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COST EFFECTIVE ANAEROBIC MUNICIPAL WASTEWATER TREATMENT

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ABSTRACT

The anaerobic treatment of wastewater has contributed to the field of environmental protection. Complex wastewaters contain a considerable amount of slowly biodegradable ingredients in the form of suspended solids. The reflection of the accumulation of such ingredients in the reactor without complete digestion induces high dilution of the active biomass. Sludge stabilization and gas production is an important factor. Unlike the aerobic processes, the anaerobic processes are claimed to be self-dependent with respect to the availability of contact between the wastewater and the biomass. Whatever the applied up flow velocity and the inlet system arrangement, the gas production is the basic to provide a good mixing intensity within the fixed bed.
The main target of the prevailing research is the assessment of the Anaerobic Treatment of Low-Strength Wastewater. The research was focused on Domestic Sewage because this waste is approximately the largest in volume especially in developing countries which have increasing rates of population. The main purpose of the experimental work is to evaluate the feasibility of the anaerobic treatment of domestic sewage using the Anaerobic Filter through three stages: Up-Flow Filter (AUF), Down Flow Filter (ADF), and Fluidized Bed Filter (AFBF) atthermophilic range of temperatures (25-35ºC).
Biological Oxygen Demand (BOD_5) removal efficiencies for AF, DSFF and AFB are 70, 55 and 43% respectively. Chemical Oxygen Demand (COD) removal efficiencies for AUF, ADF and AFBF are 63, 51 and 41% respectively. Removal efficiencies showed very little sensitivity to daily fluctuations in influent wastewater quality. Gas production averaged 0.024 L of gas per L of influent wastewater, or 0.11 m^3 of gas per kg of influent COD .Gas composition averaged 35 % nitrogen, 60 % methane and 5% carbon dioxide. Ammonia nitrogen and sulfides both increased during treatment.
The experimental results showed that the most suitable approach to apply an effective treatment was the using of Up-Flow Anaerobic Filter AF with HRT= 24 hrs. The maximum removal rate that can be obtained in this case is 76% on COD-basis and 85% on BOD-basis.

KEYWORDS: Municipal Wastewater Treatment, Aerobic and anaerobic treatment, Bioreactors

I. INTRODUCTION

The inappropriate disposal of domestic wastewaters into the environment causes many pollution problems such as eutrophication or oxygen depletion in water bodies, besides public health problems via ingestion or contact with water contaminated by pathogenic bacteria **[1,2,3].**Ancient Egyptians practiced “Basin Irrigation” based on natural rise and fall of the river that delivered ancient Egyptians with an efficient domestic wastewater treatment and disposal system. In this case the wastewater penetrates into the soil where anaerobic bacteria break down any nutrients before the wastewater reaches the water stream. When the flood in the Nile River occurs, the flood water gets mixed with the biologically degraded wastewater present in the upper soil layers and pushes it down as soon as the basin drain starts, thus, all salts and accumulated biomass is washed out and drained back to the main river stream. This practice is similar to the modern sludge activation wastewater treatment techniques. However, this ancient practice in Egypt was terminated after the construction of Lake Nasser **[4].**

Scarcity of water resources and the need to protect the environment and natural resources are the main factors leading Mediterranean Countries to introduce treated wastewater as an additional water resource in their

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national water resource management plans. From a practical point of view, it is very important to be aware of the real situation in each Mediterranean Country before suggesting innovative treatment technologies still in experimentation, and the first steps of application to wastewater treatment and reuse systems in developed countries. Furthermore, conventional technologies and available WWTPs in some of the Mediterranean Countries are not working properly or even out of use due to high maintenance costs and highly qualified people required for their daily operation and control **[5].**

Wastewater treatment in large part of the MENA region is concentrated in primary and secondary stage treatments where reuse is carried out largely for irrigation purposes. Many of the small-scale plants carry out this process before releasing wastewater into the sea or river. Domestic wastewater management is one of the greatest headaches of Lebanese. Most of the wastewater treatment plants in Lebanon are small scale and primary in nature although many proposals are pending. Ghadir plant in Southern Beirut in Lebanon provides only preliminary treatment (i.e., grit and scum removal). Morocco has about 100 small and medium size wastewater treatment plants, which treat about 13% of the total wastewater in Morocco. The technique employed in Morocco is generally basic and so far concentrated on stabilization pond technology; few of them are trickling filter plant. Therefore, the treated water is largely used for irrigation purposes. Only one plant is based in activated sludge method in Morocco. In 1980s a nation-wide water reuse program to increase the Tunisia's usable water resources was launched. Municipal wastewater receives secondary biological treatment and some tertiary treatment **[4]**.

Harare and its satellites in addressing the problems of the conventional wastewater management system. The suggested framework of operation is a decentralized domestic wastewater collection and treatment system which however has its own multifarious risks. Using systems dynamics conceptualization of the potentiality, opportunities, risks and strategies, the paper seeks to model the path and outcomes of this decentralized domestic wastewater collection and treatment system and also suggests a number of policy measures and strategies that the city of Harare and its satellites can adopt. These include, among others, the cost of collecting and treating wastewater, acceptance and social awareness, and environmental protection, all of which must be considered in implementing decentralization in urban areas in developing countries of note in Harare. According to the context of each case, the level of decentralization may be a critical issue to achieving sustainability of a wastewater management system. **[6]**.

Conventional biological wastewater treatment technologies unfortunately present some techno-economic limitations such as high aeration costs (activated sludge reactors) and poor pathogen and nutrient removal (anaerobic reactors) **[7, 8]**.Anaerobic wastewater treatment using granular sludge reactors is a developing technology, in which granular sludge is the core component. So far, around 900 anaerobic granular sludge units have been operated worldwide. Almost 100% of anaerobic granular sludge reactors operate in an up flow mode. The role of interactive pattern between hydrodynamic shear force and microbial aggregates other than the shear strength should be described in future research **[6]**.

Anaerobic wastewater treatment is receiving renewed interest because it offers a means to treat wastewater with lower energy investment. Because the microorganisms involved grow more slowly, such systems require clever design so that the microbes have sufficient time with the substrate to complete treatment without requiring enormous reactor volumes. The successful application of anaerobic technology to the treatment of industrial wastewaters is critically dependent on the development, and employ of high rate anaerobic bioreactors **[9].**

High-rate anaerobic technologies offer cost-effective solutions for sewage treatment in the Middle East and Palestine in particular. The sewage characteristics in Palestine are quite different from the values elsewhere and show solids contents of more than 1000 mg chemical oxygen demand (COD)ss/L and total COD values exceeding 2000 mg/L. While summer temperatures exceed 25 °C. The UASB-Digester combination achieved removal efficiencies of total, suspended, colloidal and dissolved CODs of 66, 87, 44 and 30%, respectively. Preliminary model calculations indicated that a total reactor volume (UASB-Digester) corresponding to 8.6 hours hydraulic retention time (HRT) might suffice for sewage treatment in Palestine**[10].**

Different types of bioreactors are utilized for the treatment of wastewater that are reliable, cost-efficient, and effective in eliminating a wide range of pollutants. The integrated bioreactors are classified into four types, which are integrated bioreactors with physical separation of anaerobic–aerobic zone, integrated bioreactors without physical separation of anaerobic–aerobic zone, anaerobic–aerobic sequencing batch reactors (SBR), and combined anaerobic–aerobic culture system. Fluidized bed process is also called suspended carrier biofilm process, which is a new efficient sewage treatment process **[11]**.

