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Attached Media Performance in Activated Sludge Wastewater Treatment: Zenein Pilot Plant

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Abstract— **Starting to use most recent methods, ideas and equipments of existing waste water treatment plant has become a demand, mostly in the developing countries. The high population, bordered financial resources and area availability need hard treated effluent quality to protect water resources. Hybrid systems could be considered as a suitable alternative. It is a conventional activated sludge treatment system and considered one of the recently tried approaches to improve the performance of the biological treatment through increasing the volume of the accumulated bio-mass in terms of attached growth as well as suspended growth. Moreover, the domestic wastewater could be easily mixed with a high strength non-hazardous industrial wastewater and treated together in these reactors if there is a need. The wastewater characteristics such Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Ammonia (NH_3) and Total Suspended Solid (TSS) are measured. The system will satisfy COD, BOD, and TSS removal and possible, Nitrification / De-nitrification activities by controlling the bio-mass concentration in both suspended and attached forms. In addition, high rate of loading either hydraulic or organic could be achieved.**

A pilot plant for such treatment system was built at Zenein wastewater treatment plant south to Cairo for treating the primary effluent from the primary settling tanks. The main objectives of the proposed study are to assess treatment and wastewater characteristics. A mathematical model simulating the bioreactor will be developed later (not included in this paper). Based on the results, design criteria of a full-scale plant could be developed. The wastewater concentration (COD), (BOD), (NH_3) and (TSS) were measured and the removal efficiencies were estimated too for both activated sludge and attached growth process.

This would be a step ahead to apply this for full-scale plant considering all advantages and disadvantages of the results of the proposed pilot study.

The goal of this study was to figure wastewater characteristics if the attached media introduced to the bioreactor (plastic media). So the Zenien pilot-scale attached growth bioreactor system is used. All results are completely descriptive and experimental data from the Zenein Pilot Plant. No calculations are needed in this study.

Performance was based on water quality testing (BOD, COD, NH3, and TSS). The bioreactor systems were more effective with attached media than conventional activated sludge process and significantly improve the overall efficiency and the characteristic of the wastewater. Also this study showed that using of two reactors in series with media produced treated water with better results than conventional activated sludge process but nearly the same if only one reactor with plastic media existed.

In presence of plastic media using one reactor, the % COD removal increased from 74% (no media used at the same flow rate) to about 88%. % BOD removal increased from 72% to above 86%. %TSS removal increased from 69% up to 89% and % NH_3 removal was almost constant. In presence of two reactors in series with plastic media, the % COD removal slightly increased from 88% to about 90% (using one reactor with plastic media at the same flow rate). % BOD removal increased from 86% to above 90%. % TSS removal increased from 89% up to 91% and % NH_3 removal was almost constant.

Using the plastic as the attached media in one bioreactor improves the percentage efficiency removal of the pollutants. Putting two bioreactors of plastic media in series don't increase wastewater removal performance.

For new installations, attached systems will generally require less volume and therefore have less capital cost than a conventional activated sludge system. These systems require little or no additional operational costs or operating staff over existing systems. However, the need for oxygen supply remains. Dispersed systems require expenditures for additional components, such as media-retaining sieves and/or pumps for regeneration.

This study showed that it is possible to design, build and operate small and decentralized treatment systems by using readily available packing materials and with minimum wastewater pretreatment.

Index Terms— **activate sludge, attached growth, domestic Wastewater, Developing Countries, hybrid Systems, wastewater treatment.**

I. INTRODUCTION

Starting to use most recent methods, ideas and equipments of existing waste water treatment plant has become a demand, mostly in the developing countries. The high population, bordered financial resources and area availability need hard treated effluent quality to protect water resources.

Activated sludge is the most widely spread technology for treating wastewater. It is an aerobic process and requires important amounts of energy to spend. Wastewater treatment by the hybrid reactor system has become wide-spread as it provides advantages of both the suspended and attached growth phase at the same time [7].

