International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Hybrid Biological Reactor for Wastewater Treatment

Abdel-Latief, M. M.; Ibrahim, M.S.A.
Public Works Department, Faculty of Engineering, ASU, Cairo, Egypt

Abstract— *Wastewater treatment using activated sludge processes has been widely practiced, mainly because of their high treatment efficiency and low operating cost . In the past few years, many efforts have been made to improve and enhance the efficiency of conventional biological wastewater treatment processes coupled with trials to reduce reactor volume and land area requirements. The integrated fixed-film activated sludge (IFAS) system is a variation of the activated sludge process in which biomass support materials or media* ***are*** *incorporated into suspended growth bioreactors. Therefore, pilot plant experimental program has been conducted in Zenien waste water treatment plant aiming at verifying the enhanced efficiency of adding attached biomass inside the aeration tank. The results indicated that COD removal values reached 85.17%, 84.97% and 80.83% at a hydraulic retention time of 6, 4, and 2 hours. Corresponding BOD removal values reached 88.52%, 88.32% and 86.94%at a hydraulic retention time of 6, 4, and 2 hours. Corresponding TSS removal values reached 85.48%, 85.28% and 83.89% at a hydraulic retention time 6, 4, and 2 hours. The results proved that the system could accommodate the increasing of organic loading rate and was efficient for removal of COD, BOD and TSS*

I. INTRODUCTION

In Egypt the activated sludge process is the most common conventional biological process used in sewage treatment plants for big cities, as it is capable of handling higher flow rates than other treatment systems, as well as high removal efficiency for both solids and organics.

In natural ecosystems, organisms play a major role in mineralizing various organic pollutants. The organisms involved in the self-purification processes in a natural water body can be broadly divided into two groups, according to their habitat. The surface-attached organisms colonize all the surfaces occurring in the water, e.g. stones, water plants, bank reinforcements and weirs. By contrast, the water column is colonized by suspended organisms such as bacterial flocs, plankton and microscopic crustaceans, right up to fish of various kinds. Engineered biological wastewater treatment systems copied natural systems and provided a favorable artificial environment. The microorganisms retained in such systems may be in suspended growth forms as in the activated sludge process, or in the attached growth form as in the trickling filters or rotating biological contactors. Some, relatively new treatment systems such as fluidized bed systems contain both suspended and attached biomass and can be called hybrid growth systems.

The fixed-film system has four principal advantages (DeFilippi and Lewandowski, 1998) over other currently available systems:

- It is simpler to operate.
- It handles shock loads, i.e. the sudden increases in incoming contaminant concentration with greater efficiency.
- It forms less solid sludge wastes and better microorganisms settling characteristics
- It is more energy efficient, or it requires less power to operate.

The use of only fixed plastic nets inside the aeration tank is enough to convert the suspended reactor to a hybrid one containing both suspended and attached biomass, such a process can improve the performance of the system and make it able to receive a higher organic load and a higher flow rate.

Hybrid system is suspected to give better results in organic matter removal as well as in nitrification. The ideal media for such a purpose should be inexpensive, durable, easy to install, does not clog and has a high specific biofilm surface area. Novel media materials used in the past include, molded polyethylene (Schlegel, 1988), corrugated cross-flow plastic media (Rogalla et al., 1989) and plastic foams, “Linpor process” (Morper and Wildmoser, 1990).

A novel hybrid system which utilizes suspended as well as attached biomass has been developed and examined in this study. The objective of the study was comparing the results of a pilot plant of the hybrid system with the conventional activated sludge system, and developing a mass balance analysis based on COD to determine the utilization rates of bacteria.

II. MATERIALS & METHODS

The present study investigates the feasibility of upgrading existing activated sludge processes by adding vertical plastic nets as a media for attaching growth of microorganism, the system became a hybrid system contains both attached and suspended growth. This study investigate the performance of that hybrid system in removal of wastewater organic matter.

The used pilot plant consists of aeration tank, pumps and settling tank. Figure 1 shows a sectional elevation and plan of the pilot plant and its main components. The experiments were conducted in Zenien WWTP The pilot-plant was shaded and the reactors were covered by black paper in order to minimize algal growth. The Plastic nets were fitted vertically inside the aeration tank on the vertical baffles. Surface area of the plastic nets as calculated from the manufactured catalog was 123,284 cm^2.

