COST EFFECTIVE WASTEWATER TREATMENT PROCESSES: ANAEROBIC DOMESTIC WASTEWATER TREATMENT USING FIXED FILM REACTOR AS A LOW-COST TREATMENT ALTERNATIVE

Low Energy, Easy Operation and Maintenance, Sustainable, and Reuse

Ezzat Abdel Shafi[1], Hisham S. Abdel Halim[1], Mohamed H.Mostafa[2], and Mohamed Nazih[2]

[1] Faculty of Engineering, Cairo University, Cairo, Egypt
[2] Housing and Building National Research Center, HBNRC, Cairo, Egypt

ABSTRACT

Most of the sewage generated in rural areas all over the country is not disposed or treated in an environmentally acceptable manner. On-site treatment systems, when used elsewhere, are mainly aerobic treatment systems, which are costly to construct and operate. An alternative approach in addressing this crisis is the adoption of low cost sanitation facilities, such as anaerobic treatment systems, which offers low construction, low energy, low cost and easy operation and maintenance as well as sustainable and reuse.

A Pilot Plant model was developed to study and the application of the anaerobic bio-filter process performance for treating municipal wastewater. The main objective and purpose of the research is to assess and investigate the feasibility and applicability of the anaerobic bio-filter process to treat low-strength domestic wastewater at different organic loading rates by using dual stage treatment. The raw wastewater is mainly domestic in origin but some small other sewages such as industrial waste may be added to the sewer network, so we consider the sewage used is low strength complex wastewater in this study. The model was directly connected to a pre-settled wastewater. The average influent BOD and COD concentrations ranged from 83 to 119, and 103 to 167 mg/l, respectively. Total Influent Suspended Solids varied from 60 to 116 mg/l. The average influent Ammonia-Nitrogen (NH_3) and Phosphor (PO_4) concentrations ranged from 21 to 27.6, and 5.9 to 7.8 mg/l, respectively. The reactor constitutes of two anaerobic compartments (tanks) filled with fixed bed media plastic material of total volume equals 0.85 m^3. The Pilot Plant was operated using constant flow of 5 m^3/day and total hydraulic retention time equals 69 hrs. The research pilot plant operation was conducted to study the effects of different organic loading rates (2.53, 1.95, 1.60 and 1.35 $kg_{cod}/m^3.d$) for 16 weeks. The samples were taken simultaneously daily or weekly to collect a considerable data to help to achieve the research's objectives. The average removal efficiencies of COD_t equal 50.49, 60.82, 72.71, and 75.85%, the average removal efficiencies of COD_s equal 56, 61.91, 73.61 and 76.52%, the average BOD removal efficiencies equal 58.77, 65.16, 81.33 and 82.16%, the average TSS removal efficiencies equal 57.16, 61.55, 74.23 and 77.52%, the average VSS removal efficiencies equal 56.53, 61.04, 73.10 and 76.77%, the average PO_4 removal efficiencies equal 17.87, 14.39, 14.81 and 19.62% at organic loading rates 2.53, 1.95, 1.60 and 1.35 $kg_{cod}/m^3.d$ respectively. It is clearly that the removal efficiency differs slightly when changing the organic loading rate from 1.60 and 1.35 $kg_{cod}/m^3.d$. Accordingly, the 1.60 $kg_{cod}/m^3.d$ organic loading rate could be decided to be the optimum one to give the better the removal efficiency. Generally, the Anaerobic Fixed film reactor proved a low cost and high performance and efficiencies for pre-settled domestic wastewater treatment under optimum operation conditions.

Keywords: Domestic Wastewater, Anaerobic Treatment, Fixed Film, Organic Loading Rate.

INTRODUCTION AND BACKGROUND

Collecting and treating domestic wastewater can be quite a problem in rural areas or small communities that are remote from municipal treatment plants. One traditional alternative to mains sewers is to use a septic tank, in which the wastewater is settled out and then partially digested by natural biological processes before being discharged as a liquid effluent into a soak away specially created for that purpose. However, in recent years, package plant using anaerobic systems have become more established as alternatives.

Wastewater treatment in the Egyptian rural areas lags far behind potable water supply. The vast majority of the Egyptian population receives piped potable water, however only urban centers and some larger rural villages possess wastewater treatment facilities. Economics of scale make conventional wastewater treatment cost prohibitive in smaller more dispersed rural settlements. Domestic wastewater is typically discharged directly or indirectly to drainage canals. This practice has contributed to widespread degradation of drainage water quality and, so, the reuse of drainage water plans in Egypt.

Based on the past experiences and learned lessons in the municipal wastewater treatment, the anaerobic technology proved a very good performance and efficiencies due to its positive advantages against aerobic ones. As reported in the USEPA Onsite Wastewater Treatment Systems Manual (2002), the Fixed-film systems (FFS) are biological treatment processes that employ a medium such as rock, plastic, wood, or other natural or synthetic solid material that will support biomass on its surface and within its porous structure. The experiments conducted by Raman et al. (1972, 1978), reveal that up-flow anaerobic filter can successfully be used as a simple secondary treatment device for septic tank effluent and for settled domestic sewage as well.