Hybrid systems could be considered as a suitable alternative. It is a conventional activated sludge treatment system and considered one of the recently tried approaches to improve the performance of the biological treatment through increasing the volume of the accumulated bio-mass in terms of attached growth as well as suspended growth by introducing elements as biofilm carrier media into a conventional activated sludge reactor. Moreover, the domestic wastewater could be easily mixed with a high strength non-hazardous industrial wastewater and treated together in these reactors if there is a need. The system will satisfy COD, BOD, and TSS removal and possible,

Nitrification / De-nitrification activities by controlling the bio-mass concentration in both suspended and attached forms. In addition, high rate of loading either hydraulic or organic could be achieved [18].
The micro-organisms retained in Aerated biological systems may be in suspended growth forms as in activated sludge process, or in the attached growth form as in the trickling filters or rotating biological contactors. Some relatively recent, treatment systems such as fluidized or expanded bed systems contain both suspended and attached biomass and can be called hybrid growth systems[1].

Hybrid growth is a relatively new technology that describes any suspended growth system that incorporates an attached growth media within the suspended growth reactor [17]. This technique encourages the growth of biomass and enhances the treatment process.
Activated sludge processes Fig (1) and (2) are one parts of a complex wastewater treatment system [7]. They are usually used following primary treatment (including screening that removes settable solids), include one or more main aerated treatment chambers, aeration devices, a device for appropriate mixing to keep the sludge in suspension, a secondary clarifier to separate the biomass from the treated effluent and collect settled biomass, generally a non-linear, highly complex circulation regime (e.g. recirculation loops, by-passing etc.) and are sometimes followed by a final polishing step (tertiary filtration and disinfection). The biological processes that occur are effective at removing soluble, colloidal and particulate materials. The reactor can be designed for biological nitrification and de-nitrification as well as for biological phosphorus removal [14]-[15].
The design must be based on an accurate estimation of the wastewater composition and volume. Treatment efficiency can be severely compromised if the plant is under- or over-dimensioned. Depending on the temperature, the solids retention time in the reactor ranges from 3 to 5 days for BOD removal, to 3 to 18 days for nitrification [13].
The excess sludge requires treatment to reduce its water and organic content and to obtain a stabilized product suitable for end-use or final disposal. It is important to consider this step in the planning phase of the treatment plant). Complete overall process flow scheme of a conventional large-scale activated sludge system. Wastewater is pre-treated (screening and settling), passes to the activated sludge chamber, is then post-settled in a secondary clarifier, eventually filtered and finally disinfected if required. Excess sludge is digested, thickened and then incinerated [8].

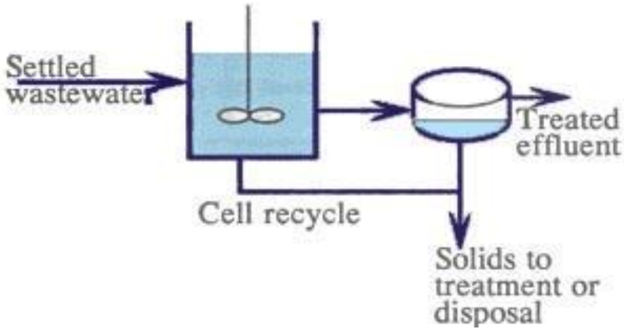

Fig. (1): Diagram of a simple activated sludge system.

Advantages of Activated Sludge Process [25]:

1. Resistant to organic and hydraulic shock loads.
2. Can be operated at a range of organic and hydraulic loading rates.
3. High reduction of BOD and pathogens (up to 99%) at after secondary treatment.
4. High nutrient removal possible.
5. High effluent quality.
6. Little land required compared to extensive natural system (e.g. waste stabilization ponds).
7. Can be modified to meet specific discharge limits.

