the quality of the treated water makes oxidation ditches suitable for developing countries providing less construction and operation cost.

Ali et al., [5], presented experimental investigation about the rotating biological contactor (RBC) the optimal type of bio filters used for aquaculture recirculation system. RBC design criteria were identified and operated to give design parameters. The RBC was manufactured locally from stainless steel and media from used polyethylene (PE) pipes. The Performance of the designed RBC proved to be adequate for the farm. An average loading and removal rate of total ammonia nitrogen (TAN) were 368.96 ± 126.20 and 133.3 ± 68.85 g TAN/(m³.day) respectively was achieved. Increases in ammonia concentrations improved removal efficiency up to an ammonia concentration of 3.75 mg/l., beyond which removal efficiency remained about 40%.

Mahmoud [6], showed that municipal wastewater treatment is a great problem that faces the developing countries. Most of the anaerobic treatment systems are of low cost, but need a long startup period. The effect of using effective microorganisms in anaerobic sequencing batch reactor to treat municipal wastewater was studied. Results showed the ability of the system to remove pollutants, bad odors, and some pathogenic microorganisms like salmonella in a small time.

In 2006 Ahmed [7], presented a study in using coagulant in trickling filter or Chemically Enhanced Primary Treatment/ Trickling Filter (CEPT-TF) system, Type of Coagulants used in CEPT was FeCl₃, Ferrous sulfate and Alum sulfate. The results indicated that major part of BOD load was removed within the CEPT module. More than 85 % of BOD

removed by the overall system is carried out in CEPT module with coagulant dose up to 12.5 % of the optimum dose (40 ppm). Moreover the percentage of CEPT module of TAC represents about 38, 28, and 19 % on using: ferric chloride, ferrous sulfate and alum respectively at 40 ppm dose, 10,000 m³/day capacities and 500 ppm BOD load. The optimum coagulant dose ranges between 30- 45 ppm (for iron salt) depending on coagulant type.

Meshref [8], showed that the UASB system is a new technique applied successfully in different countries for wastewater treatment. This research aimed at evaluation and assessment of the real performance and the applicability of the full scale UASB system in wastewater treatment in Egypt at local conditions especially in the rural areas. The UASB system was assessed and monitored in Nahtay wastewater treatment plant which lies in Zifta city at El-Gharbia governorate, delta, Egypt where the UASB system achieved high removal ratios for COD of almost 86%, BOD 89%, TSS 88.68%. On the land requirement the UASB was less than the conventional systems by 16% of total area required.

2. Materials and Methods

Kafr El-Sheikh Governorate (Egypt) is enriched with different systems of sewage treatment. Operation and maintenance of the existing treatment plants is under the supervision of the Holding Company for Drinking Water and Sanitation. Conventional systems such as oxidation ditch, activated sludge, trickling filter and aerated lagoons used for sewage treatment where comparisons take into consideration the initial construction cost in addition to the operation and maintenance cost. Electrical power consumption and use the of chlorine for disinfection is also factors of consideration. Nonconventional systems such as oxidation ponds, where the processes works without electrical power, chlorine for disinfection and operators is one of the most important systems to be taken into consideration. This study was conducted from September 2012 to February 2013 as the period represents different seasons of the year with different inflow quality. The data collected are chemical oxygen demand (COD), biological oxygen demand (BOD) and total suspended solid (TSS) for both influent and effluent flow. Monitoring of nitrification processes along each process was also part of the study. Operational parameters such as power consumption, spare parts, labors and chemicals were collected for the same period of the year.

The activated sludge processes is applied in three wastewater treatment plants (Kafr El Sheikh, Desouk and Faou). The design capacity of these plants is ranging from 20,000 m³/d to 90,000 m³/d.