A laboratory scale anaerobic filter was investigated by Kobayashi and Stenstrom (1983) to treat low strength domestic wastewater of average 288 mg/l COD. Effluent BOD averaged 38 mg/l providing COD averaged 78 mg/l providing an average removal rate of 73%. Y. Inamori (Inamori, Sudo, and Goda, 1986) concluded that low strength organic wastewater can be treated efficiently by anaerobic process under optimum operational conditions. The results show BOD removal of at least 70% at BOD loading was 0.2 kg/m^3.d. Organic loading rates (OLR) range from a low of 0.2 kg COD/m^3.d to a typical maximum of 16 kg COD/m^3.d. Hydraulic retention times (HRT) range from 12 to 96 hrs. The type of wastewater varies from domestic sewage with a COD of about 100 to 150 mg/l to industrial sewage with a COD of about 85000 mg/l. The COD removal efficiency ranged from 75 to 80% when operating at an organic loading rate of 4.4 kg COD/m^3.d at 30^{o}C.

Elmitwalli et al. (2000) presents the results of pretreatment of domestic sewage in anaerobic filter (AF) and anaerobic hybrid (AH) reactor showed that the AF reactor is an efficient process for the removal of suspended COD (COD_{ss}) by 82%, at an HRT of 4 hrs and 13^{o}C. A total COD (COD_t) removal of 71% was achieved with 60% conversion to methane.

Kobayashi and Stenstrom (1983) reported that many investigators have attempted to determine maximum organic loading rates for specific wastes, but in the case of dilute wastes, such as municipal wastewater, the organic loading rate will always be very low and will not approach the maximum loading rates observed in other investigations. Rantala and Vaananen (1985) reported that the organic volumetric loading rate is the major factor affecting the necessary volume of reactors. Design loadings below 12 kg/m^3.day are recommended unless pilot scale data are available to show satisfactory performance at higher loadings (Speece, 1983, James and Byung, 1986). Y. Inamori (Inamori, Sudo, and Goda, 1986) reported that the effect of organic loading rate was examined for 0.16, 0.32, and 0.64 kg_{BOD}/m^3.day. The results showed that the BOD removal efficiencies increased with OLR decreasing to reach 96% as at OLR and temperature equals 0.16 kg_{BOD}/m^3.day and 30^{o}C respectively.

Down flow units have been shown by some investigators to have performance characteristics similar to those of up flow units (Wilkie, 1983, Reynolds, 1983, Van Den Berg, 1986), but Wiland, and Welfert (Wiland, and Welfert, 1988) stated that some subsequent tests by others have shown that greater efficiencies can be obtained in up flow units when operated at the same organic loading rate. James and Byung (1986) concluded that in some application the COD removal efficiency in down flow reactors clearly falls below that of up flow units operating at the same HRT. The advantage of two stage operation is also verified by increased performance of two stages up flow and down flow reactor. Commercial media types available for use in anaerobic filters include Pall Rings, Loose-fill media, and Modular-block media formed from corrugated plastic sheets. One such plastic packed stationary fixed film filter is in operation since last 4 years in a cane-molasses based distillery in India and working satisfactorily without any operation problems (Daryapurkar and Kaul, 1991).

MATERIAL AND METHODS

To achieve the research objectives, the pilot plant model was constructed at Zenein wastewater treatment plant and directly connected to the pre-settled wastewater.

Pilot Plant Description:

The reactor is defined as two stages Anaerobic Fixed Bed Filter Reactor made of Coated Steel of total gross volume equal 2.26 m^3 (0.93 m^3 for 1st tank and 1.16 m^3 for 2nd tank). It constitutes of two anaerobic compartments (tanks) filled with fixed bed media of plastic material of total volume equals 0.85 m^3 (60 % of total tank net volume). The media is backed as full depth stacked blocked status. In each reactor it's possible to change the depth of the fixed bed media separately to have different Organic Loading Rates (OLR) for each. Each reactor has several sampling outlets of diameter 1 inch for each, this outlets will be used to take wastewater samples for reactor' profile analysis purposes. The top of each reactor have gas outlets of 2 inch diameter that will be used collect gas for analysis purpose. A submersible pump was used to discharge the flow to the pilot plant. This feeding pump delivers the wastewater (WW) from the source (primary treated WW) to the influent pipe of the pilot plant. Each reactor has its own inlet distribution system at top side to maintain uniform influent wastewater flow consists of 25mm diameter distributor pipes and weirs.

The pilot plant components details and dimensions could be summarized as shown in (Table 1). Figure (1) illustrates the pilot plant schematic flow diagram while Figure (2) illustrates the pilot plant detailed description. Figure (3) shows the pilot plant photos

Table 1: Pilot Plant's Detailed Dimensions

Descriptions	**Dimensions**				**Effective Net Volume** (m^3)	**Media Depth** (m)	**Media Volume** (m^3)
	Length (m)	**Width** (m)	**Depth** (m)	**Gross Volume** (m^3)			
Pilot Plant (total)	1.95	0.8	1.45	2.26	1.44	1.14	0.85
1st Reactor	0.8	0.8	1.45	0.93	0.64	0.45	0.3
2nd Reactor	1.00	0.8	1.45	1.16	0.80	0.69	0.55

Experimental Work Plan and Pilot Plant Operation:

The pilot plant was operated using flow of 5 m^3/day of total HRT equals 69 hrs (31 hrs for 1st tank and 38 hrs for 2nd tank). The total experiment duration was about 29 weeks including pilot construction, start up, and steady state stages. The research work was divided into four runs of total operation time of 16 weeks (4 weeks for each) at different organic loadings (2.53, 1.95, 1.60 and 1.35 $kg_{cod}/m^3.d$). The operation conditions could be summarized as shown in Table 2.

