Aeration Tank Behavior in the Activated Sludge Wastewater Treatment Plant Startup Conditions
Case study; (Wastewater Treatment plant of General Mosul hospital- IRAQ)

Riyadh Mahmood Saleh Al-Obaidi
Rystar_sun@yahoo.com
Environment Research Center/Mosul University, Iraq

Abstract:

The biological unit in the wastewater treatment plants can be considered the most sensitive treatment units. It begins work with dynamic conditions for several weeks until reach the steady state conditions. Therefore, this study was done to observe aeration tank behavior (activated sludge unit) in the wastewater treatment plant of general hospital complex of Mosul city. Sampling made daily for more than 30 days. The biological treatment monitoring parameter was tested. The study shown that there is need to about 45-60 days to complete the start up work to be the operation stable and successful (if it worked without seeding). There was simple growth of microorganisms with modest treatment of organic matter, and then it rose after 3 first weeks of operation. There was contrary relationship between organic content and suspended solids in the aeration tank; an equation of this relation has been presented. The pH has risen in the first days in the effluent wastewater, then return to be less than influent pH with a relative relation with the activity of the microorganisms and surface aeration in the tank. The EC was simply reduced in the Effluent along with the study.

Keywords: activated sludge, startup, operation, aeration tank.

الخلاصة :

تعد وحدة المعالجة البيولوجية الوحدة الاكثر حساسية بين وحدات محطة معالجة مياه الفضلات . تبدأ الوحدة عملها بظروف ديناميكية (غير مستقرة) لمدة أسابيع لحين وصولها الى حالة الثبات بالعمل. لذلك اجريت هذه الدراسة لمتابعة سلوك حوض التهوية (بوحدة الحمأة المنشطة) في محطة معالجة مياه الصرف الصحي لمجمع المستشفى العام في مدينة الموصل. وقد تم اخذ نماذج يومية من المحطة اثناء بدء تشغيلها لمدة تزيد على ٣٠يوما . وتم قياس مؤشرات مراقبة عمل الوحدة البايولوجية. أظهرت الدراسة بأن هناك حاجة لفترة ٤٥-٦٠ يوما لاكتمال ظروف الابتداء والوصول الى العمل المستقر للوحدة (حين عدم اضافة بذور الحمأة المنشطة). وقد كان هناك نمو بسيط للاحياء المجهرية مع معالجة معتدلة للمحتوى العضوي في المياه الداخلة للمحطة، وتصاعد النمو بعد ٣ اسابيع من التشغيل . وكان هناك علاقة عكسية بين محتوى المواد العضوية في حوض التهوية وبين المواد العالقة (الكتلة الحية). كما حصل ارتفاع لمؤشر الدالة الحامضية pH في الايام الاولى من بدء التشغيل ثم تراجع ليكون pH في المياه المعالجة اقل منه في الداخلة بسبب نشاط الاحياء المجهرية والتهوية السطحية في الحوض. بينما تناقص مؤشر التوصيلية الكهربائية بنسبة قليلة في المياه المعالجة على طول فترة الدراسة ، وتزايد استهلاك الاوكسجين عند اكتمال عملية البدء بالتشغيل.

Introduction:

Wastewater treatment plants are considered one of the largest service establishments in the cities and receive special importance, due to the big mission in save the city from pollution load carried by domestic, municipal and even industrial wastewaters. Therefore, large budgets are spent on preparing, design, construction and operation of these plants. Furthermore, concentrated studies are made on wastewater quantity and quality before design. [1]

Biological unit are the most sensitive treatment plant units, because it deals and depends on a biota (life mass) which can be influenced by simplest changes in boundary conditions. Therefore, special care is focused in the preliminary stage of design on the treatability of wastewater and determination of operation and design parameters [2]. Once the construction has been completed, the operation begins with focusing care to the biological units since the physical and chemical units work may reach to the ideal performance efficiency at the first day of operation, while the biological unit may last a certain time till performance becomes efficient and stable (i.e. after biota building completing which may last for 1-2 months).