A pilot plant system consisting of an up flow hybrid AF reactor (238 L), a nitrification tank (233 or 119 L) containing immobilized nitrifier pellets and a down flow AerF (58 L) was tested for the removal of organics, solids, and nitrogen from municipal wastewater. At an HRT of 5.5 h for the total system, complete nitrification was achieved and overall removal efficiencies of 96 to 97% for BOD5 and TSS and 74 to 75% for Total-N were obtained **[12].**

Waste stabilization ponds have demonstrated the capabilities of being a viable treatment technology, specifically in small communities and developing countries because of their inexpensive maintenance and simple design. As the worldwide water crisis increases, wastewater effluent reuse, specifically from waste stabilization ponds in some fashion, will continue to increase **[13].** Anaerobic ponds operate without the presence of dissolved oxygen. Under methanogenic conditions, the major products are carbon dioxide and methane **[14].** Typically, these ponds are designed to have a depth of 2–5 m, with a detention time between 1 and 1.5 days, an optimum pH less than 6.2, temperatures greater than 15^{o}C **[15],** and an organic loading rate of 3000 kg ha/day **[14, 15].**

Anaerobic digestion has been considered as a promising method for wastewater treatment. Nowadays, the well-known advantages of the anaerobic process encourage researchers and engineers to develop new reactors for treatment of medium strength and diluted wastewater. For the purpose of finding economically and technologically suitable WWTPs, many recent researches are aimed to use of anaerobic reactors for pre-treatment and/or treatment of municipal wastewater. This technology has been used quite often in recent years, mainly in regions with warmer climate. For example, Columbia, India and Brazil have built a couple of larger WWTPs of this type **[16]**. The performance of a laboratory-scale sewage treatment system composed of an up-flow anaerobic sludge blanket (UASB) reactor and a moving bed biofilm reactor (MBBR) at a temperature of (22–35 _C) was evaluated. An overall reduction of 80–86% for COD_{total}; 51–73% for $COD_{colloidal}$ and 20–55% for $COD_{soluble}$ was found at a total HRT of 5–10 h, respectively **[17]**.

The full-scale anaerobic suspended granular sludge bed (SGSB) reactor runs stably and achieves high COD removal efficiency (about 90%) at high loading rates (average 40 kg-COD.m^{-3}.d^{-1},maximum to 52 kg-COD.m^{-3}.d^{-1}) based on the SGSB theory, and its expansion degree is between 22% and 37% **[18].**Within the spectrum of anaerobic sewage treatment technologies, the up-flow anaerobic sludge blanket (UASB) reactor offers great promise, especially in developing countries that are usually located in hot and moderate climatic zones [**19, 20**]. In an UASB reactor, anaerobic microorganisms can form granules through self-immobilization of bacterial cells, and the performance of theUASB system is strongly dependent upon granulation process with a particular wastewater **[21]**.The UASB reactor was operated without recycle, at hydraulic retention time (HRT) of 8 h and achieved consistent removal of BOD, COD and TSS of 60–70% for more than 12 months **[18].**Researc found a COD gap of about 10–15% of the total input COD of the UASB reactor treating sewage at 20^{o}C. This is partially attributed to COD consumption for cell synthesis **[22]**. A higher value of unaccounted COD of 40.8–41.5% was recorded for anaerobic filter (AF) treating municipal wastewater **[23].**

Study achieved 97.5% COD reduction at an initial concentration of 2 g/L and for a superficial gas Velocity of 0.00212 m/s at HRT of 40 h using fluidized bed. The UASB reactor uses an anaerobic process while forming a blanket of granular sludge which suspends in the tank. The UASB is widely applicable for treating various types of wastewater and has advantages over aerobic treatment **[24].**Like aerobic treatments, the UASB requires a post-treatment to remove pathogens, but due to low removal of nutrients, the wastewater, as well as the stabilized sludge, can be used in agriculture. Three different types of upflow anaerobic reactor such as upflow anaerobic sludge blanket (UASB), upflow anaerobic sludge-fixed film (UASFF), and upflow fixed film (UFF) reactors are used in the anaerobic process**[25].**

The capability of a cost-effective and a small size decentralized pilot wastewater treatment plant (WWTP) was investigated to remove enteric viruses. This pilot plant is an integrated hybrid anaerobic/aerobic setup which consisted of anaerobic sludge blanket (UASB), biological aerated filter (BAF), and inclined plate settler (IPS). Both the UASB and BAF are packed with a non-woven polyester fabric (NWPF). Although the pilot WWTP investigated is cost effective, has a small footprint, does not need a long distance network pipes, and easy to operate, its efficiency to remove enteric viruses is comparable with the conventional centralized WWTPs**[26,**

27]. Most of the related publications describe the practical realization of the anaerobic treatment of municipal wastewater by use of a UASB reactor.

Three types of anaerobic reactors (UASB reactor, upflow anaerobic filter-UAF and anaerobic sequencing batch reactor- AnSBR) were tested under laboratory conditions.Contrary to expectation, the UASB reactor did not effectively remove organic pollution from the tested wastewaters. The mean removal efficiency of COD depended on the type of anaerobic reactor, temperature, used HRT and was found between 37-48% (UASB), 56-88% (AnSBR) and 46-90% (UAF). By contrast, UAF and AnSBR seemed to be more useful for thepurpose as these reactors performed relatively well in thewhole range of used temperatures and HRT values. Thegreatest effectiveness (above 70%) was reached at temperatures 15 and 23^{o}C**[16]**.

An anaerobic/anoxic/oxic (A^2O) moving bed biofilm reactor (MBBR) system was designed and investigated for the simultaneous organic matter and nutrients removal of organic matter and nutrients (nitrogen and phosphorous) from a synthetic wastewater. Synthetic wastewater with characteristics similar to those of the typical municipal wastewaters was prepared to avoid the variability of real wastewater compositions. The COD, TN, and TP removals were 90 ± 0.8, 80 ± 1.2, and 70 ± 1.0%, respectively. Obtained results indicated the good stability of the optimized system and the ability of MBBRs to remain stable at influent organics and nutrient variations **[28]**.

II. STATEMENT OF THE ENVIRONMENTAL PROBLEM

In most of Egyptian Governorates, more than 95% of local villages and sub-villages are not provided with wastewater facilities. Approximately two thirds of the population in rural and sub-urban areas has no hygienic means of wastewater treatment and disposal. Due to the little water consumption in those regions, the concentration of wastewater becomes very high compared to the normal municipal WW. To implement conventional type WW treatment in these areas to comply with environmental regulations, the required cost is about LE 7 to 9 million excluding the O&M cost and would take at least 20 years to put into practice even with assuming the availability of financial resources. Also in most of cities having small and medium industries in Egypt, the factories discharge their industrial WW directly to the public sewers to be collected and transported with domestic WW. The mixture of these industrial and domestic wastewaters has a high pollution concentration enough to be described as medium strength municipal wastewaters which areabove the limits of the Egyptian Environmental Regulation (Decree 44/2000). Accordingly, a cost-effective treatment of these municipal wastewaters is considered as urgent needs.

III. OBJECTIVES OF THE STUDY

The main objective of this research was to investigate the use of anaerobic reactors as a low cost technology to treat domestic wastewater generated in Egypt villages and sub-villages. A semi-pilot plant for such anaerobic treatment was built at Egyptian Wastewater Treatment Plant.

Other objectives of this research are: to demonstrate and implement naturally oriented low cost technology for municipal wastewater treatment through UASB-bioreactor system and determine its economic feasibility, providing methodologies, technologies, monitoring systems and sustainable economic solutions for UASB start-up, operation and maintenance; produce biogas as an alternative source of energy to substitute fossil energy; evaluate the activated sludge process as a post treatment aeration technology after the UASB reactor at a reduced cost as well as determination of the reduction in its capital, and running operation and maintenance costs due using of UASB as a pre-treatment step; evaluate the treated wastewater for re-use in agriculture purposes to recover nutrients which are very useful for soil reclamation. As well as to investigate using this reactor as a household wastewater treatment unit in rural areas considering the eligible post treatment or disposal options which might be required to achieve full compliance with the environmental regulations.

IV. MATERIALS AND METHODS

A semi-pilot plant for such anaerobic treatment was built at Wastewater Treatment Plant in Cairo, Egypt for treating the raw WW. The design, start-up and operation parameters of that pilot plant was determined depending on the results received from lab scale experiments, which will be implemented at Arizona University.

Description of Semi-Pilot Plant SPP

The SPP reactor was sized based on the volumetric organic load following the average values reported in literatures. The reactor was made of PVC cylinder with 1m in height and 15 cm internal diameter, packed with flexible plastic pipes (av. 3cm in length and 16mm in diameter). The reactor has a total volume of 16 l with fixed media occupies a volume of 10 L. The total support surface area is 1.6 m^2 with specific surface area 160 m^2/m^3. The reactor supported by sampling ports located along the length of the reactor at intervals of 30 cm and the gas produced in the reaction was evacuated from the top. The reactor is thermostatically controlled. The wastewater was introduced to the reactor from a primary sedimentation tank in in the wastewater treatment plant through a metering pump. Figure (1) illustrates a schematic diagram of the SPP.