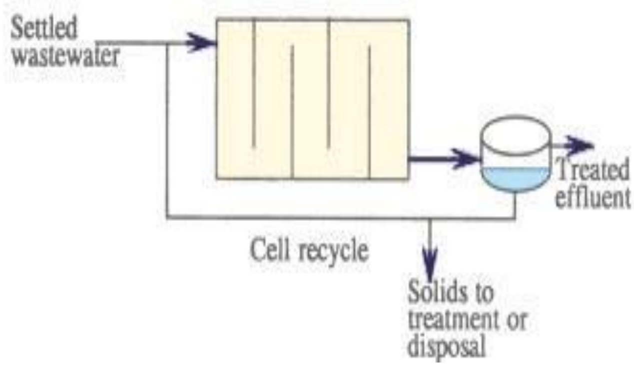

Fig. (2): Diagram of a conventional activated sludge process.

Disadvantages of Activated Sludge Process [25]:

1. High energy consumption, a constant source of electricity is required. High capital and operating costs.
2. Requires operation and maintenance by skilled personnel.
3. Prone to complicated chemical and microbiological problems such as bulking, in which the sludge from the aeration tank will not settle, and foaming, developed by biological surface.
4. Not suitable for application on community level.
5. Not all parts and materials may be locally available.
6. Requires expert design, construction and supervision.
7. Sludge and possibly effluent require further treatment and/or appropriate discharge.

The attached process combines the advantages of conventional activated sludge with those of biofilm systems in a single reactor. Typically, hybrid system configuration is similar to an activated sludge plant where biomass carriers are introduced into carefully selected zones within the activated sludge process. The microorganisms responsible for treatment are attached to some inert medium (rocks, slag, ceramic or plastic materials) [11].
Attached growth processes are classified as aerobic (either aerated or non-aerated), anaerobic and hybrid (anaerobic/anoxic and aerobic). The main advantage of attached growth systems is that they maintain a high concentration of microorganisms resulting in high removal rates at relatively small hydraulic retention times [20]. The basic design and operational characteristics of various systems are presented in terms of packing materials, organic loading rates, treatment temperature, as well as achieved emoval rates [1]. The advantages and disadvantages of hybrid systems are:

Advantages of Hybrid Technology Wastewater Treatment:

1. In general they have a higher treatment effect than single systems, especially for nitrogen, because the advantages of the different filters can be combined.
2. As long as no free-surface filter is involved, they do not lead to increased mosquito breeding.
3. Construction can provide employment to local laborers.
4. Utilization of natural processes.
5. Electricity generally only required for pumps.
6. Process stability.
7. Ideal for retro-fit and upgrade scenarios.

Disadvantages of Hybrid Technology Wastewater Treatment:

1. Very space consuming.
2. Expert construction knowledge and experience needed.
3. Requires expert design and supervision.
4. Moderate capital cost depending on land, liner, fill, etc.; low operating costs.
5. Pre-treatment is required to prevent clogging.
6. Not very tolerant to cold climates. The aerobic attached film expanded bed process has been shown to be capable of treating medium strength wastewater at low temperature and for relatively short times [15].

The amount of biomass that grows on the media depends on many factors such as: organic loading, dissolved oxygen concentration, temperature, mixing energy, suspended phase biomass concentration, and solids retention time. The attached biomass combines with the suspended microorganisms / bacteria to achieve much greater total biomass. Since the attached biomass is retained in the activated sludge basin, and not sent to the clarifiers, use of a hybrid attached growth technology can increase the capacity of the activated sludge system in the same tank volume.

How the plastic media works

The specific type of media used in a given system is determined by the organic loading and wastewater treatment objectives: roughing, complete treatment, or nitrification. The media's specific surface area, void volume, and distribution characteristics are important to the specific application and system performance. The most common material of fabrication for plastic media is either high density polyethylene (*HDPE*) or high density polypropylene (*HDPP*).The material is low-cost, durable, with high surface to volume ratio, light, and allows air to circulate [26].

A jelly-like biological film forms on the plastic where the bacteria break down the organic matter. The film becomes very thick and eventually falls off of the supporting surface, and a new slime layer begins to grow in its place. The collected liquid is passed to a sedimentation tank where the solids are separated from the treated wastewater.

The bacteria clumps that drop off must be treated as suspended solids. In the 1950s, plastic packing began replacing rock in the U.S. Plastic media allows high loading rates and less land area providing quick installation and a high quality product.