The influent wastewater to the pilot plant was subtracted from the effluent channel of the primary sedimentation tank in Zenien treatment plant. Samples were taken from influent and effluent of the pilot plant in addition to the MLSS inside aeration tank. The samples were analyzed to measure BOD, COD, TSS, VSS, MLSS, MLVSS, RSS, RVSS, and SV30

The pilot plant accomplished in 5 runs during its operation period at preset influent flow rates to give hydraulic retention times of 2, 4 and 6 hours. The first run ripping phase lasts for one month with a flow rate of 0.83 liter/minute, zero occupation of media and 100% recirculation sludge.

Abdel-Latief, M. M. and Ibrahim, M.S.A., “Hybrid Biological Reactor for Wastewater Treatment,” *International Research Journal of Advanced Engineering and Science,* Volume 4, Issue 3, pp. 459-462, 2019.

The second run (ordinary phase) lasts for one month with a flow rate of 0.83 liter/minute, zero occupation of media and 100% recirculation sludge.

The third run lasts for one month with a flow rate of 0.83 liter/minute, 50% occupation of media and 100% recirculation sludge.

The fourth run lasts for one month with a flow rate of 1.25 liter/minute, 50% occupation of media and 100% recirculation sludge.

The fifth run lasts for one month with a flow rate of 3.50 liter/minute, 50% occupation of media and 100% recirculation sludge

Each experimental run lasted between 4 weeks of stable operation with about 7 days between successive runs to allow for adaption to new conditions. The third run is the first run after changing of flow rate and the biofilm has been formed over. It lasted 30 days to form the biofilm on the surface of the media without any parameter measured, after that parameter was measured during the next month.

III. EXPERIMENTAL PROGRAM

The experimental program consisted of five runs and continued for several months (October 2010 till May 2011) during which the wastewater temperature was in range of 18 to 31 C. Each experimental run lasted 4 weeks of stable operation, with about 7 days between successive runs to allow for adaption to new conditions and to reach to steady state operation. The experimental program is indicated in Table (1)

TABLE 1. The Experimental Work Program.

Run No.		**Run No.1**	**Run No.2**	**Run No.3**	**Run No.4**	**Run No.5**
Period (month)		1	1	1	1	1
Flow Rate	m^3/day	1.20	1.20	1.20	1.80	3.60
	Liter/min.	0.83	0.83	0.83	1.25	2.50
Retention Time (hr)		6	6	6	4	2
Media occupation (%)		0	0	50	50	50
Media surface area (m^2)		0	0	12.50	12.50	12.50