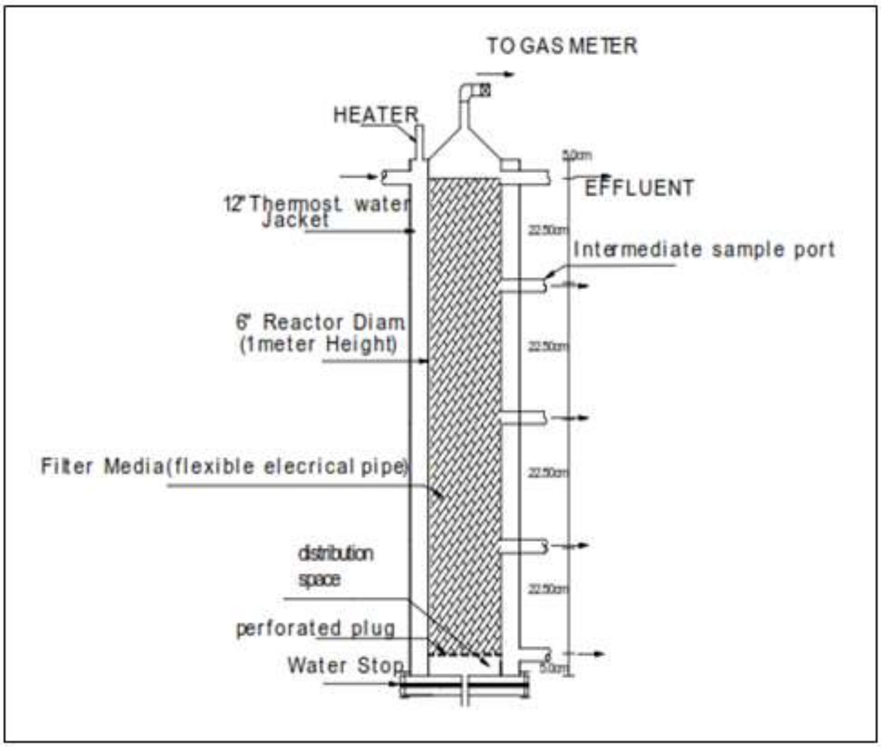

Figure 1: Schematic Diagram of the Semi-Pilot Plant SPP

Experimental Work Schedule

The main purpose of the experimental work is to evaluate the feasibility of the anaerobic treatment of domestic sewage using the Anaerobic Filter through three stages:Up-Flow Filter AUF, Down Flow Filter ADF, and Fluidized Bed Filter AFBF. Figures (2), (3), and (4) illustrate a schematic diagram of the SPP for the three stages: Up-Flow Filter AUF, Down Flow Filter ADF, and Fluidized Bed Filter AFBF.

Factors affecting the treatment processes were focused. The investigations of the AUF, ADFas well as the AFBFreactors were one of the main goals of this study. The materials and methods used during the prevailing study were adapted to a general progressive schedule of various experimental arrangements as demonstrated in Tables 1a, b, and c.

Start-up Procedures and Problems

The SPP influent pump was connected to a tank filled with the effluent of the primary settling tanks to simulate a settled wastewater. The reactor was started up by filling one third of its volume with an-aerobically treated sludge and two-thirds pre-settled domestic wastewater. This anaerobic sludge was used as the microorganisms for wastewater treatment and the mixture was circulated in an up-flow pattern for 2-4 weeks at 28-30ºC. A bottle partially filled with water and diluted acid was connected to the gas outlet pipe and used to monitor the gas production. This would indicate the microbial activities within the reactor. Once a displacement of water in water bottle had been observed, the influent pumping rate was allowed to increase gradually to increase loading and avoid shock load to the reactor. As commonly seen in anaerobic reactors startup operations, several

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problems were encountered which impeded proper startup of the system. These problems could be summarized as the following:

- The use of low water content an-aerobically digested sludge clogged the reactor completely. The reactor had to be disassembled for cleaning and washing.
- The higher rate of circulation led to the possibility of washing out the sludge from the media, thus reduce sludge age.
- The increase of the flow rate sometimes led to sudden drop of reactor performance and it was necessary to restart of the system.

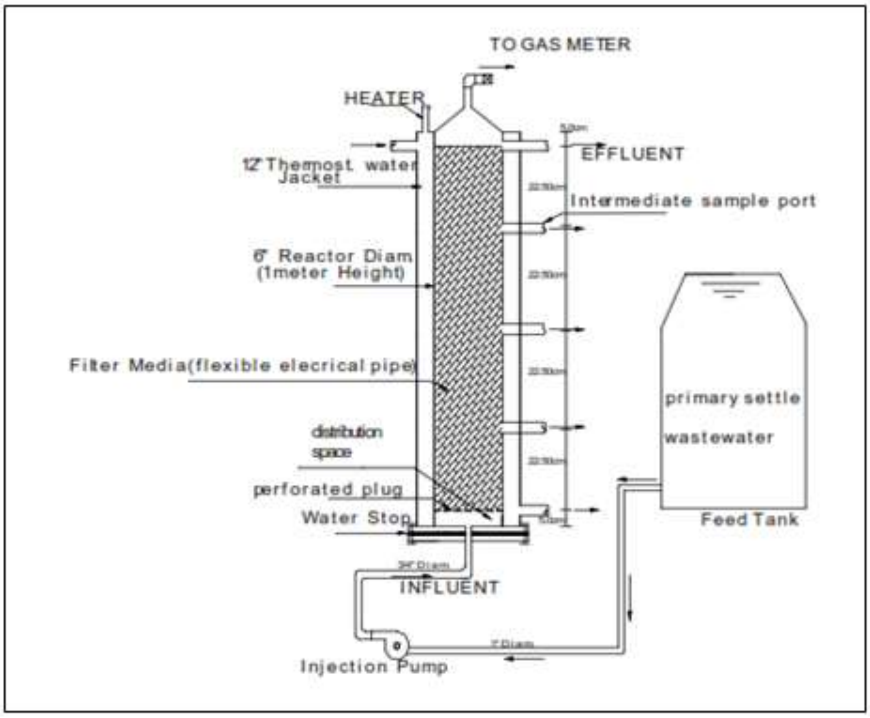

Figure 2: Schematic Diagram of the Up-Flow Pattern Reactor

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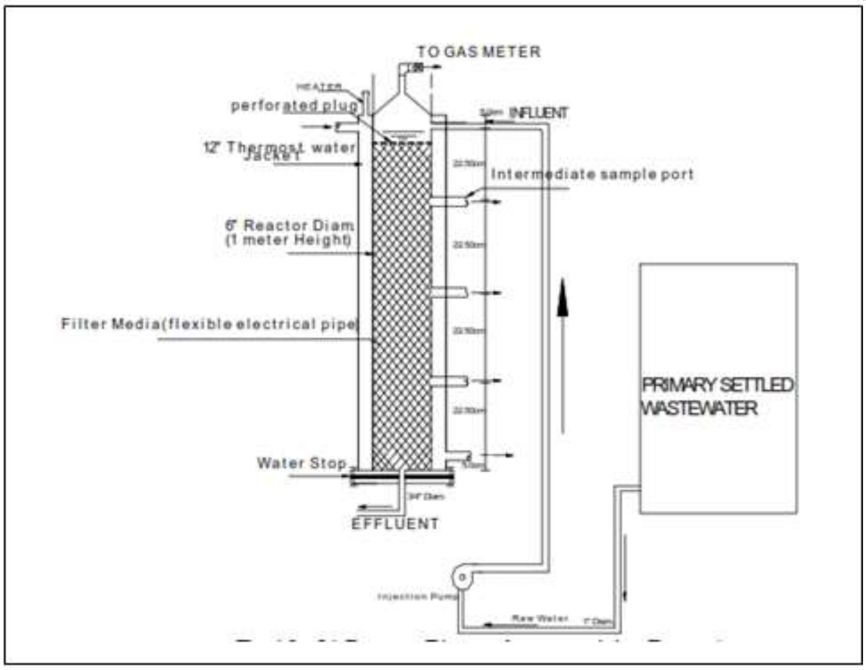