The oxidation ditch processes is applied in four wastewater treatment plants (EL Riad, Sanhwar El Madina, Sidi Ghazi and Shabas Al Malh). The design capacity of these plants ranges from 2,000 m³/d to 10,000 m³/d while trickling filter processes is found in El Hamoul wastewater treatment plant with a design capacity of 20,000 m³/d . The Aerated Lagoon system is used for treatment of waste water of El Hasfh village a design capacity of 1,100 m³/d while oxidation ponds was applied in El Moufty wastewater treatment plant with a design capacity 230 m³/d.

Work Plan:

To conduct the desired comparison a set of factors and analyses to be collected was prepared and results from the different laboratories operated by the governmental operation companies where collected. Analyses for TSS, BOD, COD, Phosphorus and Ammonia in addition to data for the power

consumption, labors, spare parts and consumables were collected, certified and reviewed.

3. Results and Discussion

The study resulted in a comparison between activated sludge (A.S), oxidation ditch (O.D), trickling filter (T.F), aerated lagoons, and oxidation ponds (O.P) systems for BOD removal, COD removal, TSS removal. Wastewater treatments representing each process was chosen for this comparison named Kafr El-Sheikh WWTP representing activated sludge, El-Riad WWTP for oxidation ditch, El-Hamoul WWTP for trickling filters, El-Hasfh WWTP for aerated lagoons and El-Moufty WWTP oxidation.

Analyses of influent and effluent wastewater characteristics at the different plants were carried out at the plants laboratories and results of relevant removal efficiencies are shown in Figs. (1) to (3)

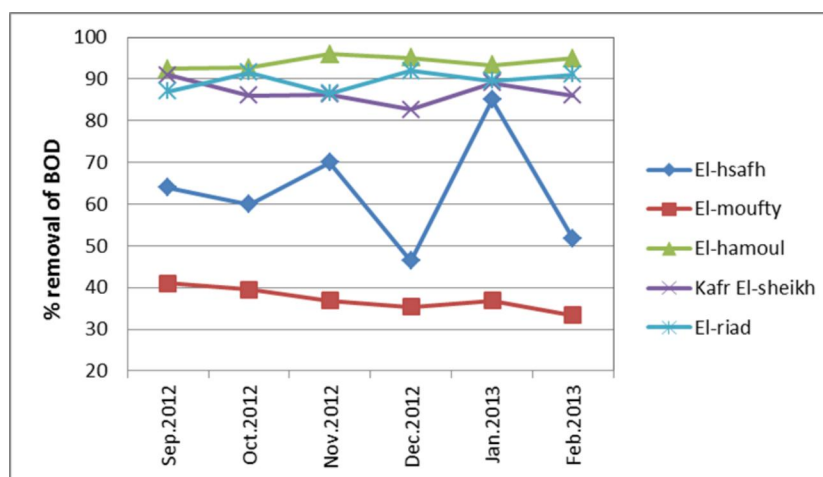


Fig. (1) BOD Removal efficiency for the different processes.

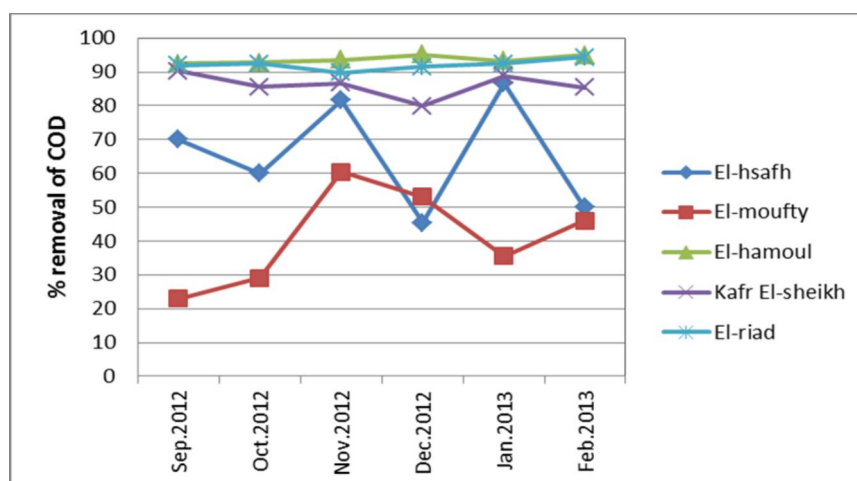


Fig. (2) COD Removal efficiency for the different processes.