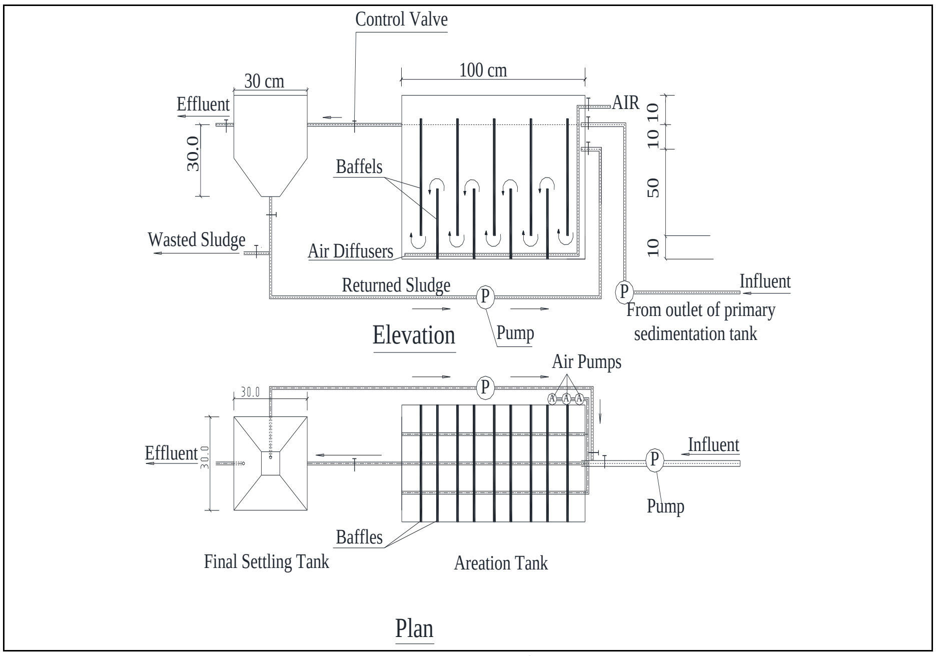

Fig. 1. Schematic Diagram of the Pilot Plant

IV. RESULTS

From the obtained results of the different runs, a comparison between these results will be discussed in the following section.

A. *COD, BOD, TSS, and VSS Removal Ratio*

In general, the COD, BOD, TSS, and VSS removal efficiency was about 67.35%, 62.07%, and 72.96%, and 71.80% respectively in Run No. 1. The COD and BOD, removal efficiency increased to 70.54% and 68.82 respectively, while the removal efficiency for TSS and VSS was decreased to 69.11% and 68.31% respectively in Run No.2. After placing the plastic media in Run No.3, the COD, BOD, TSS, and VSS removal efficiency was increased to 85.17%, 88.52, 85.48%, and 84% respectively. The COD, BOD, and TSS removal efficiency had a minor decrease in Run No.4 to be 84.97%, 88.32, 85.28%, and 83.80% respectively. The COD, BOD, and TSS removal efficiency was decreased again in run No. 5 to be 80.83%, 86.94%, 83.89%, and 82.41% respectively. The results are indicated in Table (2).

TABLE 2. COD, BOD, TSS, and VSS Removal Ration for Different Runs

Parameter	Removal Ratio %				
	Run 1	Run 2	Run 3	Run 4	Run 5
COD	67.35	70.54	85.17	84.97	80.83
BOD	62.07	68.82	88.52	88.32	86.94
TSS	72.96	69.11	85.48	85.28	83.89
VSS	71.80	68.31	84.0	83.80	82.41

B. MASS balance analysis of total experiment:

The COD mass balance is a very powerful tool for checking (i) the data measured on experimental systems (Ekama et al., 1986), (ii) the results calculated for design from the steady state model.

In the activated sludge system, COD theoretically must be conserved so that at steady state the COD mass flow out of the system must equal to the COD mass flow into the system over a defined time interval. The COD of the influent organics are (i) retained in the un biodegradable particulate and soluble organics, (ii)transformed to OHO mass and therefore conserved in a different type of organic material, or (iii) passed on to oxygen to form water. So, in general the difference between influent COD and effluent COD is almost equal to the MLSS plus the incolom start media retained in the activated sludge system at steady state and the difference may be due to the product of gases.

The mass balance has been calculated for the whole experimental for 220 days that was the duration of all runs .the parameter calculated are shown in Table (3)

TABLE 3. COD Mass Balance

Parameter	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5
Duration	1month	1 month	1 month	1 month	1 month
Flow rate (L/day)	1200	1200	1200	1800	3600
COD Mass in (Kg/day)	3.30	3.06	2.67	3.73	9.13
COD Mass out (Kg/day)	1.08	0.91	0.40	0.56	1.75
COD Mass retained (Kg/day)	2.21	2.16	2.27	3.17	6.82
***COD Mass Of MLVSS (Kg/day)**	0.20	0.370	0.83	1.15	2.40
****Utilization rate of COD %**	8.87	17.38	36.48	36.24	32.54

Where;
*COD Mass of MLVSS = (A+B) × fcv
A suspended biomass = (Mass of MLVSS at the end of each run - Mass of MLVSS inoculum)
B attached biomass = Mass of VSS = 0.85 of TSS (Metcalf & EDDY)
fcv COD/VSS ratio of the VSS (1.48mg COD/mgVSS) (Biological Wastewater Treatment: Principles, Modeling and Design George A. Ekama and Mark C. Wentzel)
**Utilization rate of COD % = [COD Mass of MLVSS ÷ $COD_{Mass\ retained}$]×100