Figure 3: Schematic Diagram of the Down Flow pattern Reactor

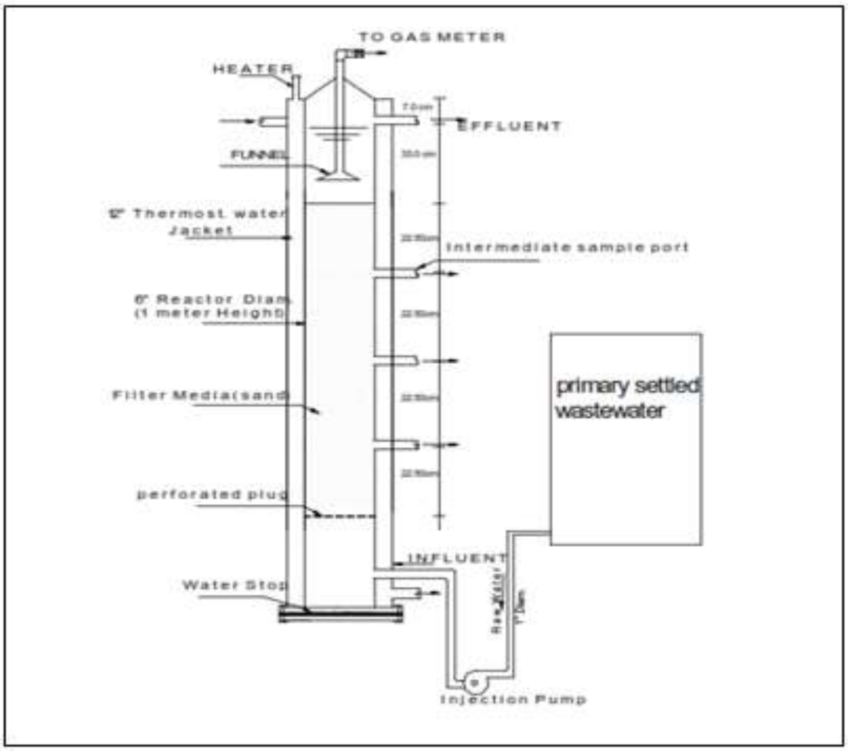

Figure 4: Schematic Diagram of the Fluidized Bed Reactor

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Table 1: Experimental Arrangement used in the SPP
Table 1-a:Up-Flow Pattern

Run No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HRT, hrs	6	6	6	12	12	12	24	24	24	30	30	30	40	40	40
Temp., °C	28	28	30	31	33	32	30	28	30	32	34	34	31	29	30

Table 1-b: Down-Flow Pattern

Run No.	1	2	3	4	5	6	7	8	9	10	11	12
HRT, hrs	6	6	6	12	12	12	24	24	24	30	30	30
Temp., °C	29	31	31	30	33	34	35	33	32	30	28	27

Table 1-c: Fluidized Bed Pattern

Run No.	1	2	3	4	5	6
HRT, hrs	6	6	6	12	12	12
Temp., °C	31	30	32	34	34	33

V. RESULTS AND DISCUSSION

1. Influent Quality

The characteristics of the influent wastewater varied slightly from day to day. The average influent BOD and COD concentrations ranged from 105 to 145, and 201 to 261 mg/l, respectively. The average temperature ranged between 25 to 30o C. Total Influent Suspended Solids varied from 60 to 115 mg/l.

2. Up-Flow Filter (AUF) Stage

Influent and Effluent Quality, AUF

The different hydraulic detention times used in this research through the 43 days was varied from 6 to 40 hrs. The influent and effluent BOD_5 and COD concentrations' were analysed for the 43 days during the Up-Flow filter operation. The analysis results indicate that the Influent COD concentrations' ranged from a low of 101 to over 165 mg/l with average of 143 mg/l "in some cases the influent COD was higher than the values shown on the graph "while the effluent concentrations ranged from a low of 28 to over 82 mg/l with average of 59 mg/l. For BOD_5 concentrations, the analysis results indicate that the Influent concentrations ranged from a low of 78 to over 105 mg/l with average of 91 mg/l while the effluent concentrations ranged from a low of 11 to over 59 mg/l with average of 27 mg/l.

Total Suspended Solids concentrations (TSS) were analysed as well, the analysis results indicate that the Influent concentrations ranged from a low of 50 to over 105 mg/l with average of 75 mg/l while the effluent concentrations ranged from a low of 11 to over 51 mg/l with average of 27 mg/l. Ammonia nitrogen was slightly removed. Other different pollutants concentrations were analysed as well as shown and summarized in table-1. Figures 5a, 5b and 5c show the influent and effluent pollutants concentrations.

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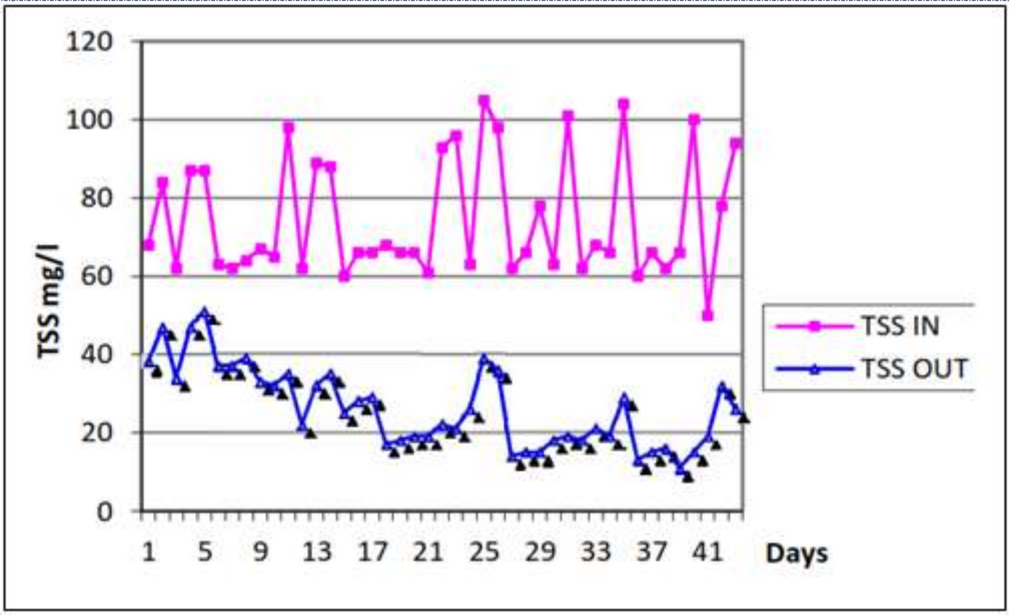