In normal circumstances the plant operates under more or less steady state conditions. During startup, however, conditions are dynamic, with MLSS (Mixed Liquor Suspended Solids) concentration and possibly load varying rapidly. In these circumstances F:M ratio is a more meaningful control parameter than sludge age [1] .

The aim of process startup is to achieve normal operation as quickly as possible without discharging effluent of poor quality.

Two main problems can occur during startup: foaming and loss of solids in the effluent. Both problems occur at high F:M ratio (short sludge age), of foaming because detergents in the sewage have not been degraded and solids loss because of poor flocculation.

There are several modes of activated sludge process. These modes came from the need to special requirements for each site (industrial, municipal or others) in order to get the best results of biological treatment. The mode used to treat the hospital wastewater is almost extended aeration ; this mode of process holds wastewater in an aeration tank for 18 hours or more and the organic wastes are removed under aerobic conditions. Air may be supplied by mechanical or diffused aeration. Mixing is by aeration or mechanical means. This process operates at a high solids retention time (low F:M), resulting in a condition where nitrification may occur. The microorganisms compete for the remaining food. This highly competitive situation results in a highly treated effluent with low solids production [5]. The extended aeration mode may be used as sequencing batch reactor (SBR), or even oxidation ditches.

Literature Review :

Knight et al [8] studied the Development of the microbial community of a full scale biological nutrient removal activated sludge plant during start-up. They showed that the filamentous bacterial populations seen in the mixed liquor, and foam were monitored regularly over period of startup, and after early changes, several types of organisms (like Microthrix parvicella and Eikelboom types) assumed dominance in the mixed liquor, while Nocardia amarae-like organisms and Type 0092 together with M. parvicella were in the foam.

Espinosa and Tom Stephenson [9] compared the grease degradation rates for a natural population of acclimatized activated sludge micro-organisms with a commercial bioaugmentation product (bioadditive) under optimum conditions in laboratory-scale batch reactors. They showed that during acclimatization (startup) , the bioadditive reactor achieved slightly better chemical oxygen demand (COD) removal efficiency than the activated sludge reactor. They concluded that the use of natural activated sludge micro-organisms was sufficient to acclimatize biological processes to removing grease.

Meijer et al [10] simulated the start-up of a full-scale biological phosphorus and nitrogen removing wastewater treatment plant. For the simulation, they used a metabolic phosphorus model integrated in ASM2d, referred to as the Technical University Delft Phosphorus (TUDP) model. They showed that during the startup , the process changed from partly nitrifying to fully nitrifying, denitrifying and phosphate removing. They ended that Temperature appeared highly sensitive and therefore should not be neglected when modeling biological phosphorus removal during startup.

Balku and Berber [11] also used the computer programming to identify the optimum operation of aeration and non-aeration period in a single reactor during startup. They developed a model (called ASM3) to be used for dynamic modeling and start-up simulation in order to establish the continuous operation mode in systems of nitrification de-nitrification . The model is applied to the modeling of microbiological processes in the aeration tank and a 10 layer settling model is adapted to the settling tank.

Chong and Chen [12] studied the treatment of xenobiotic by activated sludge during startup and shocks. They showed that Lab-scale continuous flow activated sludge systems that were acclimated to 2,4-dichlorphenoxyacetic acid (2,4-D) under sole 2,4-D influent and without sludge wastage, were able to maintain successful 2,4-D treatment when both 2,4-D and a biogenic substrate were fed and the systems operated with finite mean cell residence times (θc). They finalized that when shocked, systems with sole 2,4-D influent had a slight advantage over dual substrates by showing a faster recovery from shocks with the help of re-acclimation.

Paul et al [13] studied the operation of 20 wastewater treatment package plants (working with extended aeration mode). They found that only 4 were with accepted treatment results. They showed that the other 16 plants were suffering from low biotic , problems with oxygen providing and the mechanical problems , which resulted in the drop of the plants operation.