The media provides large open pores and high surface area for higher performance and long-term low maintenance. The plastic blocks provide consistent treatment with no plugging problems.

These media systems require a small amount of space for installation and can be scaled for different sized applications by adding additional modules. The resulting effluent is often of high enough quality to be discharged into short shallow trenches without further treatment.

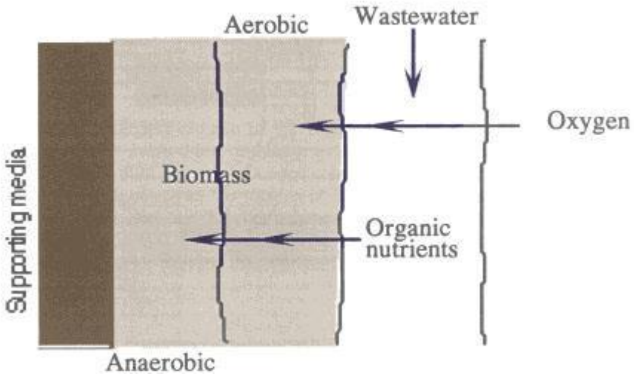

Fig. (3): Cross-section of an attached growth biofilm.

Fundamental Differences between Activated Sludge and Hybrid Systems

1. In a suspended-growth system (activated sludge processes) the waste flows around and through the attached microorganisms, gathering into biological flocs that settle out of the wastewater. The settled flocs retain the microorganisms, meaning they can be recycled for further treatment. By contrast, attached-growth systems (hybrid systems) use a medium (gravel, peat moss, ceramic, plastic, or textile media) to retain and grow microorganisms over which sewage passes and creates a bio-film that becomes thick and falls off (called "sloughing"). The type of organic load coming into the system is an important factor.

2. Attached-growth systems generally require less energy, simpler operation, and less equipment maintenance than suspended-growth systems.

3. However, disadvantages attributed to attached-growth processes (on the whole) include a larger land requirement, odor issues associated with clogging of certain media, and the inability to handle high volumes of wastewater. Consequently, urban facilities often opt for suspended-growth processes, while attached-growth processes thrive in small- to medium-sized operations. [19].

The goal of all biological wastewater treatment systems is to remove the non-settling solids and the dissolved organic load from the effluents by using microbial populations. Biological treatments are generally part of secondary treatment systems. The microorganisms used are responsible for the degradation of the organic matter and the stabilization of organic wastes. With regard to the way in which they utilize oxygen, they can be classified into aerobic (require oxygen for their metabolism), anaerobic (grow in absence of oxygen) and facultative (can proliferate either in absence or presence of oxygen although using different metabolic processes). Most of the micro-organisms present in wastewater treatment systems use the organic content of the wastewater as an energy source to grow, and are thus classified as heterotrophes from a nutritional point of view [30]. Energy gained from such hybrid system is therefore both sustainable and environmental friendly which may be good source of bio-energy to compliment the power of a treatment plant [31]. *Reference [7]* reported the Fixed-film systems as a 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.

Attached growth technologies work on the principle that organic matter is removed from wastewater by microorganisms. These microorganisms are primarily aerobic, meaning they must have oxygen to live. They grow on the media (materials such as gravel, sand, peat, or specially woven fabric or plastic), essentially recycling the dissolved organic material into a film that develops on the media.

Many types of natural and synthetic in Attached-Growth Systems [24]:

- ***Natural Media***
  - Sand/Gravel
  - Shale
  - Limestone
  - Activated Carbon
  - Peat or Peat Fiber
  - Coconut Fiber (Coir)
- ***Synthetic Media***
  - Open Cell Foam
  - Geo-textile Fabric
  - Crushed Glass
  - Tire Chips
  - Hard Plastic

The application of Hybrid systems in Egypt is very limited in the field of Industrial wastewater treatment. The idea could be applied for the existing facilities to improve treated effluent quality and / or upgrade the hydraulic and organic loads capacity.