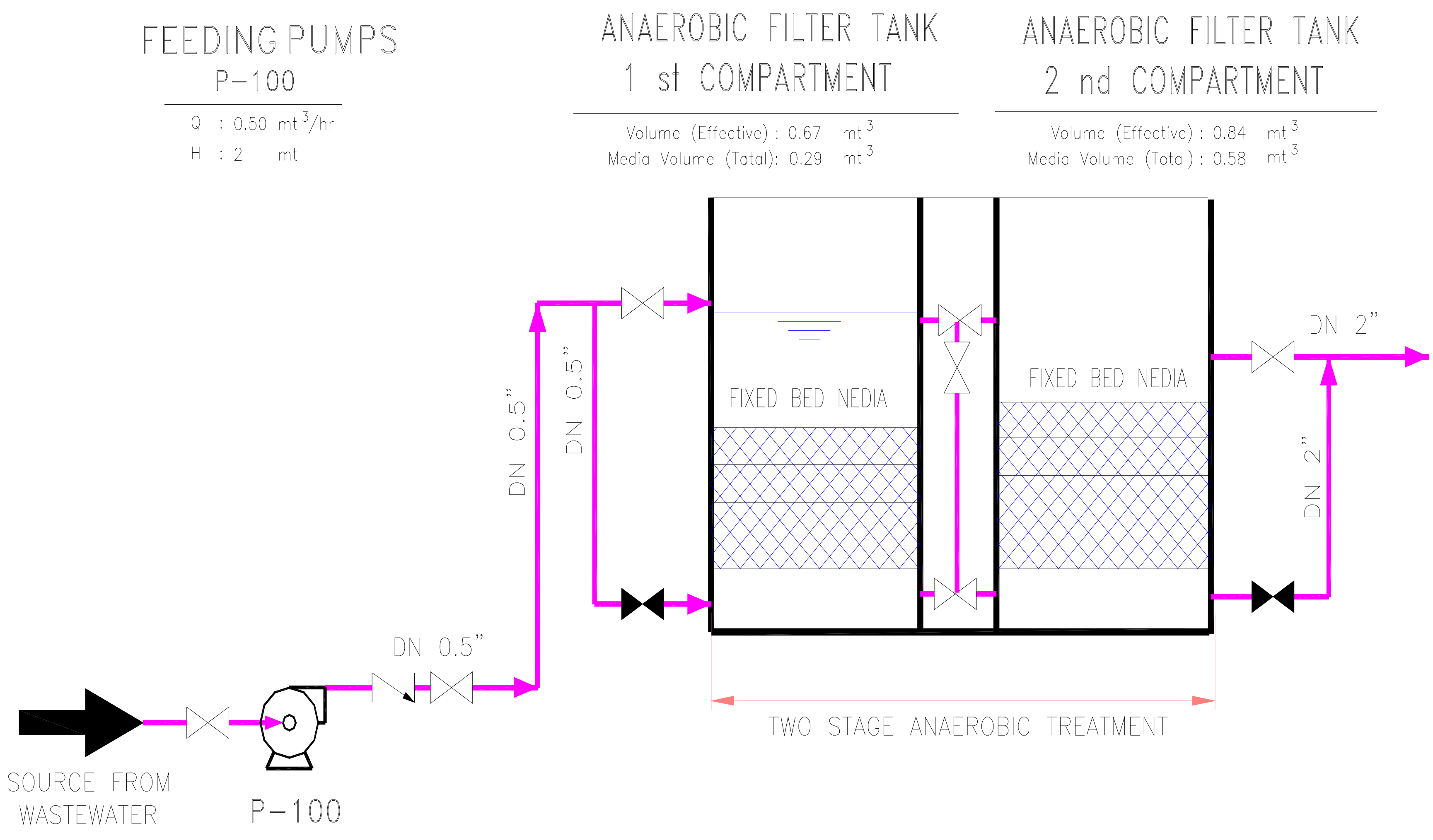


Figure 1: Pilot Plant Schematic Diagram

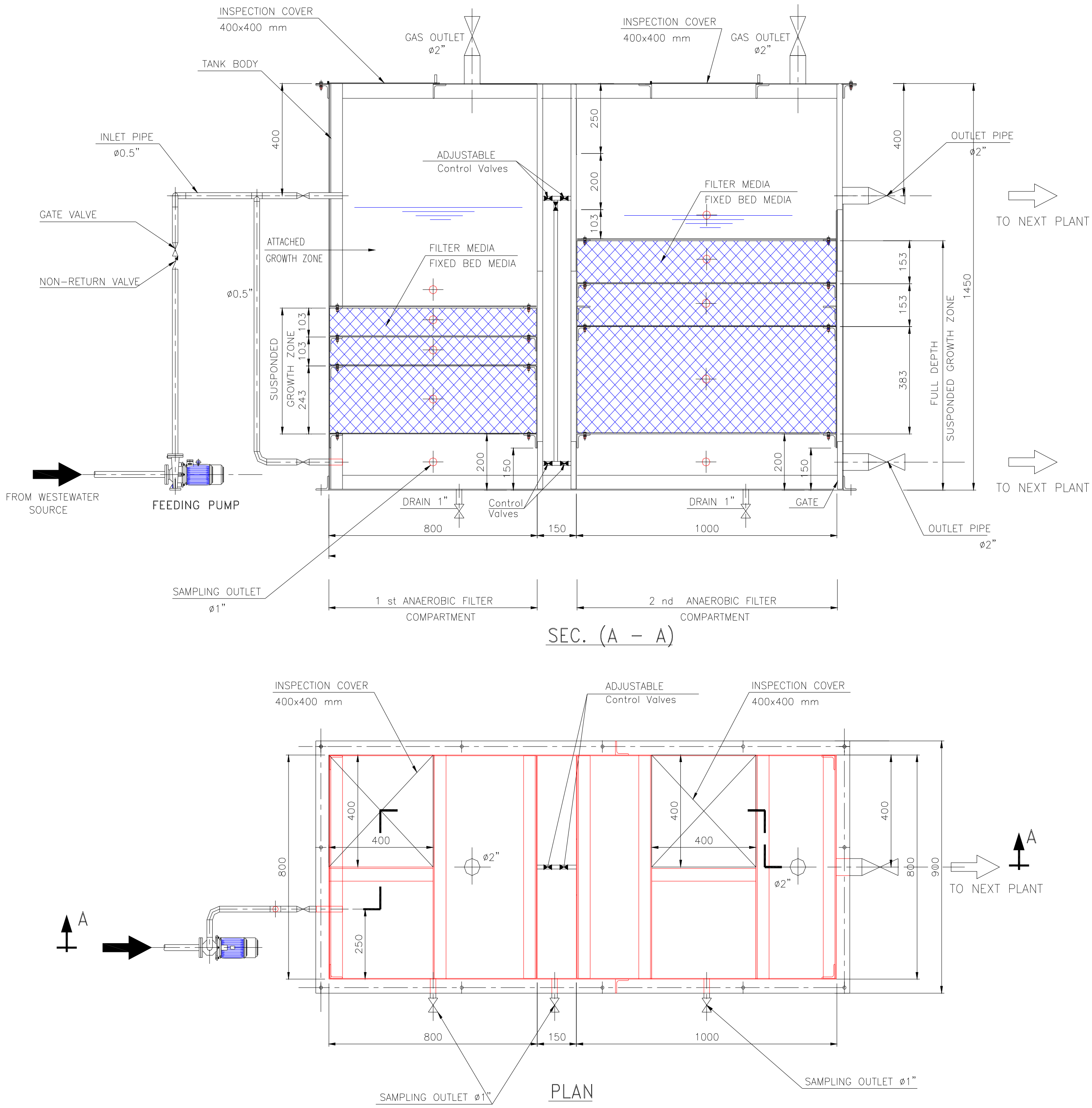
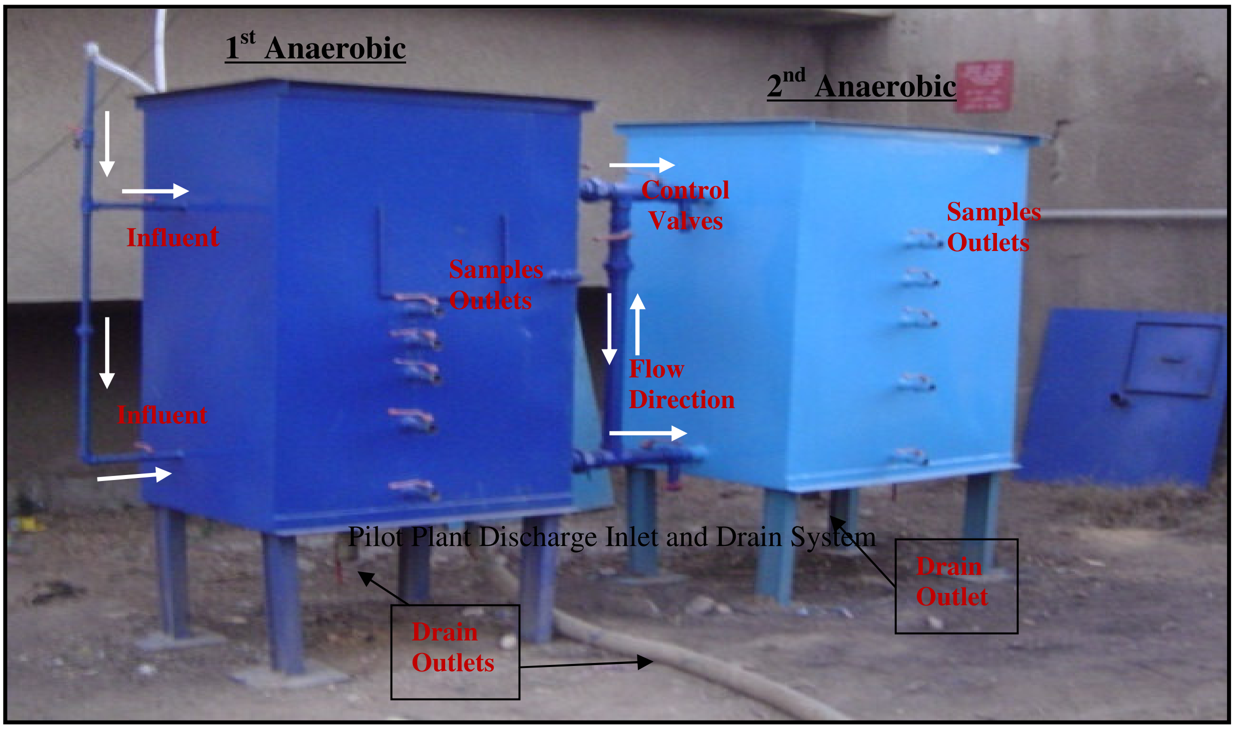


Figure 2: Pilot Plant Detailed Description



Rector Component Details

Figure 3: Pilot Plant Detailed Photos

Table 2: Operation Conditions during the Experimental Works

[redacted]

Reactor Start-up:

The used sludge is an-aerobically treated mesophilic sludge. At the beginning before the wastewater introduced to the reactor, it was firstly inoculated with an-aerobically treated mesophilic sludge. The whole reactor volume was filled with clean water which was circulated for two days without any addition of wastewater to re-activate the sludge as well as to remove any residual COD in the sludge. Then the reactor was operated as a batch reactor for 2 weeks. Gas production was monitored and observed, the gas production was gradually declined to nearly zero at 4th week, indicating that the initial feed was exhausted. The reactor was then operated continuously for 6 weeks more feed with domestic wastewater until steady state was obtained. Based on stability results of COD removal efficiencies and controlling the values of volatile fatty acids and pH in the reactor, the start of steady state period was decided, so the reactor was started-up in around 10 weeks.