Locally, only several studies about the operation of wastewater treatment plants has been done , without any caring to the startup of operation nor after shut-down and maintenance periods.

Al-Rawi and Al-Tayar [14] , evaluated the operation of a wastewater treatment plant of a residential area in the north of Mosul city. They concluded that the plant was not efficient in treating organic content of the wastewaters for several reasons like the absence of the experienced operators. Also the operational problems like the deficit of dissolved oxygen caused in the efficiency decline in the aeration tank of the plant.

Objectives:-

1- Biological unit performance monitoring and its developing at first operation days.
2- Investigate different operation parameters and relations between each others.
3- Putting the imagination for stand shutoff after operation especially at maintenance while.

Experimental work:-

To achieve the study, the work of (new) wastewater treatment plant of main hospital of Mosul city (400 km to the north of Baghdad) has been daily monitored for 40 days of the beginning operation.

The Studied Plant Properties:

The studied plant consists of the following units (fig. (1)):

1- Uplift station : to pump the coming wastewater from the sewers of the complex hospitals to the equalization tank. The dimension of this unit (3.0 x 1.4 x 1.85m) provided with 3 submersed pumps (each pump with 30cubic meter/hr). The bar rack is in the front of this unit.
2- Equalization tank: this unit is used to equalize the flow of the wastewater in addition to control the fluctuations of wastewater characteristics which can disturb

the next units (especially biological unit) performance [4]. In the studied plant the dimension of the equalization tank is (14.4 x 6.0 x 4.0m), mixed with two-floated surface mixers, turn the flow to the aeration tank by gravity.

3- Aeration tank volume = 1090 m3 (two parallel rectangular tanks, the volume of each one =545 m3 (20.5 x 7.0 x 3.8m)). Each tank is aerated mechanically with three floated surface aerators (propeller type) .
4- Biological unit working in the mode of extended aeration activated sludge, hydraulic detention time at aeration tank is 24hrs (according to the average flow of the plant) but during peak flow the detention time may be at the range of (10-16 hrs). The designated mean cell residence time is more than 20 days.
5- Clarification tank : this tank is a circular (9m diameter) and its depth is 3.5m (as a higher water level). The SOR (surface overflow rate) =17 m3/ m2/day. The average detention time is about 4.8 hrs.
6- The other units are chlorination chamber in addition to sludge solar dryers.

Sampling and Testing :

The tests were made to the samples after about 25 min from sampling at Mosul university labs according to the standards methods [6]. Table (1) gives an idea about the general characteristics of wastewater coming from equalization tank to the aeration tank.

The startup of operating the plant began in July 2001 (in addition to several (shut-down re-operation periods) after that date (2004, 2006). The sampling was done usually at about 10:30 pm. The parameters of monitoring biological treatment were tested daily.

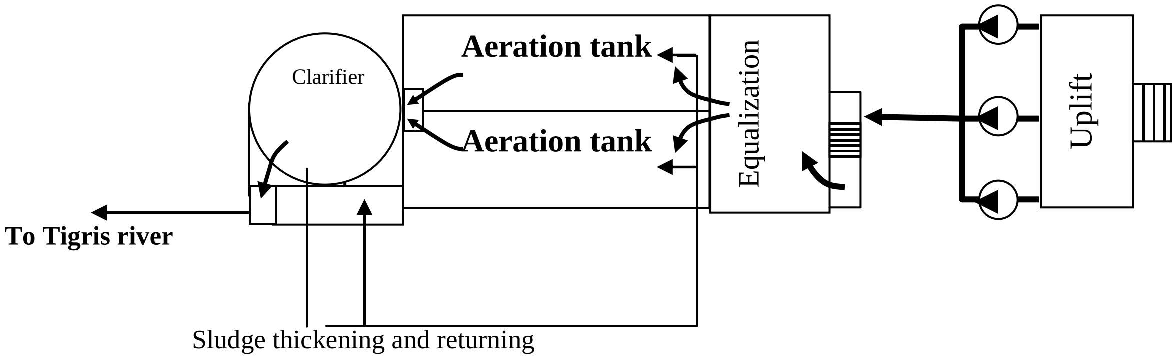


Fig.(1): flow diagram of studied plant units.