Figure 5c: Influent and Effluent TSS Concentrations, AUF

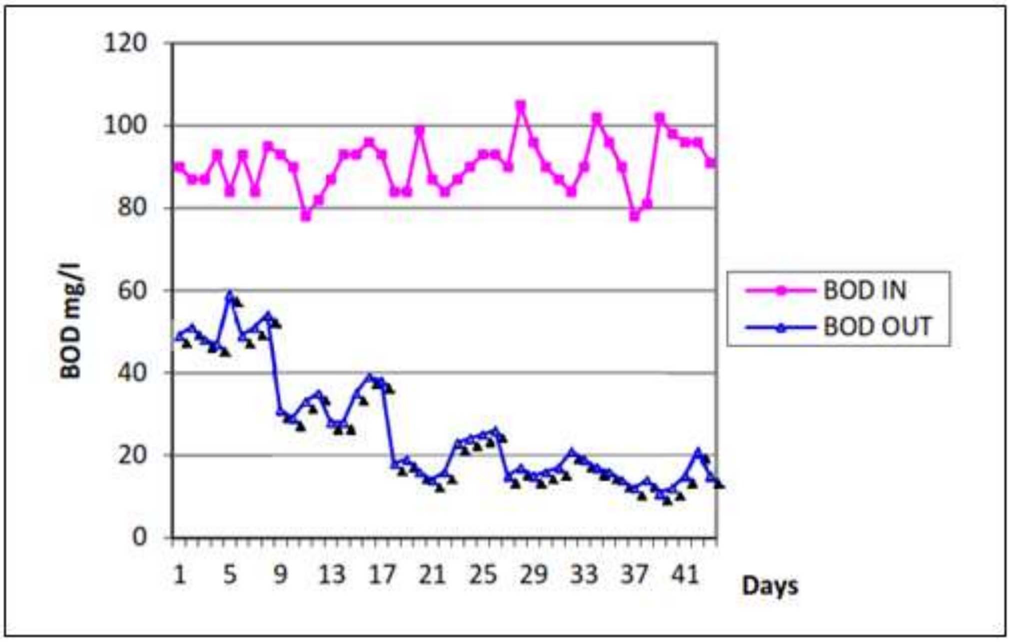

Figure 5b: Influent and Effluent BOD Concentrations, AUF

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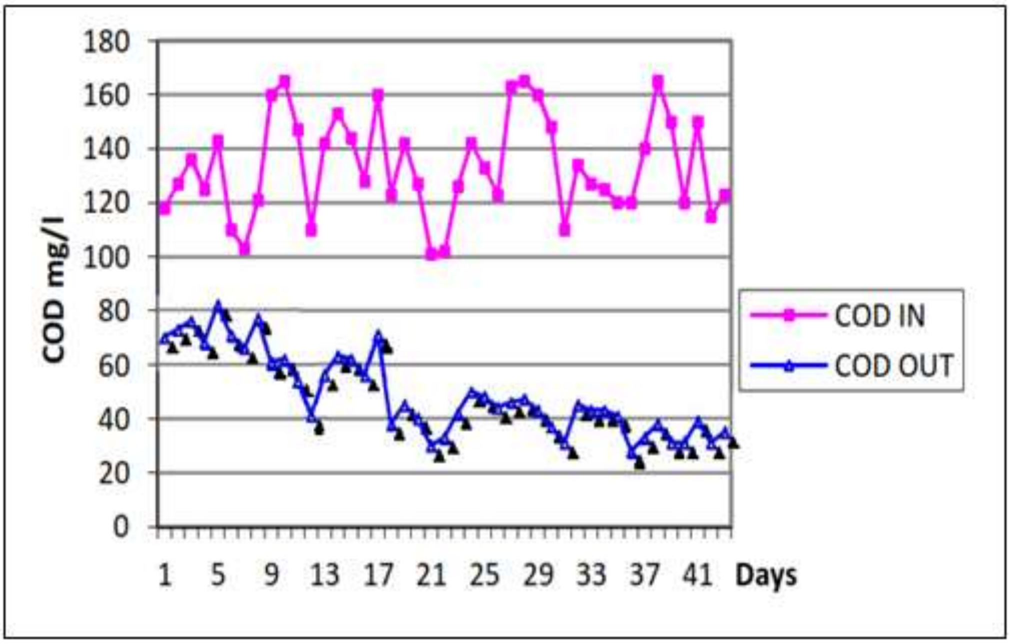

Figure 5a: Influent and Effluent COD Concentrations, AUF

Table 2: Influent and Effluent Pollutants Concentrations, AUF

Parameter	*Influent*		*Effluent*		Removal Eff. (%)
	Range	Average	*Effluent*	Average	
pH	6.93-7.3	7	6.99-7.68	7.2	----
BOD_5(mg/L)	87-105	91	11-59	27	70
COD (mg/L)	101-165	134	28-82	59	63
Ammonia (mg/L)	27-32.3	29	18.8-29.8	25	15
Sulfide (mg/L)	0.6-0.82	0.72	0.23-0.54	0.42	42
Alkalinity (mg/L)	250-330	289	240-310	269	7
Volatile suspended Solids (mg/L)	68-84	70	8-44	20	72
Total Suspended Solids (mg/L)	50-105	75	11-51	27	65
Volatile fatty acids	Not Detectable				
Organic loading rate (Kg COD/m³/day)	0.09-0.57				

Gas Production and Composition, AUF

The fluctuation of organic matter in the influent induced an irregularity in the volume of gas produced daily. Biogas production is shown in Figure (6) and ranged from a low of 30 ml/day to over 300 ml/day. Gas production rates were highly variable due to the size of the system. Gas pockets were observed in the filter, head space, and gas collection tubing. It appeared that the gas pockets tended to grow until they reached a limiting size when they would break loose and rise through the filter .Therefore gas production tended to occur in “spurts” rather than at regular rates. Actual micro-biological gas production probably occurred at a much more even rate than Figure (6) shows.

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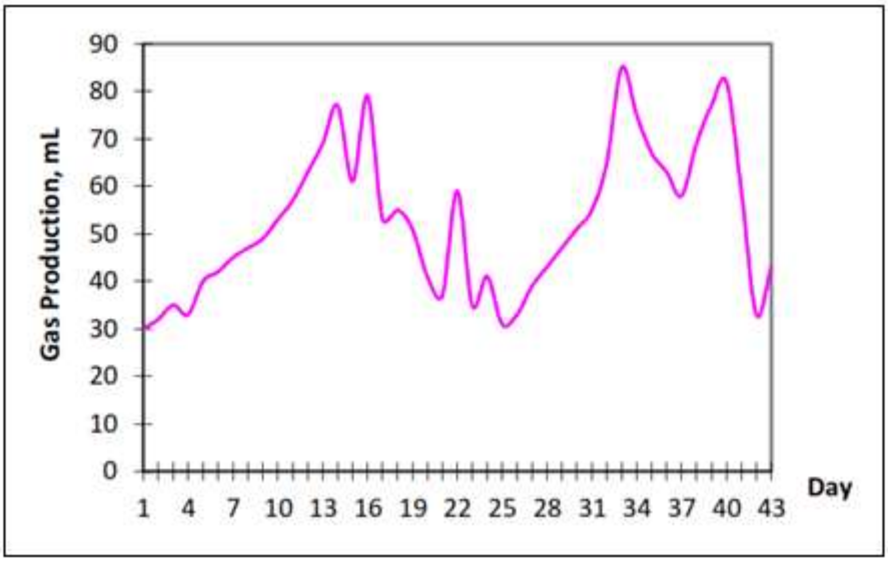

Figure 6: Biogas Production, AUF

The average methane concentration was observed to be ranged between 62 to 67% methane with low strength wastewater. While in days with higher strength, the gas composition influenced by the changes in the organic matter content of the sewage; a more concentrated influent resulted in higher CH_4 and a lower N_2 fraction while CO_2 ranged always between 4- 8 %. The gas composition, ignoring the nitrogen fraction, ranged from 90 to 95 % methane.

Results Discussion, AUF

The anaerobic filter compares favorably with other treatment processes with respect to the loadings which can be applied and the removals obtained. In addition to the efficient treatment of dilute soluble wastes, the anaerobic filter is of simple design and requires no sludge or effluent recycle to maintain high treatment efficiency. Unlike aerobic treatment processes which produce significant quantities of sludge requiring further treatment, the long solids retention time possible in the anaerobic filter results in an exceptionally low solids production. The filter can be operated for long periods of time without sludge wasting. For low solids producing wastes such as fatty acids and proteins, the filter conceivably could be operated for longer periods before sludge wasting would be required. However, periodic sludge wasting would help prevent any serious plugging which conceivably could occur.

The filter reaction to instantaneous doubling of loadings indicates that the anaerobic filter readily accepts shock loads. If the shock loads are short duration, the effluent quality often does not change appreciably. Like other treatment processes, the filter cannot treat all types of wastes satisfactorily. Completely soluble organic wastes are most appropriate. Small amounts of degradable suspended solids perhaps could be accepted without problems of plugging.

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3. Down-Flow Filter (ADF) Stage

Influent and Effluent Quality, ADF

The different hydraulic detention times used in this research through the 43 days was varied from 6 to 40 hrs. The influent and effluent BOD_5 and COD concentrations' were analysed for the 43 days during the Down-Flow filter operation. The analysis results indicate that the Influent COD concentrations' ranged from a low of 103 to over 165 mg/l with average of 132 mg/l while the effluent concentrations ranged from a low of 41 to over 105 mg/l with average of 64 mg/l. For BOD_5 concentrations, the analysis results indicate that the Influent concentrations ranged from a low of 82 to over 117 mg/l with average of 95 mg/l while the effluent concentrations ranged from a low of 30 to over 58 mg/l with average of 42 mg/l.