Sampling Frequency:

Samples were taken from each of the two tanks and analyzed to evaluate the reactor performance. That samples were taken simultaneously after achieving steady state conditions from each model daily or weekly to gain a considerable data to help to achieve the research's objectives as shown in Table 3.

Analyses and Measurements:
Different process parameters and removal efficiencies were analyzed and calculated periodically according to Standard Methods such as BOD, COD, TSS, NH_3, PO_4 as well as gas quantity inclusive the specific gas production.

Reactor Operation:
After the start-up period, when the reactor reaches stable effluent characteristics, which was considered as the “steady state” operation, the reactor was operated continuously for 16 weeks after starting the steady state to investigate the process performance under the fluctuation of inflow wastewater characteristics. The feeding pump was submerged into the outlet channel of the primary sedimentation tank. The required flow rate is adjusted manually. The flow rate, which indicates the retention time, was set with the outlet valve (outlet control). The system was being continuously operated under constant flow and head condition.

Table 3: Sampling, Analyses, and Measurement Frequency for the Pilot Plant

Measured parameter	**Abbreviation**	**unit**	**Wastewater**		**Biogas**	**Measurement Frequency**
			Influent	Effluent		
Temperature	T	°C	x	x	–	3/week
pH	–	–	x	x	–	3/week
Total COD	COD_t	mg/L	x	x	–	3/week
Suspended COD	COD_{ss}	mg/L	x	x	–	3/week
Volume of biogas	V_{biogas}	L	–	–	x	1/Run
Total suspended Solids	TSS	mg/L	x	x	–	3/week
Volatile Suspended Solids	VSS	mg/L	x	x	–	3/week
BOD_5	BOD	mg/L	x	x	–	1/week
Total Nitrogen	TN	mg/L	x	x	–	1/week
Total Phosphor	TP	mg/L	x	x	–	1/week
Sludge Volume	V_{slg}	L	–	–	–	1/Run

The pilot was filled with packed plastic media using different depths to keep the required organic loading rate. The organic loading rates were changed gradually by changing the volume of the fixed media. Accordingly, the pilot plant was operated under different OLR through the runs with up-flow mode for 16 weeks duration to decide the optimum organic loading rate which gives the best operation performance.

RESULTS AND DISCUSSIONS

Wastewater Characteristics:
The influent pollutants concentrations of Zenien wastewater treatment plant are varied from day to other. The average influent BOD and COD concentrations ranged from 83 to 102, and 103 to 165 mg/l, respectively. Total Influent Suspended Solids varied from 62 to 116 mg/l. The average influent Ammonia-Nitrogen (NH_3) and Phosphor (PO_4) concentrations ranged from 21 to 27.6, and 5.9 to 7.8 mg/l, respectively. The average

(mean) values are considered, this leads to variations in the effluent pollutants concentration. Accordingly, the average influent and effluent pollutants concentration are used in observation and evaluation of the process performance. It is obvious that the fluctuation of the influent total BOD concentration to the reactor is slightly low.

Results and Discussions of Run 1/1

The organic loading rate (OLR) of value equals 2.53 $kg_{cod}/m^3.d$ was used to evaluate the pilot plant operation performance through run 1/1.

COD (Total and Soluble):

The influent total COD concentrations were ranged between 103 and 157 mg/L along the time of this run with average value of 130 mg/L. The influent soluble COD concentrations were ranged between 78 and 136 mg/L with average values of 108. Total COD removal was ranged between 48.49% and 59.52% along the different operation time with average value of 54.49% for this run. Soluble COD removal was ranged between 50.40% and 61.09% along the different operation time with average value of 56% for this run. Table 4 shows the total and soluble COD removal efficiencies during this run.

BOD:

The influent BOD concentrations were ranged between 83 and 93 mg/L along the time of this run with average value of 89 mg/L. Based on influent and effluent BOD concentrations, the BOD removal efficiency was determined along operation time for this run. Total BOD removal was ranged between 52.94% and 61.1% along the different operation time with average value of 58.77% for this run. Table 4 shows the total and soluble BOD removal efficiencies during this run.

TSS and VSS:

The influent TSS-values were ranged between 62 and 94 mg/L along the operation time with average value of 74 mg/L for this run. The effluent TSS-values were ranged between 23 and 44 mg/L along the operation time with average value of 34 mg/L for this run. The influent VSS-values were ranged between 68 and 47 mg/L along the operation time with average value of 58 mg/L for this run. The effluent VSS-values were ranged between 20 and 34 mg/L along the operation time with average value of 27 mg/L for this run. It was found that the average TSS removal efficiencies were ranged between 51.36% and 62.20% with total average value of 57.16% for this run, as shown in Table 5. Also, the average VSS removal efficiencies were found ranged between 50.88% and 59.72% with total average value of 56.53%.