Results and Discussion:-

The evidence of sound work of biological treatment unit in the start up conditions is significant variation taking place in the monitoring parameters i.e. efficiency of COD removal, micro organism's activity, respiration rate and other characterizations, in spite of slight variation may be happened from day to other[4]. That may be clear after several weeks of operation, especially if there were no seeding of activated microorganisms is followed (as we have here). Worldwide, the aeration tanks are charged with seeding (of microorganisms) in the startup stage of treatment to speed the building of biota and to reach the designated efficiency and stability of work as soon as possible.

1- Organic matter variation :-

The organic content in the wastewater is one of the most important things which monitored during the beginning times of aeration tank operation (since the main target of the plant construction is to remove organic matter) . By other words, the fail of the tank in reduce the organic content of wastewater makes it useless tank. The evidence of work success is the reduction of wastewater organic content and production of suspended solids (which gradually will build up the life mass on which the work depends).

Organic content as COD was monitored in the aeration tank influent and effluent wastewaters. As it can be seen in fig.(2), there were big fluctuations in treatment results. In the first days, simple efficiency noticed and the effluent COD were out of legal (local) limitation (100 mg/l). This was expected because the work is in prime matter and the life mass did not build up so far.

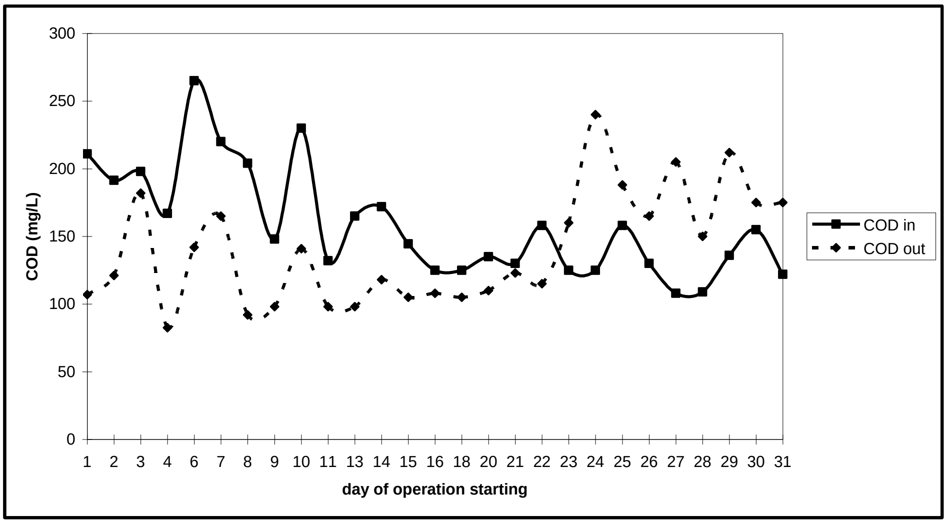
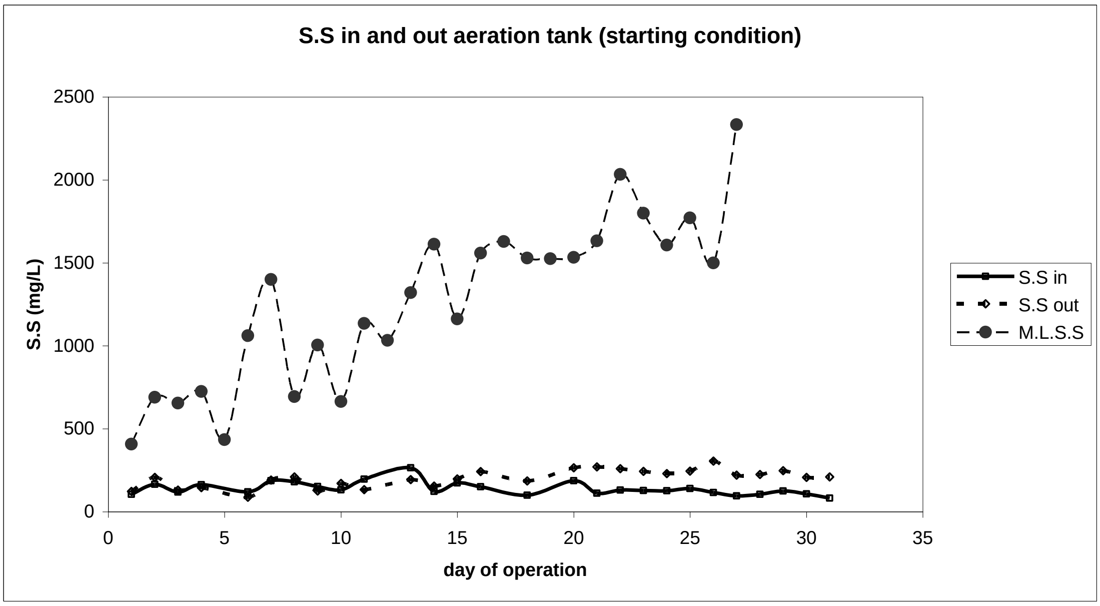