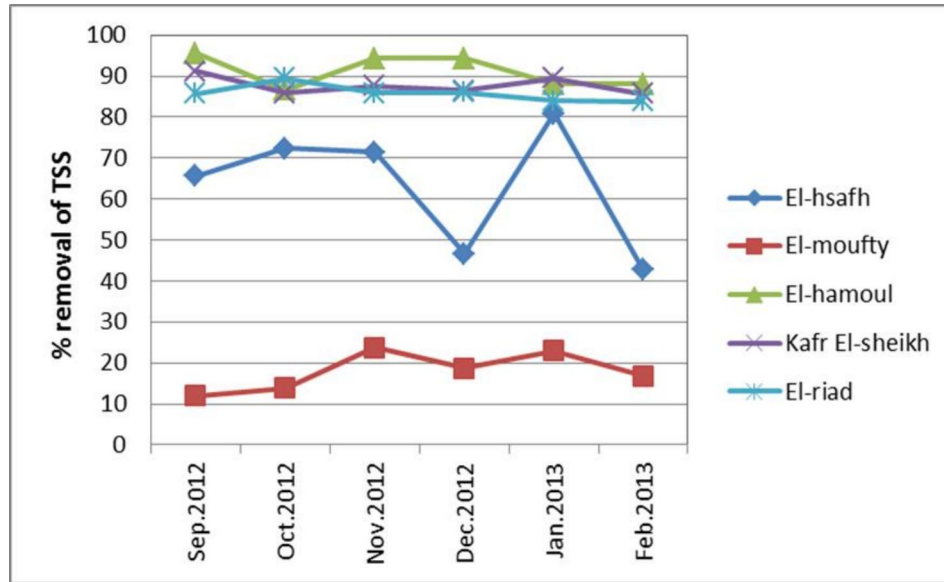


Fig. (3) COD Removal efficiency for the different processes

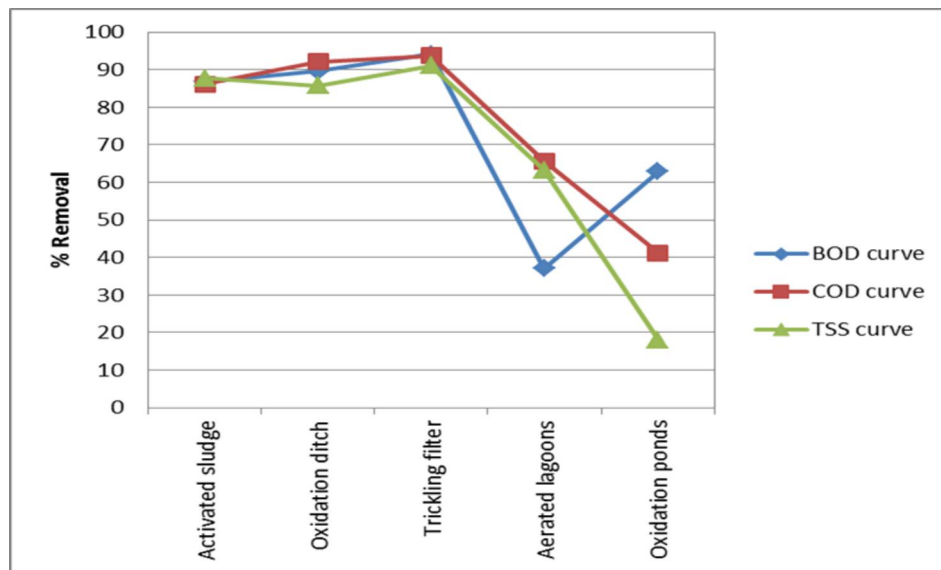


Fig. (4) Comparison between the different processes in BOD, COD & TSS removal efficiency

Results showed that the highest TSS, BOD and COD removal efficiencies were achieved by the Trickling filter, Activated sludge and Oxidation ditch processes with values exceeding 90%. It should be noted that for El-Hamoul WWTP where the trickling filter processes was applied, the plant was under loaded from the hydraulic capacity point of view where the hydraulic load did not exceed 40% from the design capacity by the time of the research. In general re assessment of this plant is highly recommended under the full hydraulic loading.