Total Suspended Solids concentrations (TSS) were analysed as well, the analysis results indicate that the Influent concentrations ranged from a low of 60 to over 108 mg/l with average of 75 mg/l while the effluent concentrations ranged from a low of 23 to over 68 mg/l with average of 35 mg/l. Ammonia nitrogen was slightly removed.Other different pollutants concentrations were analysed as well as shown and summarized in table-3. Figures 7a, 7b and 7c show the influent and effluent pollutants concentrations.

Table 3: Influent and Effluent Pollutants Concentrations, ADF

Parameter	***Influent***		***Effluent***		**Removal Eff. (%)**
	Range	**Average**	***Effluent***	**Average**	
pH	6.93-7.3	7	6.99-7.68	7.2	----
BOD_5(mg/L)	82-117	95	30-58	42	56
COD (mg/L)	103-165	132	41-105	64	51.5
Total Suspended Solids (mg/L)	60-108	75	23-68	35	53
Volatile fatty acids	Not Detectable				
Organic loading rate (Kg COD/m³/day)	0.09-0.73				

Gas Production and Composition, ADF

Measurement of the produced gas was difficult due to the relative small amount produced corresponding to the COD loading. The amount of produced gas was calculated based on the COD removal rate. However, the production ranged between 0.25 to 0.56 l/day. CH4 concentration was observed as 62 to 67%.

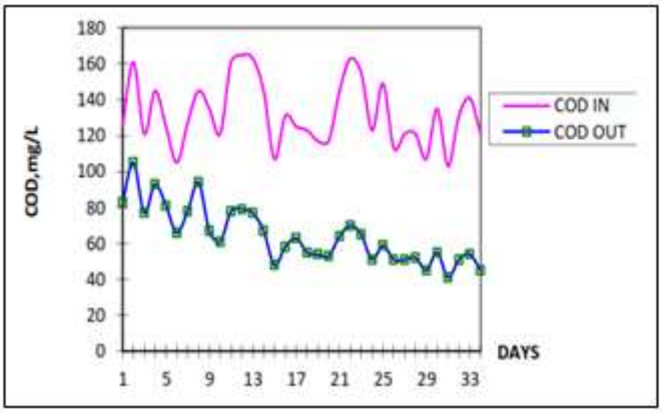

Figure 7a: Influent and Effluent COD Concentrations, ADF

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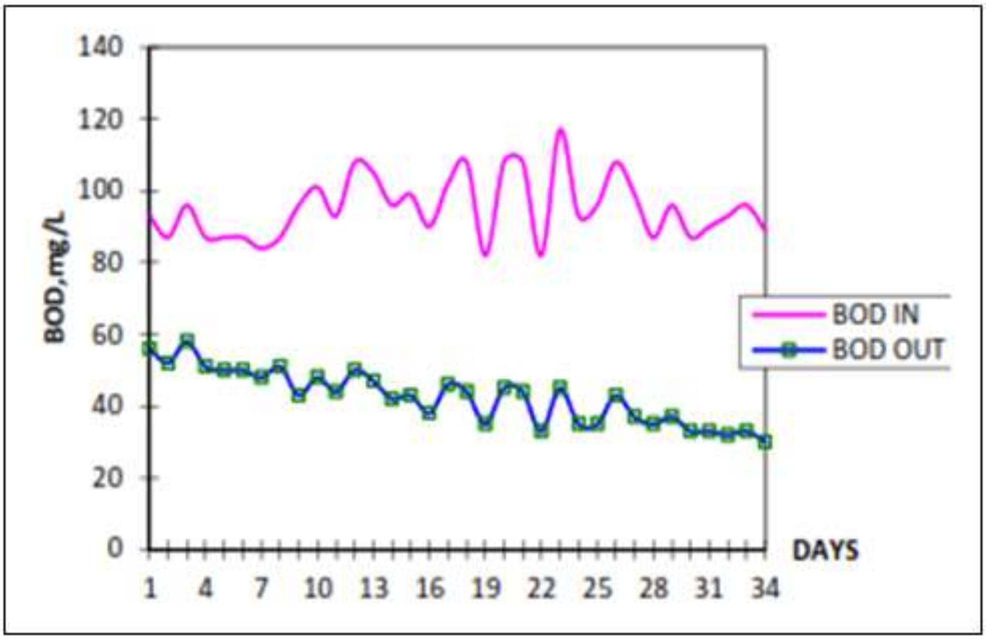

Figure 7b: Influent and Effluent BOD Concentrations, ADF

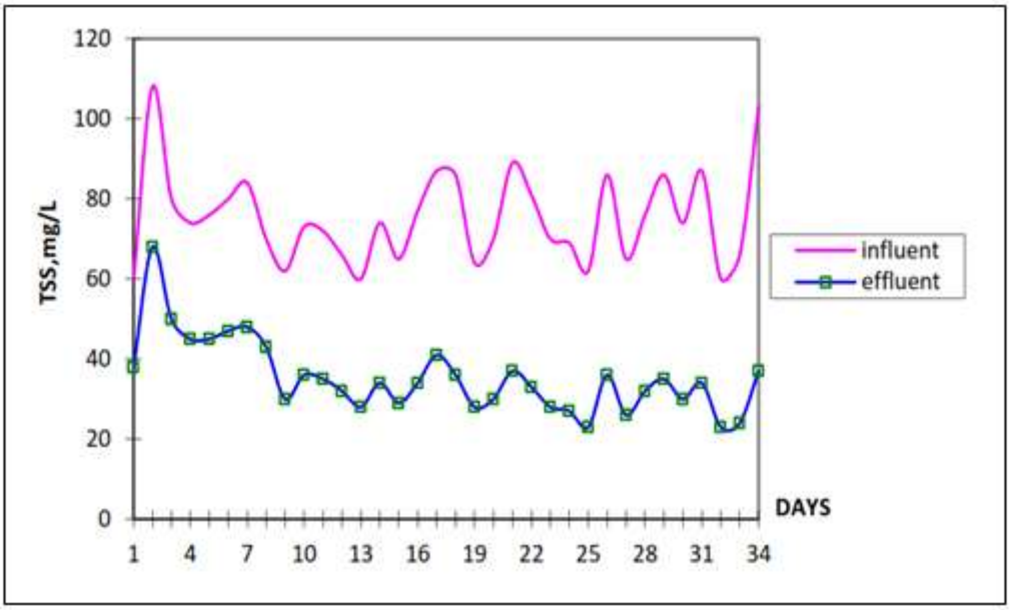

Figure 7c: Influent and Effluent TSS Concentrations, ADF

4. Fluidized Bed Filter (AFBF) Stage

Influent and Effluent Quality, AFBF

In this case, since the medium should be kept in fluidized form, up flow velocities must be high enough to keep the particles in suspension. This makes the recirculation of some of the wastewater being treated necessary; otherwise, the detention time would be too short. Since recirculation dilute the influent, which would, in turn, reduce the amount of alkalinity required; and minimize the effect of shock loading. A Separation tank was provided to avoid loss of biomass in the effluent. Sand with effective size of 0.30-0.50 mm was used as a medium with an expansion ratio of about 70%. The vertical velocity including recycling was 6-10 m/hr.

The different hydraulic detention times used in this research through the 43 days was varied from 6 to 40 hrs. The influent and effluent BOD_5 and COD concentrations' were analysed for the 43 days during the Fluidized

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Bed filter operation. The analysis results indicate that the Influent COD concentrations' ranged from a low of 101 to over 165 mg/l with average of 126 mg/l while the effluent concentrations ranged from a low of 52 to over 95 mg/l with average of 74 mg/l. For BOD_5 concentrations, the analysis results indicate that the Influent concentrations ranged from a low of 87 to over 108 mg/l with average of 96 mg/l while the effluent concentrations ranged from a low of 38 to over 72 mg/l with average of 52 mg/l. Total Suspended Solids concentrations (TSS) were analysed as well, the analysis results indicate that the Influent concentrations ranged from a low of 60 to over 138 mg/l with average of 90 mg/l while the effluent concentrations ranged from a low of 30 to over 89 mg/l with average of 50 mg/l. Ammonia nitrogen was slightly removed.Other different pollutants concentrations were analysed as well as shown and summarized in table-4. Figures 8a, 8b and 8c show the influent and effluent pollutants concentrations.