Fig.(2): Aeration tank influent and effluent COD in startup conditions.

The simple treatment was interpreted to happen by aeration and stripping supporting by small growth. The natural work in this stage may expose to some disturbance, especially, when large quantity of discharge comes in a short time (shock loading), or reach of toxic material in the influent (toxic shock) leading to inhibit the growth of the originally small amounts of microorganisms (as it can be seen in the 23rd day of operation in fig (2)). This may take several days, thus what usually happens to aeration reactor during shocks) [7].

2- **Suspended Solids S.S and MLSS**:

This parameter refers to the concentration of microorganisms in aeration reactor. In fact, it's expected to be the suspended solids in the influent wastewater low due to the detention well which works as a primary sedimentation. As it can be seen in fig.(3), influent S.S fluctuated around 125 mg/L, while it increased in the reactor day by day. This natural phenomenon indicates that the reactor uses the organic matter and nutrients in building new cells in the way to reach the designated mixed liquor suspended solids MLSS (2000-2500 mg/L).



Fig(3) : Suspended Solids and (MLSS) variation in aeration tank startup conditions.

3- Oxygen Uptake Rate (OUR) :

This indicator can give an idea about the activity of microorganisms in the aeration tank, it simply depends on measuring the oxygen consumption rate by monitoring the oxygen concentration drop in a (500ml)closed flask containing sample of aeration tank mixed liquor and using D.O measuring probe [2]. It's well known that the consumption of oxygen would be related to each of life mass and organic content together (in absence of inhibitor constituents). The oxygen uptake rate in the aeration tank in the beginning of operation was as shown in fig.(4).