Ammonia-Nitrogen (NH_3-N):

The influent NH_3-values were ranged between 22.77 and 26.52 mg/L along the operation time with average value of 24.78 mg/L for this run, while the effluent NH_3-values were ranged between 29.7 and 30.46 mg/L along the operation time with average value of 30.05 mg/L for this run. The effluent results show increasing in the NH_3-values comparing to the influent ones.

Phosphorus (PO_4):

It was found that the average PO_4 removal efficiencies were ranged between 13% and 25% with total average value of 18% for this run, as shown in Table 5.

Table (4): Weekly Average Removal Efficiency during Run 1/1

[redacted]

Results and Discussions of Run 2/1

The organic loading rate (OLR) of value equals 1.95 $kg_{cod}/m^3.d$ was used to evaluate the pilot plant operation performance through run 2/1.

COD (Total and Soluble):

The influent total COD concentrations were ranged between 123 and 146 mg/L along the time of this run with average value of 133 mg/L. The influent soluble COD concentrations were ranged between 103 and 121 mg/L with average values of 112. Total COD removal was ranged between 55.50% and 64.02% along the different operation time with average value of 60.82% for this run. Soluble COD removal was ranged between 56.62% and 65.03% along the different operation time with average value of 61.91% for this run. Table 5 shows the total and soluble COD removal efficiencies during this run.

BOD:

The influent BOD concentrations were ranged between 84 and 90 mg/L along the time of this run with average value of 87 mg/L. Total BOD removal was ranged between 60.48% and 68.04% along the different operation time with average value of 65.16% for this run. Table 5 shows the total and soluble BOD removal efficiencies during this run.

TSS and VSS:

The influent TSS-values were ranged between 69 and 82 mg/L along the operation time with average value of 78 mg/L for this run. The effluent TSS-values were ranged between 22 and 45 mg/L along the operation time with average value of 31 mg/L for this run. The influent VSS-values were ranged between 56 and 66 mg/L along the operation time with average value of 62 mg/L for this run. The effluent VSS-values were ranged between 18 and 36 mg/L along the operation time with average value of 24 mg/L for this run. It was found that the average TSS removal efficiencies were ranged between 53.98% and 66.45% with total average value of 61.55% for this run, as shown in Table 5. Also, the average VSS removal efficiencies were found ranged between 53.54% and 66.96% with total average value of 61.04%.

Ammonia-Nitrogen (NH_3-N):

The influent NH_3-values were ranged between 25 and 27 mg/L along the operation time with average value of 23 mg/L for this run, while the effluent NH_3-values were ranged between 29.75 and 32.07 mg/L along the operation time with average value of 30.86 mg/L for this run. The effluent results show increasing in the NH_3-values comparing to the influent ones.

Phosphorus (PO_4):

It was found that the average PO_4 removal efficiencies were ranged between 11% and 21% with total average value of 14.39% for this run, as shown in Table 5.

Table (5): Weekly Average Removal Efficiency during Run 2/1

[redacted]

Results and Discussions of Run 3/1

The organic loading rate (OLR) of value equals 1.60 kg_{cod}/m^3.d was used to evaluate the pilot plant operation performance through run 3/1.

COD (Total and Soluble):

The removal efficiencies of different COD were calculated at the different operation runs. The influent total COD concentrations were ranged between 123 and 158 mg/L along the time of this run with average value of 136 mg/L at organic loading rate equals 1.60 $kg_{cod}/m^3.d$. The influent soluble COD concentrations were ranged between 106 and 139 mg/L with average values of 117. Total COD removal was ranged between 56.91% and 78.63% along the different operation time with average value of 72.71% for this run. Soluble COD removal was ranged between 66.38% and 79.39% along the different operation time with average value of 73.61% for this run. Table 6 shows the total and soluble COD removal efficiencies during this run.

BOD:

The influent BOD concentrations were ranged between 84 and 96 mg/L along the time of this run with average value of 92 mg/L. Total BOD removal was ranged between 79.50% and 88% along the different operation time with average value of 83.62% for this run. Table 6 shows the total and soluble BOD removal efficiencies during this run.

TSS and VSS:

The influent TSS-values were ranged between 64 and 104 mg/L along the operation time with average value of 81 mg/L for this run. The effluent TSS-values were ranged between 18 and 38 mg/L along the operation time with average value of 24 mg/L for this run. The influent VSS-values were ranged between 47 and 87 mg/L along the operation time with average value of 66 mg/L for this run. The effluent VSS-values were ranged between 11 and 34 mg/L along the operation time with average value of 21 mg/L for this run. It was found that the average TSS removal efficiencies were ranged between 69.47% and 79.58% with total average value of 74.23% for this run, as shown in table 6. Also, the average VSS removal efficiencies were found ranged between 68.36% and 78.64% with total average value of 73.10%.

Ammonia-Nitrogen (NH_3-N):

The influent NH_3-values were ranged between 25.99 and 27.60 mg/L along the operation time with average value of 26.55 mg/L for this run, while the effluent NH_3-values were ranged between 30.67 and 31.18 mg/L along the operation time with average value of 30.91 mg/L for this run. The effluent results show increasing in the NH_3-values comparing to the influent ones.

Phosphorus (PO_4):

It was found that the average PO_4 removal efficiencies were ranged between 10% and 19% with total average value of 14.81% for this run, as shown in Table 6.

Table (6): Weekly Average Removal Efficiency during Run 3/1

[redacted]

Results and Discussions of Run 4/1

The organic loading rate (OLR) of value equals 1.35 $kg_{cod}/m^3.d$ was used to evaluate the pilot plant operation performance through run 4/1.