The lowest removal efficiency was recorded at El-Hsafah plant where aerated lagoons process was

applied. Inlet raw sewage recorded severe contamination; however the evaluation of the system after two years of continuous operation showed deterioration in removal efficiencies. This could be referred to accumulation of sediments in the lagoons where septicity conditions could be easily monitored. In addition, the highly polluted influent including animal wastes with high values of COD had definitely affected the plant performance.

Such raw wastewater that contains high organic loads could not be directly supported by the typical aerated lagoon process. The influent water from this typical Egyptian village could be seen extremely

black, contains animal farms concentrated wastes' with the presence of exchange livestock, animal barns, manure animals and animal fluids resulting in high levels of ammonia and H₂S.

While uncompleted waste water collection systems and lack of solid waste management results in abusing the wastewater gravity networks by farmers, the lack of education, knowledge and awareness requires more concentration in developing local training and media awareness tools to keep the invested capitals in wastewater collection and treatment valuable.

On the other hand For El-Moufty wastewater treatment plant where the traditional oxidation ponds was applied, the BOD removal efficiency did not exceed 65%, however this plant depends on the oxidation ponds. In comparison to the same plant performance recorded by Ashmawy et al. [9], under almost same influent quality, the plant efficiency has tremendously deteriorated which high lights that although the oxidation ponds processes claims maintenance free, the operation and maintenance concerning the sediments removal and performing non septic conditions play a major role in achieving stable plant performance.

Economic assessment of the applied processes:-

Application of different wastewater treatment processes is governed directly by both the capital and operation and maintenance cost in addition to the technical efficiency. Five different processes are considered in this comparison regarding the operation and maintenance costs only considering the following factors:-

- Power cost (EGP/m³).
- Fuel cost represents the cost of oil and diesel (EGP/ m³).
- Spare parts cost (EGP/ m³).
- Others costs that represent unforeseen periodic costs (EGP/ m³).

It should be noted that the labor cost in this comparison was not taken into consideration as the data collected reflected nonrealistic employment strategy.

Data collected are presented in Table (1) and Fig.(5) comparing between the different systems. The operation and maintenance costs were converted to Egyptian pounds per cubic meter of treated wastewater to act as a base for comparison.

Table (1) Operation and Maintenance Cost during Study Period

Type of process	Activated Sludge	Oxidation Ditch	Trickling Filter	Aerated Lagoons	Oxidation Ponds	
Plant	Kafr El-Sheikh	El-Riad	El-Hamoul	El-Hasfh	El-Moufty	
Actual flow (m ³ /day)	57000	2900	5000	507	230	
Operation & Maintenance Cost (EGP/Year)	Electricity Consumption	600000	111111	128734	7708	1750
	Manpower (Labor)	537294	141179	237964	75671	7500
	Oil & Diesel	128843	9622	3651	2000	None
	Spare Parts	32296	110	3774	2750	None
	Others	6189	1673	5266	2250	3500
	Total Annual O & M Cost	1304622	263695	379389	90379	12750
Electricity cost (EGP/m ³)	0.0288	0.1050	0.0705	0.0417	0.0208	
Labors cost (EGP/m ³)	0.0258	0.1334	0.1304	0.4089	0.0893	
Oil & Diesel cost (EGP/m ³)	0.0062	0.0091	0.0020	0.0108	0.0000	
Spare parts costs (EGP/m ³)	0.0016	0.0001	0.0021	0.0149	0.0000	
Total cost (without labor cost) (EGP/m ³)	0.0366	0.1142	0.0746	0.0674	0.0208	
Total cost (EGP/m ³)	0.0624	0.2475	0.2050	0.4762	0.1102	