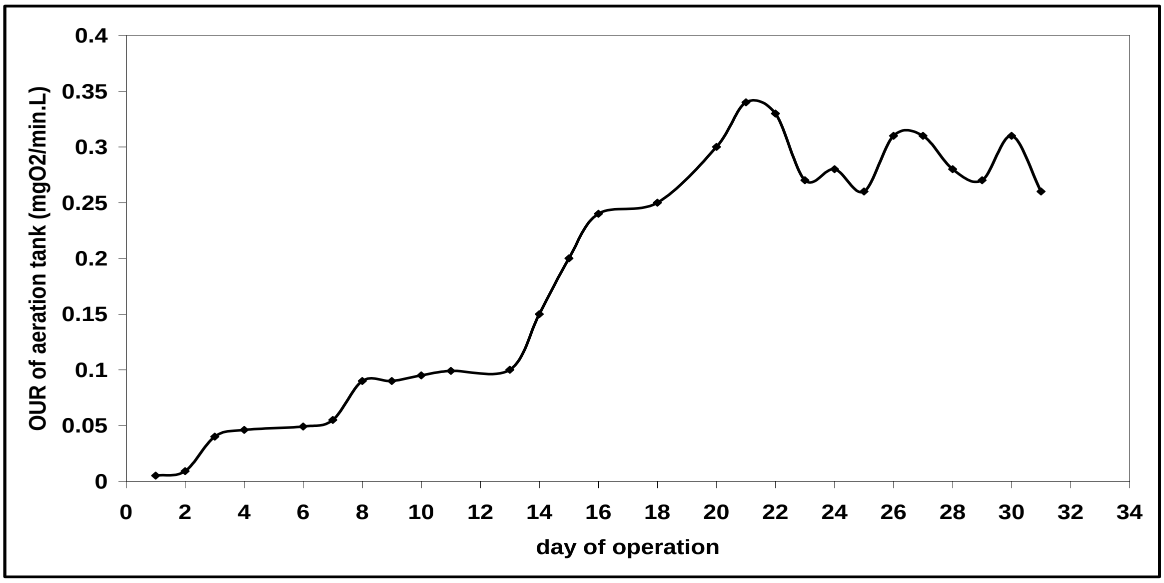


Fig. (4): Aeration tank oxygen uptake rate in startup conditions.

4- Dissolved Oxygen D.O :

The dissolved oxygen is one of the most important parameters which can significantly influence the aeration tank operation. Because of the detention in the equalization tank the D.O is dropped to be in the range of 0.6-3.5 . In the first days of operation there are no more of biomass consuming the oxygen , therefore , the D.O in the aeration tank was high (fig. 5). When the biomass was built-up , the D.O became low to be about 4mg/L. Sometimes, the D.O increase because of the low activity of the biomass (especially when there are inhibitors in the coming wastewater) as it can be seen in the 23rd day of operation. Furthermore, If the wastewater stays in the tank long enough, the DO concentration will increase, because the oxygen is not any longer consumed (treated wastewater is equivalent to the substrate being biologically degraded); and if the wastewater does not stay in the tank long enough, the DO will decrease, thus the wastewater is not treated (the explanation is that aerobe metabolism reactions are taking place)[15].