COD (Total and Soluble):
The removal efficiencies of different COD were calculated at the different operation runs. Total COD removal was ranged between 73.02% and 78.13% along the different operation time with average value of 75.85% for this run. Soluble COD removal was ranged between 73.78% and 78.10% along the different operation time with average value of 76.52% for this run. Table 7 shows the total and soluble COD removal efficiencies during this run.

BOD:
The influent BOD concentrations were ranged between 83 and 102 mg/L along the time of this run with average value of 94 mg/L. Total BOD removal was ranged between 78.84% and 85.38% along the different operation time with average value of 82.16% for this run. Table 7 shows the total and soluble BOD removal efficiencies during this run.

TSS and VSS:
The influent TSS-values were ranged between 66 and 110 mg/L along the operation time with average value of 85 mg/L for this run. The effluent TSS-values were ranged between 12 and 24 mg/L along the operation time with average value of 19 mg/L for this run. The influent VSS-values were ranged between 49 and 96 mg/L along the operation time with average value of 68 mg/L for this run. The effluent VSS-values were ranged between 10 and 20 mg/L along the operation time with average value of 16 mg/L for this run. It was found that the average TSS removal efficiencies were ranged between 75.07% and 79.36% with total average value of 77.52% for this run,

as shown in Table 7. Also, the average VSS removal efficiencies were found ranged between 74.59% and 78.27% with total average value of 76.77%.

Ammonia-Nitrogen (NH_3-N):

The influent NH_3-values were ranged between 26.98 and 21 mg/L along the operation time with average value of 24.07 mg/L for this run, while the effluent NH_3-values were ranged between 35.77 and 21.39 mg/L along the operation time with average value of 30.62 mg/L for this run. The effluent results show increasing in the NH_3-values comparing to the influent ones.

Phosphorus (PO_4):

The influent and effluent values of total phosphor were measured during the operation time The removal efficiencies were also determined and the average removal efficiencies were calculated. It was found that the average PO_4 removal efficiencies were ranged between 10% and 19% with total average value of 14.81% for this run, as shown in Table 7.

Table (7): Weekly Average Removal Efficiency during Run 4/1

[redacted]

CONCLUSIONS

The organic loading rate represents one of the most important factors which affect the performance of the anaerobic treatment process. The main of the study is to assess the effects of the organic loading rate on the pilot plant performance. The effect of the organic loading rate (OLR) on the removal of different pollutants was studied with the other parameters constant to achieve reliable results. After the start-up period, when the reactor reaches stable effluent characteristics, which was considered as the “steady state” operation, the reactor was operated continuously for 16 weeks after starting the steady state to investigate the process performance under the fluctuation of inflow wastewater characteristics. Depending on the results obtained from different runs, the pilot plant performance was evaluated. The average removal efficiencies of COD_t equal 50.49, 60.82, 72.71, and 75.85%, the average removal efficiencies of COD_s equal 56, 61.91, 73.61 and 76.52%, the average BOD removal efficiencies equal 58.77, 65.16, 81.33 and 82.16%, the average TSS removal efficiencies equal 57.16, 61.55, 74.23 and 77.52%, the average VSS removal efficiencies equal 56.53, 61.04, 73.10 and 76.77%, the average PO_4 removal efficiencies equal 17.87, 14.39, 14.81 and 19.62% at organic loading rates 2.53, 1.95, 1.60 and 1.35 $kg_{cod}/m^3.d$, respectively. The average removal efficiencies for different organic loading rates could be summarized as shown in Figure 4.

The above mentioned results proved that the removal efficiencies of different pollutants (COD, BOD, TSS, and PO_4) are increasing with decreasing the organic loading rate. The maximum removal efficiency was achieved at 1.35 $kg_{cod}/m^3.d$ organic loading rate. It is clearly that the removal efficiency differs slightly when changing the organic loading rate from 1.60 and 1.35 $kg_{cod}/m^3.d$. Accordingly, the 1.60 $kg_{cod}/m^3.d$ organic loading rate could be decided the optimum one to give the better the removal efficiency.