In this pilot study the hybrid system will be applied to the primary treated wastewater and the media will be placed in an aeration tank of an activated sludge process with the following objectives:

1- Provide an attachment surface for the formation of biomass which leads to increasing of biomass concentration.
2- Measuring the characteristic conditions of the system such as COD, BOD, TSS, and NH3 to optimize the system performance.
3- Develop and verify a heterogeneous mathematical model for hybrid growth system. The model will be based on distinguishing between liquid / solid phase (bio-film and bio-floc).

In this research the effective of upgrading of the activated sludge systems will be investigated and design criteria for the hybrid systems of treatment for domestic and / or domestic and industrial WW developed. The system should provide: A satisfactory treatment efficiency in terms of COD, BOD, TSS and –if possible- pathogenic organisms; A sufficient stabilization of accumulating solids; A sufficiently high sludge hold-up in a compact reactor, so that sludge discharge is only required over a reasonable period of time.

This would be a step ahead to the implementation of a full-scale plant (out of scope of this project) considering all advantages and disadvantages of the results of the proposed pilot study.

Pilot study

The technology of introducing plastic media into aeration tanks which is combining suspended and fixed growth processes has not been applied yet on a technical scale or even a pilot scale in Egypt. The pilot has been designed and prepared to carry out these processes and study their effect on the behavior of wastewater treatment operation.

The pilot is located in Zenien wastewater treatment plant (WWTP), it consists of two series tanks followed by cylindrical one, and the two first tanks have a dimension of 3*1.5 m and 1 m depth. This tanks work as aeration tanks which the air is pumped to and the plastic media is put in.

The next tank has a cylinder shape with 1 m diameter and 0.6 m depth, this tank works as a final sedimentation tank which the flow is disposed from and the sludge is returned with a small pump that has been put in the tank cone. The waste water is pumped to the pilot Aeration tank from the primary sedimentation tank of Zenien WWTP with a small submerged pump. Two stages reactors provide treated water with better performance. Samples from each tank were taken to evaluate performance and efficiency for each one. The photographic images for the pilot are shown in Figure (4) and the schematic diagram illustrated in Fig (5).

Fig (4): Zenien wastewater pilot plant.

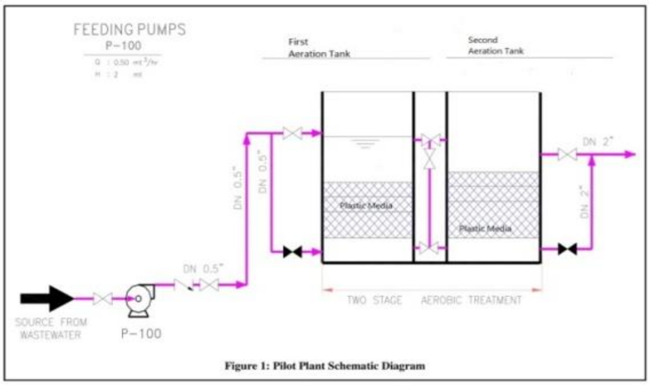

Fig (5): Schematic Diagram of Zenein pilot plant.

In each reactor it is possible to change the depth of the media separately to have different organic loading rates for each. There are several sampling outlets of diameter 1 inch for each reactor used to take wastewater samples for reactor profile analysis purposes. The top of each reactor has gas outlets of 2 inch diameter and will be used to collect gas samples. A submersible pump is used to discharge the flow to the pilot plant. This feeding pump delivers the wastewater from the source (primary treated wastewater) to the influent pipe of the pilot plant. Each reactor has its own inlet distribution system at a top side to maintain uniform influent wastewater flow where it consists of 25 mm diameter distributor pipes and weirs.

The reactor is filled with 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 media.