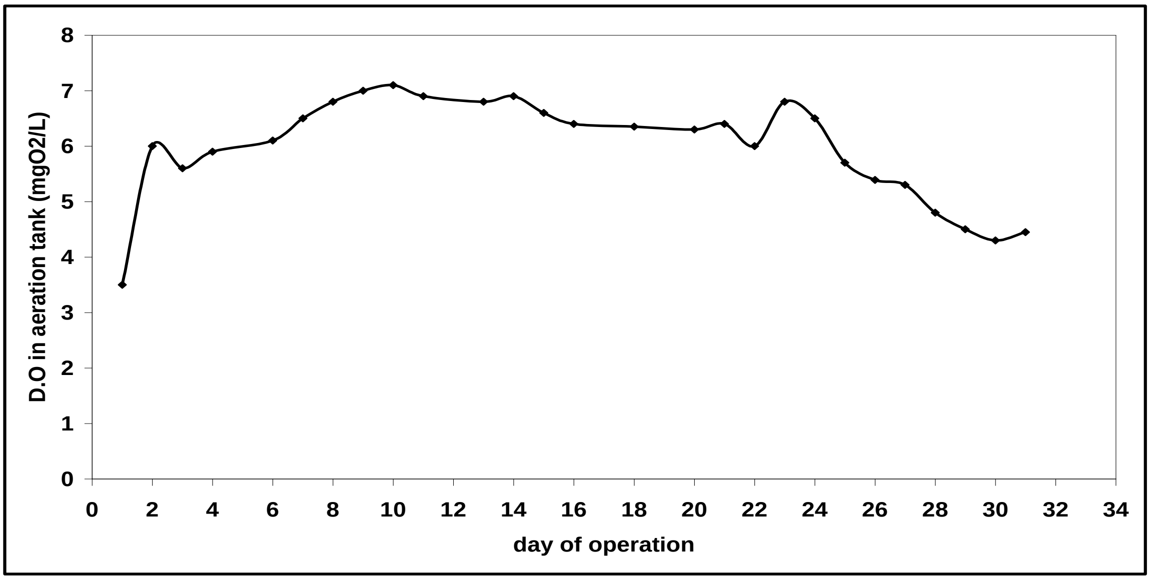
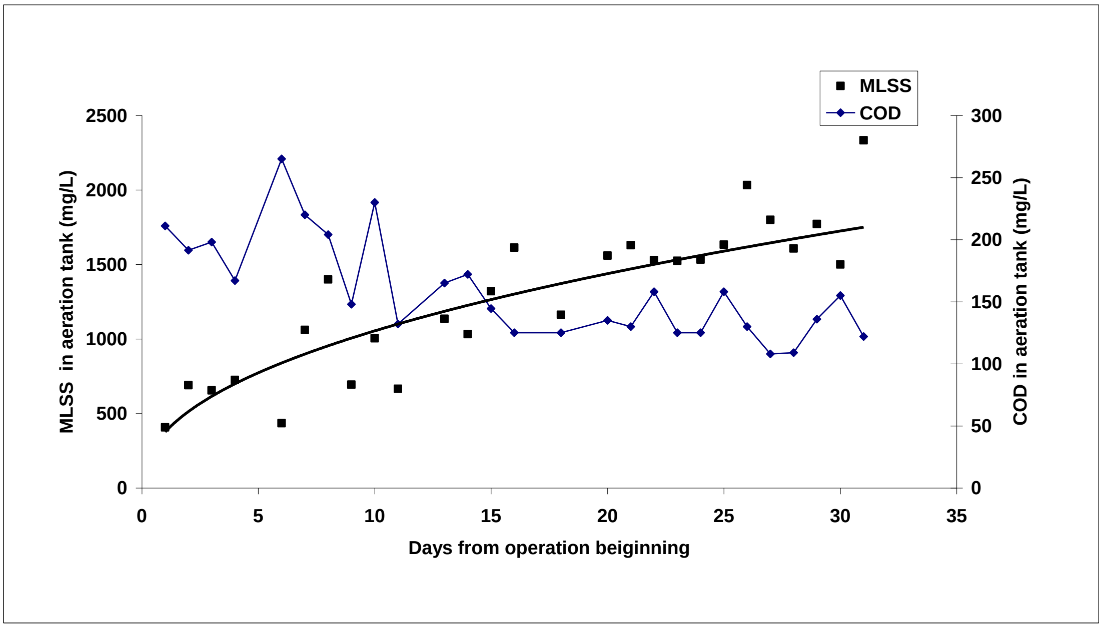


Fig (5): Dissolved oxygen variation in the aeration tank in startup conditions.

5- Relation between S.S (MLSS) & COD in The Starting Conditions of Biological Reactor :-

Since removed and extracted organic matter in the reactor are transformed in the presence of oxygen and little of microorganisms coming in the influent wastewater into new cells, so it is normal to see increasing in the suspended solids in the reactor (this growth often tends to be in logarithmic relation with the food or COD) as in fig.(6), exactly as what happens in BOD test bottle [2],[3] and [5].



Fig(6):Sludge growth in aeration tank in the first days of operation (without seeding).