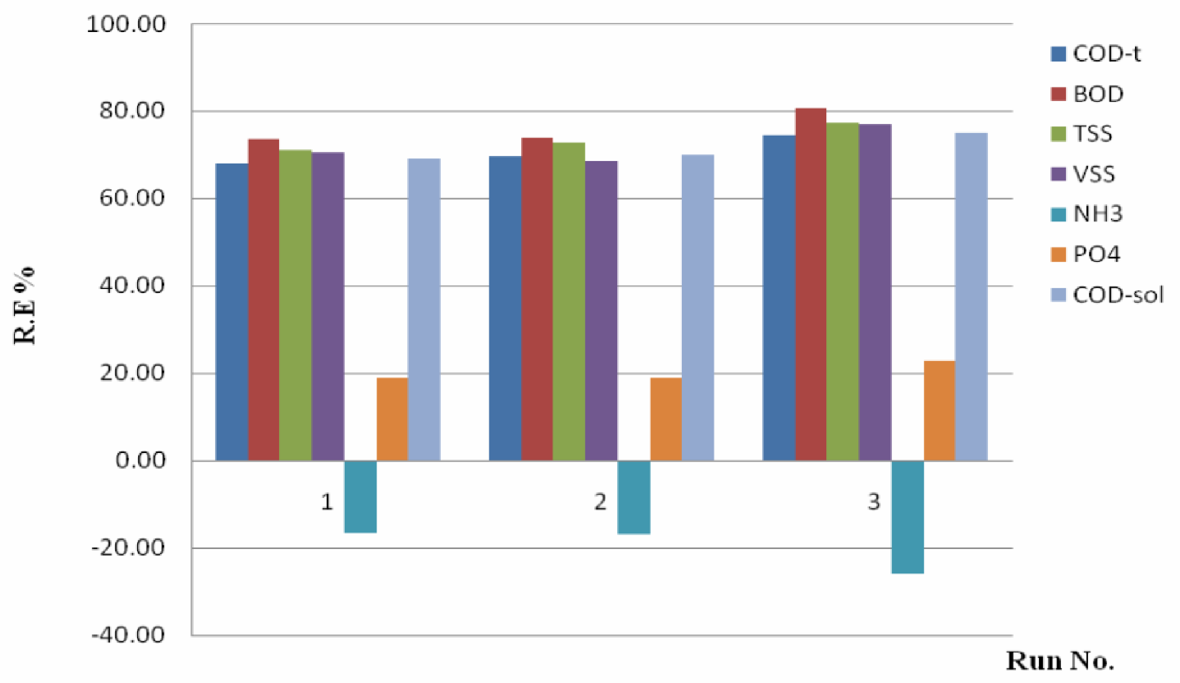


Figure 4: Pollutants Removal Efficiency (R.E)

General Conclusions:

- The Anaerobic Fixed film reactor proved a very good performance and efficiencies for domestic wastewater treatment and could be used as a secondary treatment using a pre-settled wastewater.

- The up-flow anaerobic fixed film filter can successfully be used as a simple secondary treatment system for pre-settled low strength organic domestic wastewater treatment.
- The advantage of two stage operation is also achieved and verified by increased performance of two stages up flow reactor.
- The organic loading rate represents one of the most important factors which affect the performance of the anaerobic treatment process.
- The percentage of the removal efficiency were increased by ranges 28% to 39% companied the decreasing of the organic loading rate from 2.53 to 1.35 $kg_{cod}/m^3.d$ respectively, this means that the organic loading rate affect strongly on the removal efficiency.
- The ammonia nitrogen (NH_3-N) was not removed, as expected, and increased due to the conversion of organic nitrogen to ammonia. Also this leads to most of the influent NH_3 go out from the reactor without any removal, which in turns means that the an-aerobically treated wastewater has valuable value of nutrients (NH_3) which could be used for soil reclamation if this wastewater will be re-used in agriculture purposes.
- It was found that the tendency of the removal efficiencies of PO_4 are slightly small, this means that most of the influent PO_4 go out from the reactor without any removal, which in turns means that the an-aerobically treated wastewater has valuable value of nutrients (PO_4) which could be used for soil reclamation if this wastewater will be re-used in agriculture purposes.

Finally, the results proved a very good reactor treatment performance using the fixed media reactor after the primary sedimentation to give good removal of all pollutants using plastic fixed media at optimum OLR (1.6 $kg_{cod}/m^3.d$).

REFERENCES

Daryapurkar, R.A., and Kaul S.N. "Experience with Full Scale Anaerobic Fixed Film Reactor" *J. Environ. Sci. Health*, A26(3), P317 (1991).

Elmitwalli, T.A. "Anaerobic treatment of domestic sewage at low temperature" Ph.D. Thesis, Wageningen University. Wageningnen, the Netherlands (2000).

Inamori, Y., Sudo, R. and Goda, T. "Domestic Sewage Treatment Using Anaerobic Biofilter with an Aerobic Bioifilter" *J. Wat. Sci. Tech.*, V18, P209 (1986).

James C. Young, and Byung S. Yang, "Design Considerations for Full-scale Anaerobic filter" *J. Water Pollut. Control Fed.*, V61, P1576 (1986).

Kobayashi, H.A., Stenstrom, M.K., and Mar, R.A. "Treatment of Low Strength Domestic Wastewater using the Anaerobic Filter" Wat. Res., V17, No. 8, P903 (1983).

Raman, V., and Khan, A. N. "Upflow Anaerobic Filter: a Simple Sewage Treatment Device" *Pres. at Int. Conf. Water Pollution Control Developing Countries*, Bangkok, Thailand, P21 (1978).

Raman, V., and Chakladar, N. "Upflow Filter for Septic Tank Effluent" *J. Water Pollut. Control Fed.*, V44, No. 8, P1553 (1972).

Rantala, P., and Vaananen, P. "Cost Comparison of Aerobic and Anaerobic Wastewater Treatment System" Wat. Sci. Technol., V17, P255 (1985).

Speece, R. E., "Anaerobic Biotechnology for Industrial Wastewater Treatment" *J. Environ. Sci. Technol.,* V17, P416A (1983).

USEPA "Onsite Wastewater Treatment Systems Manual", *Office of Water, Office of Research and Development, U.S. Environmental Protection Agency*, (2002).

Van Den Berg, L., "Anaerobic Down flow Stationary Fixed Film Reactors: Performance under Steady State and Non-steady State Conditions" Proc. *Sem. Anaerobic Fixed Film Digestion. Pollu. Control Asso.,* (Nov, 1986).

Wilkie, A., "Effect Media Effects in Anaerobic Filters" In "Anaerobic Filters: An Energy Plus for Wastewater Treatment". *W. J. Van Din Brink, AWWT Symp. Secretariat, TNO, The Hague, Neth.,* 242 (1983).

Wiland, P. J., and Welfert, K., "Anaerobic Treatment of Stillage Using Different Pilot Scale Fixed Bed Reactors in Up and Down Flow Mode of Operation". *Proc. 5th Int. Symp. Anaerobic Digestion,* E.R. Hall, Pergamon Press, New York, N.Y., 147 (1988).