Sludge Preparation:

At the beginning, the used sludge *an-aerobically treated mesophilic* sludge is firstly inoculated. The clean water pumped to the reactor is 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. The reactor operated as a batch reactor for two weeks. Gas production is monitored and observed, it gradually declined to nearly zero at 4th week, indicating that the initial feed was exhausted. The reactor is then operated continuously for six weeks with more feed of domestic wastewater until steady state is 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 is decided, so the reactor started-up in around 10 weeks.***Results and Discussion***

The process had duration of 10 months, and studied several variables such as *COD*, *BOD*, *TSS* and NH_3 in five stages each of different flow rate with or without plastic media in the reactor.

COD, Chemical Oxygen Demand, determines the quantity of oxygen required to oxidize the organic matter in a waste sample, under specific conditions of oxidizing agent, temperature, and time. Nowadays, portable instrument allows you to easily take readings for COD. The result of a chemical oxygen demand test indicates the amount of water-dissolved oxygen (expressed as parts per million or milligrams per liter of water) consumed by the contaminants.

BOD, Biochemical Oxygen Demand, also often referred to as biological oxygen demand, is a test performed to measure the potential of wastewater and other waters to consume the oxygen level of receiving waters. It is performed to determine what effect dirty water, containing bacteria and organic materials. If bacteria are taking in large amounts of oxygen, this will have a detrimental effect on the surrounding ecosystem. On the contrary, when there are low levels of organic waste in the water, there are fewer bacteria present, the BOD will be lower and the dissolved oxygen levels will be higher.

TSS, Total Soluble Solid, is dry weight measure of the particulates present in the water sample expressed in units derived or calculated from the volume of water filtered (typically milligrams per liter or mg/L). It is determined by pouring a carefully measured volume of water through a pre-weighed filter of a specified pore size, then weighing the filter again after drying to remove all water. Filters for TSS measurements are typically composed of glass fibers.

NH_3, Ammonia, Nitrogen is present in many forms in the septic system. Most nitrogen excreted by humans is in the form of organic nitrogen (dead cell material, proteins, and amino acids) and urea. After entering the septic tank, this organic nitrogen is broken down fairly rapidly and completely to ammonia, NH3, by microorganisms in the septic tank. Ammonia is the primary form of nitrogen leaving the septic tank [10].

A. The samples are collected and transferred to the lab. The analyses to be performed are:

- Daily: COD, TSS, VSS on 24 hrs composite samples…
- Frequently: BOD (2-3 times weekly)…
- Weekly: bicarbonate alkalinity, NH_4-N, Tot. N, NO_3…
- Incidentally: the sludge settle-ability, assessment of sludge TSS and VSS.

Process Operation:

After the start-up period (ten weeks), when the reactor reaches the "steady state" operation, the reactor was operated continuously for 16 weeks to investigate the process performance under the fluctuation of inflow wastewater characteristics. At start up period all variables values fluctuated till steady state is reached. The feeding pump was submerged into the outlet channel of the primary sedimentation tank. The required flow rate is adjusted manually. The flow rate, or retention time, was set with the outlet valve (outlet control). Samples were taken from each of the two tanks and analyzed using suitable equipment for each variables to evaluate the reactor performance.

1st Stage:

The flow rate at the start of operation was determined to be 3 Liter/minute which is equal to 4.32 m^3/day and no plastic media was added, these conditions continued for about 10 weeks.

Values of influent and effluent COD measured in mg/liter and plotted against time as shown in fig (6). At 3 liter/minute flow rate without any media, influent values fluctuated from 110 mg/liter to 225 mg/liter while effluent values ranged from 26 mg/liter to 77 mg/liter. Effluent results show decreasing in the COD values comparing to the influent ones that means good treatment as organic substances decayed and consumed oxygen decreased.

%COD removal estimated based on influent and effluent values. %COD also plotted against time in fig (6). The %COD= ((Influent COD) - (Effluent COD)) / (Influent COD) * 100.

In first few weeks (start up) %COD removal fluctuated from 40-80% then it remains in narrow range from 70-88% with an average of 77%.

Fig (7) illustrated the relationship between BOD influent and effluent with time. Influent values of BOD at 3 liter/ minute flow rate fluctuated from 85 to 175 mg/lit and effluent values are from 10 mg/liter to 62 mg/lit. % BOD removal estimated as %COD and represented in Fig (7) with an average value of about 75%.