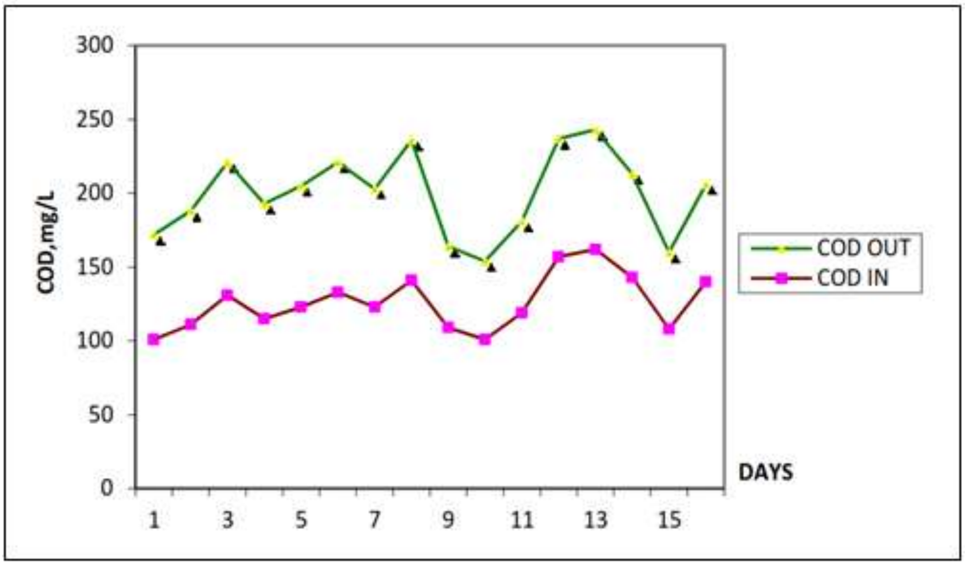

Figure 8a: Influent and Effluent COD Concentrations, AFBF

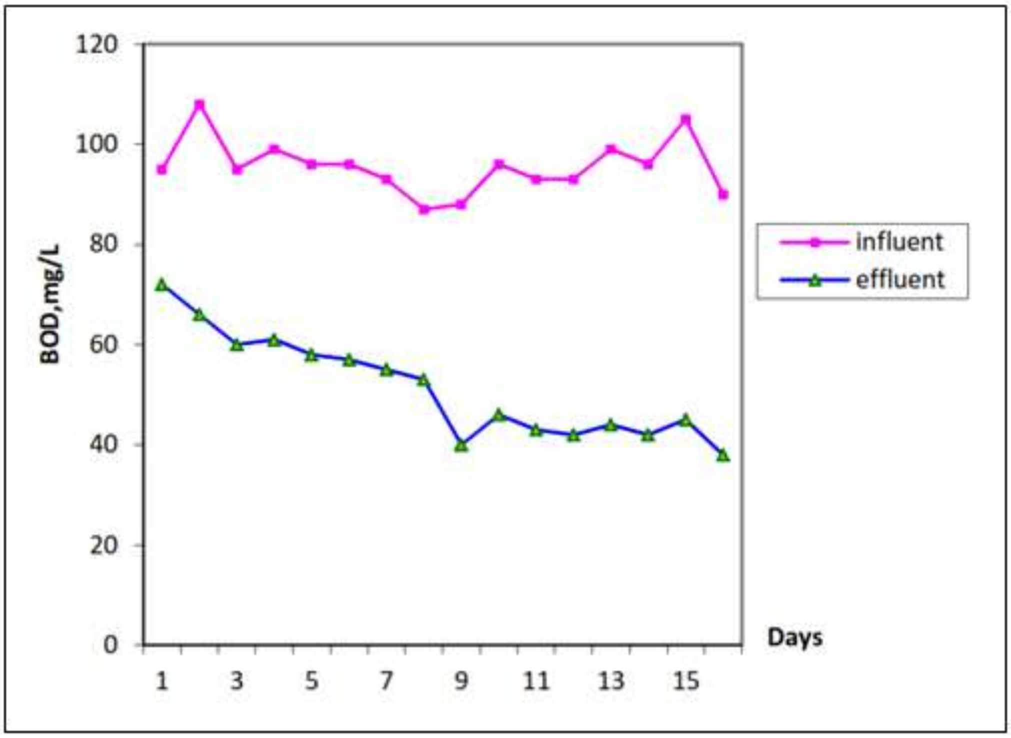

Figure 8b: Influent and Effluent BOD Concentrations, AFBF

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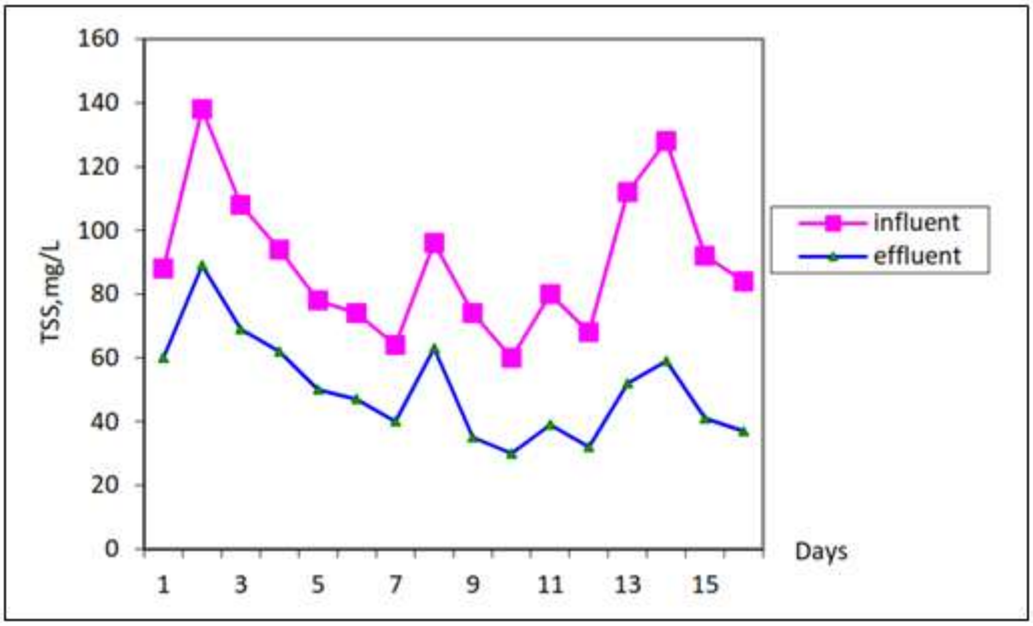

Figure 8c: Influent and Effluent TSS Concentrations, AFBF

Table 4: Influent and Effluent Pollutants Concentrations, ADF

Parameter	*Influent*		*Effluent*		Removal Eff. (%)
	Range	Average	*Effluent*	Average	
pH	6.93-7.3	7	6.99-7.68	7.2	----
BOD_5(mg/L)	87-108	96	38-72	52	45
COD (mg/L)	101-165	126	52-95	74	41
Total Suspended Solids (mg/L)	60-138	90	30-89	50	44
Volatile fatty acids	Not Detectable				
Organic loading rate (Kg COD/m³/day)	0.09-0.17				

Gas Production, AFBF
Not investigated due to the observed poor performance and operation difficulties.

Results Discussion, AFBF
A study on anaerobic fluidized beds was conducted and evaluated investigating the treatment of a municipal waste-water (containing industrial wastes) with an average sulphate concentration of 250 mg/L, COD removal efficiency ranged from 40 to 50 % for hydraulic retention time of 6 to 24 hours. Methane production was found to be low due to the effect of the thermodynamically favoured reduction of the influent sulphate that was occurring in the reactors. Study was conducted over five-month intensive testing period and over a wide range of organic volumetric loading rates ,(0.18 –0.41 g BOD/l.d) and at a hydraulic retention time varying from 1.67 to 6.37 hrs.; a mean effluent 5 day BOD of 47.2 mg/l and a mean suspended solids (SS) concentration of 30.5 mg/l were achieved . The influent BOD and SS were 74.2 and 35.5 mg/l respectively.