TABLE 4. MLVSS and VSS Mass Values

Parameter	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5
Duration	1month	1 month	1 month	1 month	1 month
Flow rate (L/day)	1200	1200	1200	1800	3600
Mass of MLVSS Inoculum (Kg/day)	0.28	0.28	0.28	0.28	0.28
MLVSS Mass at end of each run (Kg/day)	0.41	0.53	0.64	0.73	0.96
VSS Of Attached biomass (Kg/day)	0	0	0.20	0.32	0.94
Total MLVSS biomass produced (kg/day)	0.13	0.25	0.56	0.78	1.62

V. MASS BALANCE DISCUSSION

- The max biodegradation rate is 36.48 %
- Although the efficiency of COD removal varied between 67.35 % to 80.83% the utilization rate varied between 8.87% to 36.48%.
- The removal efficiency depends on the whole system while the utilization rate based on biomass metabolism.
- Mass of substrate is decreasing with time due to substrate utilization.
- The max substrate utilization rates occur at high substrate concentration.
- Substrate is being used at its max rate. The bacteria are also growing at their max rate.
- In the outer portion of the biological slim layer the organic material is degraded by aerobic microorganism.
- As the microorganism grow and slim layer thickness increase. Oxygen is consumed before it can penetrate the full depth and an anaerobic environmental is established neat the surface of media.
- As the slim layer increase in the thickness the substrate in waste water is used before it can penetrate the inner depth of the biofilm.
- The substrate concentration at the surface of the biofilm decreases with biofilm depth as the substrate is consumed and diffused into the biofilm layers. As a result, the process is said to be diffusion limited.
- Formation of biomass attached to new media does not affect by HRT.
- HRT success for reduction because oxidation or utilization of organic matter staked to the media is not influenced by HRT. New media acting as digester simulated to trickling filter.
- As there was no waste or sludge drawn for the system SRT is almost infinity and the total biomass accumulate inside aeration tank and can utilize any organic load.

VI. CONCULSIONS

- Hybrid system is an effective, easy and inexpensive facility in upgrading the existing activated sludge systems.

- Hybrid system is an effective system in organic matter removal from primary treated wastewater.
- The hybrid system achieved overall BOD removal efficiencies of more than 86% at all hydraulic retention times including the 2 hours.
- The hybrid system achieved overall COD removal efficiencies of more than 83% at all hydraulic retention times including the 2 hours.
- The hybrid system achieved overall TSS removal efficiencies of more than 83% at all hydraulic retention times including the 2 hours.
- The hybrid system achieved overall VSS removal efficiencies of more than 82% at all hydraulic retention times including the 2 hours.
- Increasing the hydraulic loading rate had a minor effect on the BOD and COD percentage removal efficiencies indicating a robust biological process that is resilient to hydraulic shock loads, her by offering a variable upgrading option.
- The hybrid process presents minimal operational problems and could be a viable option for upgrading overloaded activated sludge treatment systems.

The main advantage of the hybrid system is:

- Allows plants with relatively smaller footprints to assimilate more discharges and organic loads without physical expansion of a treatment plant and with a minimum cost.
- No changes to standard operating procedures required. i.e. low training requirements.
- Upgrading results in minimal disruption of normal operations.
- Reduces solids loading rate to final clarifiers.
- The general description of conversion in a completely mixed liquid phase of a biofilm reactor in steady state is based on a balance for the compounds of interest.

REFERENCES

[1] Biological Wastewater Treatment: Principles, Modeling and Design George A. Ekama and Mark C. Wentzel.

[2] Metcalf and Eddy, Inc. (2003). Wastewater Engineering: Treatment, Disposal, Reuse. 4th ed., McGraw-Hill Book Co., New York, USA.

[3] Morper, M. and Wildmoser, A. (1990). "Improvement of existing wastewater treatment plants efficiencies without enlargement of tankage by application of the Linpor-process-case studies" Water Sci Technol (1990) 22 (7-8): 207-215.

[4] Rogalla, F., Bacquet, G., Bonhomme, M., Boisseau, M (1989). "Fixed biomass carriers in activated sludge plants" Water Sci Technol (1989) 21 (12): 1643-1646.

[5] DeFilippi, L.J., Lewandowski, G.A., 1998. Biological Treatment of Hazardous Wastes. John Wiley and Sons. ISBN No.0-471-0486-5.