Comparison showed a rational result that oxidation ponds treatment plant recorded the lowest electricity cost with 0.0208 EGP/m³. On the other hand, the oxidation ditch plant recorded the highest

electricity consumption/treated cubic meter with a value of 0.105 EGP/m³ and the oxidation ponds recorded no oil/ diesel and spare parts costs.

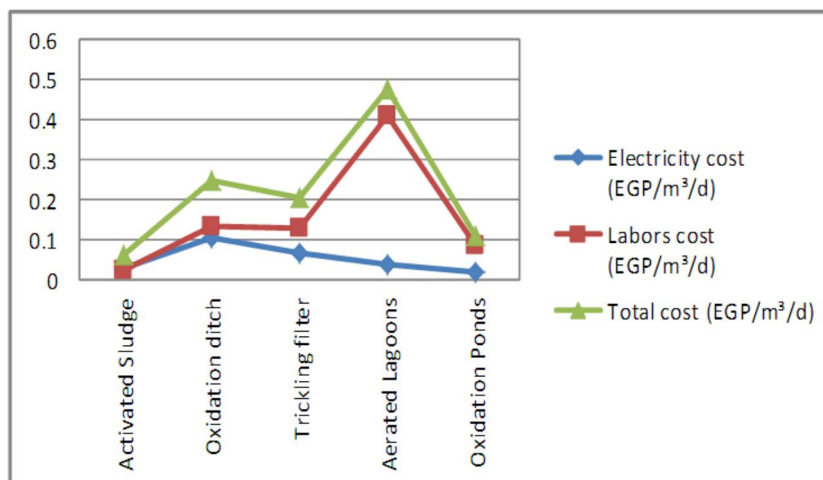


Fig. (5) Comparison of the operation and maintenance cost for the five processes

It could be seen from the figure -excluding the labor cost-that the highest cost for operation and maintenance was recorded by the oxidation ditch system with a value of 0.1142 EGP/m³ while the lowest cost was that recorded by the oxidation ponds system with a value of 0.0208 EGP/ m³.

Conclusion and Recommendation

Based on the results and findings, the following points were concluded:

- Applying the activated sludge process in big cities producing wastewater of discharges exceeding 20000 m³/day in the Delta region is highly recommended. Removal efficiencies can reach up to 95.9 %, 95.12 % and 91.16 % for BOD, COD and TSS respectively, While Applying the trickling filter process for discharges up to 20000 m³/day proved removal efficiencies that can reached up to 95.5 %, 95.12 % and 95.5 % for BOD, COD and TSS respectively under certain operation condition and influent characteristics .
- The oxidation ditch process is suitable for application in treatment of the Egyptian villages' waste water of small discharges up to 10000 m³/d with capability of achieving removal efficiencies up to 94.3 %, 94.3 % and 89.4 % for BOD, COD and TSS respectively.

- Both aerated lagoons and oxidation pond processes are not recommended for application in the Delta region of Egypt. Limited removal efficiencies values of 85 % BOD, 86.7 % COD and 80.8 % TSS for the aerated lagoons and 41 % BOD, 60.5 % COD and 23.8 % TSS were recorded in addition to the large area requirement compared to the other processes. Taking into consideration that the Egyptian population is distributed all over the country and not only in the Delta region, which means that in some cases the desert area adjacent to communities might be widely available specially in upper Egypt, the following recommendations were given:
 - Activated sludge and oxidation ditches are highly recommended for the treatment of waste water in the delta region.
 - Where Deseret land is available a modified and upgraded trickling filter processes could be advised. Plastic media bio-filters, up-flow bio-filter processes and rotating biological contactors can be applied.

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