The NH_3 values were plotted against time operation in Fig (8). The influent values are between 13 and 37 mg/L while the effluent NH_3 values were between 2 and 3 mg/L . The % NH3 removal results are in the range from 82-99% with average value of 91% and remained in these ranges overall the study.

The influent TSS values in Fig (9) were ranged between 85 to 150 mg/L along the operation time with average value of 110 mg/L for this flow rate. The effluent TSS values were ranged between 7 to 37 mg/L with average value of 23 mg/L . Average %TSS removal efficiencies were fluctuated between 43-95% with total average value of 69%.

2nd Stage:

The flow rate is increased to be 10 L/min (14.4 m^3 /day) without adding any plastic media too, the system could accumulate this flow rate and the efficiency is not affected negatively with the increase of the flow rate. This stage period was two weeks.

At 10 L/min flow rate without any media added, influent values fluctuated from 177 mg/L to 227 mg/L while effluent values ranged from 35 to 75 mg/L. %COD removal estimated by ((Influent COD) - (Effluent COD)) / (Influent COD) * 100, and plotted against time in Fig (6) it ranged from 63-77% with an average of 74%.

In Fig (7) influent values of BOD were from 90 mg/L to 120 mg/L and effluent values were from 23 to 50 mg/L. % BOD removal was ranged from 65-80% of an average value 72 %.

Ammonia values were almost in the ranges of the first stage and also its percentage removal efficiency was about 91%.

TSS influent values Fig (9) were ranged between 80 to 125 mg/L along the operation time with average value of 103 mg/L for this flow rate. The effluent TSS values were ranged between 23 to 74 mg/L with average value of 49 mg/L . Average %TSS removal efficiencies were fluctuated between 42-80% with an average value of 69%.

3rd Stage:

Increasing the flow rate to be 15 L/min, some problems attacked the system as overflow and flooding lead to a disturbance results from the system. All variables were estimated and plotted in fig (6, 7, 8 and 9), their values were changed sharply according to system disturbance and these results represented the problems occurring in the system due to high flow rate.

%COD removal had an average of 37%, % BOD removal average value was 35% and the average %TSS removal was 31%. The % NH3 removal results were about 40%.

This stage was a step to choose suitable flow rate. It was very suitable to perform the process with a flow rate 10 L/min and getting all results based on this flow rate. The reactor was then 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.

4th Stage:

Operating one reactor filled with packed plastic media at flow rate 10 L/min and measuring COD, BOD, TSS and NH_3 with time to investigate reactor performance when plastic media added to the system. The stage period was about 8 weeks.

Values of influent and effluent COD according to Fig.(6) were from 155 mg/liter to 227 mg/liter while effluent values ranged from 23-100 mg/L. Effluent results show decreasing in the COD values comparing to the influent ones that means good treatment as organic substances decayed and consumed oxygen decreased. %COD removal range was 83-90% with an average of 88%.

Fig (7) showed influent values of BOD from 75-145 mg/L and effluent values are from 15-23 mg/L. % BOD removal produced with an average value of about 89%. The $\%NH_3$ removal was about 91% average values Fig (8).

The influent TSS values in Fig (9) were ranged between 60-135 mg/L along the operation time with average value of 98 mg/L for this flow rate. The effluent TSS values were ranged between 10-15 mg/L with average value of 12 mg/L . Average %TSS removal efficiencies were between 87-91% with total average value of 89%.

5th Stage:

Two reactors filled with packed plastic media were operated at flow rate 10 L/min. The second box of plastic media has been added to the system and all variables values represented in figures (6, 7, 8 and 9).

COD influent and effluent values measured and plotted against time in Fig (6). At 10 L/min flow rate with two boxes of backed plastic media, influent values ranged from 105-220 mg/L while effluent values ranged from 15-25 mg/L. %COD removal was plotted against time in Fig (6), it changed from 83-97% with an average of 90%.

BOD influent values fluctuated from 90-125 mg/L and effluent values are from 10-13 mg/L. %BOD removal values shown in Fig (7) with average value about 90%.