It was noted that the recovery of the system after an upset condition takes a relatively long time. This can be explained by the fact that the process of biofilm formation is slow and after a situation whereby biomass is lost from the system usually it takes some time to build up the maximum possible concentrations. Due to the fact that a limited amount of biomass can be retained in the reactor, the system has no inherent buffering capacity towards shock loads in toxicants or COD. Overall the stability of the process is therefore limited. Because of the relatively delicate operation of an AFBF reactor, it makes them non-adaptable to the needs and possibilities of sewage.

VI. CONCLUSION

Biological Oxygen Demand (BOD_5) removal efficiencies for AF, DSFF and AFB are 70, 55 and 43% respectively. Chemical Oxygen Demand (COD) removal efficiencies for AUF, ADF and AFBF are 63, 51 and 41% respectively. Removal efficiencies showed very little sensitivity to daily fluctuations in influent wastewater quality. Gas production averaged 0.024 L of gas per L of influent wastewater, or 0.11 m^3 of gas per kg of influent COD .Gas composition averaged 35 % nitrogen, 60 % methane and 5% carbon dioxide. Ammonia nitrogen and sulfides both increased during treatment.

The experimental results showed that the most suitable approach to apply an effective treatment was the using of Up-Flow Anaerobic Filter AUF with HRT= 24 hrs.The maximum removal rate that can be obtained in this case is 76% on COD-basis and 85% on BOD-basis. However a high content of Ammonia-Nitrogen is contained in the produced effluent. So, a post-treatment step is always essential to dispose such effluent into water recipients or to reuse it in agricultural or industrial purposes safely.

In general, both Up and down flow tests proved promising results in pollutant removal. In comparison, the up-flow mode was observed to be slightly more efficient than the down flow reactor. Both flow patterns were found to have the advantages of:

- Elimination of mechanical mixing device. The rising gas bubbles provide enough mixing effect,
- Recycling is not necessary,
- The process is more stable, and
- Simplicity in construction and operation

VII. REFERENCES

[1] Abdel-Raouf N, Al-Homaidan AA, Ibraheem IBM, “Microalgae and wastewater treatment”. Saudi J BiolSci, 19, pp. 257–275, (2012).
[2] Cai T, Park SY, Li Y,“ Nutrient recovery from wastewater streams by microalgae: status and prospects”. Renew Sust Energy Rev 19, pp. 360–369, (2013).
[3] Posadas E, Garcia-Encina PA, Soltau A, Domيnguez A, Dيaz I, “Carbon and nutrient removal from centrates and domestic wastewater using algal-bacterial biofilm bioreactors”. BioresourTechnol, 139, pp. 50–58, (2013).
[4] DigambaraPatra, “Reducing Energy Cost for Wastewater Treatment in the Middle East: A Physiochemical Prospective”, Springer International Publishing AG 2017, (2017).
[5] SixtoMalato et al. “Technologies for Advanced Wastewater Treatment in the Mediterranean Region”. Springer-Verlag Berlin Heidelberg, HdbEnvChem, 14, pp. 1–28, (2011).
[6] Innocent Chirisa, ElmondBandauko, Abraham Matamanda, Gladys Mandisvika, “Decentralized domestic wastewater systems in developing countries: the case study of Harare (Zimbabwe)”. Appl Water Sci, 7, pp. 1069–1078, (2017).
[7] de la Noüe J, Laliberté G, Proulx D, “Algae and waste water”. J ApplPhycol, 4, pp. 247–254, (1992).
[8] Posadas E, Garaia-Encina PA, Dominguez A, Becares E, Blanco S, “Enclosed tubular and open algal-bacterial biofilm photobioreactors for carbon and nutrient removal from domestic wastewater”. EcolEng, 67, pp. 156–164, (2014a).
[9] SitiRoshayu Hassan, IrvanDahlan. “Anaerobic wastewater treatment using anaerobic baffled bioreactor: a review”. Cent. Eur. J. Eng., 3(3), pp. 389-399, (2013).
[10] Nidal Mahmoud et al. “Adapting High-rate Anaerobic Treatment to Middle East Conditions”. Springer-Verlag Berlin Heidelberg, pp. 149-161, (2008).
[11] NipunjotKaurSoni-Bains et al. “Perspectives of Bioreactors in Wastewater Treatment”, Springer International Publishing AG 2017, (2017).
[12] Ioannis D. Manariotis, Sotirios G. Grigoropoulos, and Yung-Tse Hung. “Anaerobic Treatment of Low-Strength Wastewater by a Biofilm Reactor”.Cent. Eur. J. Eng., 3(3), pp. 389-399 Handbook of Environmental Engineering, Volume 11: Environmental Bioengineering, (2010).
[13] Mara D, “Waste stabilization ponds: past, present and future”, Desalination Water Treat., 4, pp. 85–88, (2012).
[14] QuirogaFJ,“Waste stabilization ponds for waste water treatment, anaerobic Pond”, http://home.eng.iastate.edu / *tge/ ce421521/ Fernando%20J.%20T revino%20Quiroga.pdf. Desalination, 215, pp. 29–36, (2011).

ISSN: 2277-9655
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CODEN: IJESS7

[15] Kayombo S, Mbwette TSA, Katima JHY, Ladegaard N, Jorgensen SE " Waste stabilization ponds and constructed wetland design manual". UNEP International Environmental Technology Center.http://www.unep.or.jp/Ietc/Publications/Water_Sanitation/ponds_and_wetlands/Design_Manual .pdf. Accessed 18, (2013)
[16] Bodik, B. Herdova, M. Drtil. "Anaerobic treatment of the municipal wastewater under psychrophilic conditions", Bioprocess Engineering 22, pp. 385-390, (2000).
[17] Tawfik, F. El-Gohary, H. Temmink, "Treatment of domestic wastewater in an up-flow anaerobic sludge blanket reactor followed by moving bed biofilm reactor". Bioprocess BiosystEng, 33, pp. 267–276, (2010).
[18] Mingxia ZHENG, Zhong YAN, Jiane ZUO, Kaijun WANG. "Concept and application of anaerobic suspended granular sludge bed (SGSB) reactor for wastewater treatment". Environ. Sci. Eng., 8(5), pp. 797–804, (2014).
[19] Halalsheh M, "Anaerobic pre-treatment of strong sewage. A proper solution for Jordan".A proper solution for Jordan.PhD thesis, Environmental Technology Department, Wageningen University and Research Center, The Netherlands, (2008).
[20] Sousa JT, de Foresti E, "Domestic sewage treatment in an up-flow anaerobic sludge blanket-sequencing batch reactor system". Water SciTechnol, 33(3), pp. 73–84, (1996).
[21] Tay, J.H., Liu, Q.S. & Liu, Y, "Microscopic observation of aerobic granulation in sequential aerobic sludge reactor". Journal of Applied Microbiology, 91, pp. 168–175, (2001).
[22] Singh KS, Viraraghavan T, "Start up and operation of UASB reactors at 20 C for municipal wastewater treatment". J Ferment Bioeng, 85(6), pp. 609–614, (1998).
[23] Ioannis DM, Sotirios GG, "Restart of anaerobic filters treating low-strength wastewater". BioresourTechnol, 99, pp. 3579–3589, (2008).
[24] Haribabu K, Sivasubramanian V. "Biodegradation of organic content in wastewater in fluidized bed bioreactor using low-density bio support", Desalin Water Treat., 57(10), pp. 4322–4327, (2017).
[25] Bhuyar KD, "Treatment of domestic wastewater in an up flow anaerobic packed bed reactor (UAPBR)", Int J AdvEng Res Stud., 2(3), pp. 122–124, (2013).
[26] WaledMorsy El-Senousy, Sohair Imam Abou-Elela. "Assessment and Evaluation of an Integrated Hybrid Anaerobic–Aerobic Sewage Treatment System for the Removal of Enteric Viruses". Food Environ Virol., 9, pp. 287–303, (2017).
[27] Abid Ali Khan et al. "UASB/Flash aeration enables complete treatment of municipal wastewater for reuse". Bioprocess Biosyst Eng., 35, pp. 907–913, (2012).
[28] J. Jaafari et al. "Simultaneous biological organic matter and nutrient removal in an anaerobic/anoxic/oxic (A2O) moving bed biofilm reactor (MBBR) integrated system", Int. J. Environ. Sci. Technol., 14, pp. 291-304, (2017).

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