The $\%NH_3$ removal values still in the same ranges of 91%. The influent TSS values Fig (9) were ranged between 103-132 mg/L along the operation time with average value of 118 mg/L for this flow rate. The effluent TSS values were ranged between 9-12 mg/L with average value of 11 mg/L . Average %TSS removal efficiencies were in narrow rage between 90-93% with total average value of 91%.

The fourth and the fifth stages represent that the system will operate with the same efficiency however adding any plastic media. The percentage removal of pollutants is raised slightly in presence of two reactors but increased in reasonable values comparing with second stage where no media added at the same flow rate.

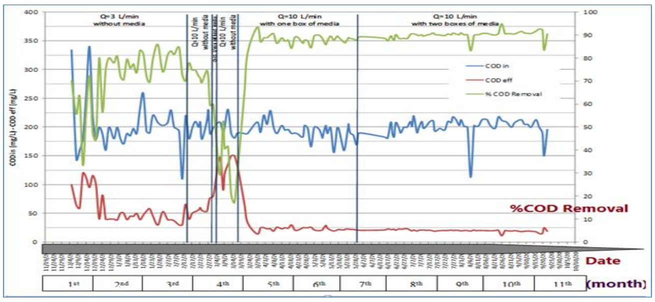

Fig (6): “COD influent, COD effluent and % COD Removal”

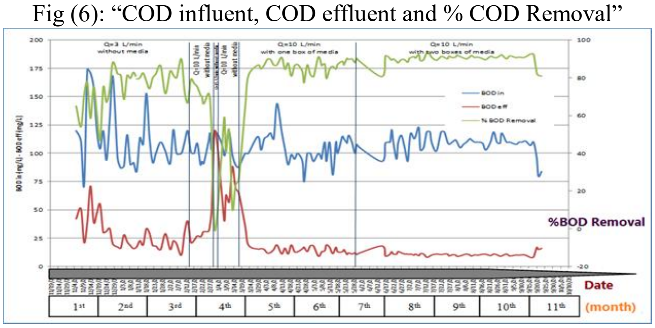

Fig.(7): “ BOD influent, BOD effluent and % BOD Removal".

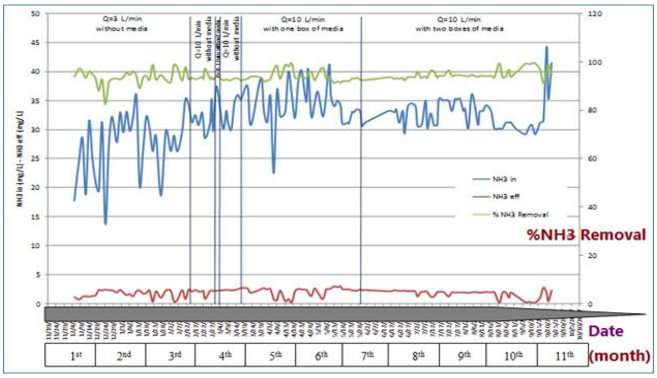

Fig. (8): "NH_3 influent, NH_3 effluent and % NH_3 Removal".

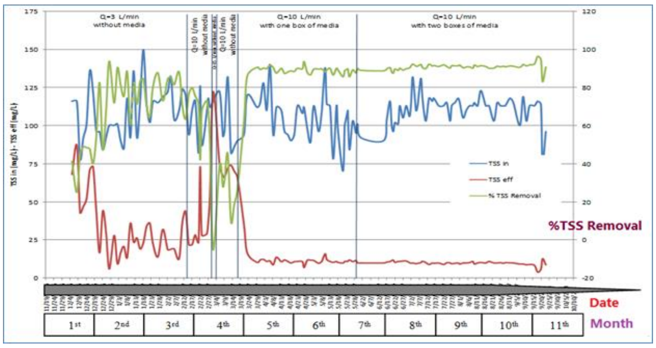

Fig.(9): "TSS influent, TSS effluent and % TSS Removal".

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