6- pH Behavior in Aeration Reactor :-

pH parameter has significant importance in monitoring the work of biological reactor, which is due to its direct relations with other parameters. At first days, pH was raised to be higher in the effluent (influent and effluent> 7) due to the following several reasons :- pH in the reactor depends on CO_2 gas content and alkalinity; CO_2 gas produced by the microorganisms degrading organic matter aerobically, the aerators work to strip the CO_2 gas to the atmosphere and transfer the oxygen from air to the reactor, all of that leads to rise pH as a result of losing CO_2 which consists carbonic acid (H_2CO_3). By days of operation, with life mass growth, CO_2 content becomes more stable, and effluent pH becomes approximately equal to or nearer to influent pH. But in the advanced stages of aeration, nitrification enters the scene and consumes alkalinity in transforming organic nitrogen and NH_3-N into nitrate (NO_3) (approximately about 7.2 mg alkalinity as $CaCO_3$ is used to nitrify 1 mg of NH_3-N into NO_3-N.[3] and that leads to drop pH. If there is denitrification, the pH will rise again slightly. When there are no much of alkalinity in the influent the nitrification may reduce pH to be less than 5.1, this did not happen in this study as can be seen in fig(7).

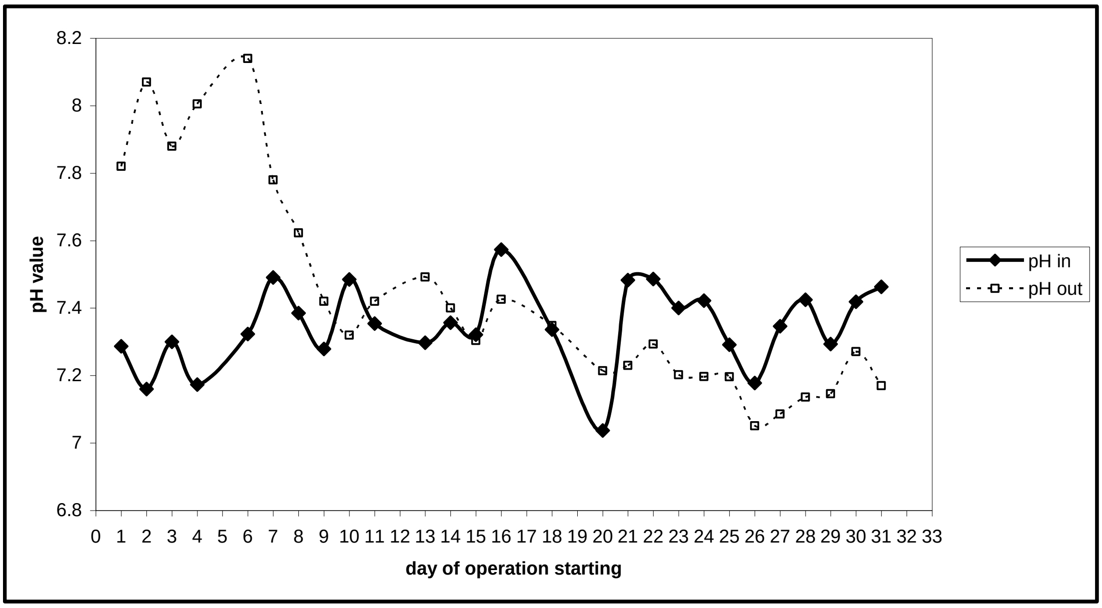


Fig (7) : pH variation through aeration tank during startup conditions.

7- Electrical Conductivity (EC) Behavior :-

electrical conductivity can be simply measured in the reactor by a portable meter. It's well known that there is a strong relationship between EC and dissolved solids in water (except organic materials). The behavior of EC may not be clear in this work. However, its variation was as illustrated in fig.(8). There was slight reduction in the EC along with work days and that may be happened because of loss of small fraction of salts by one or more of removal ways i.e. stripping, settling, absorption, adsorption, etc. happening in aeration tank.

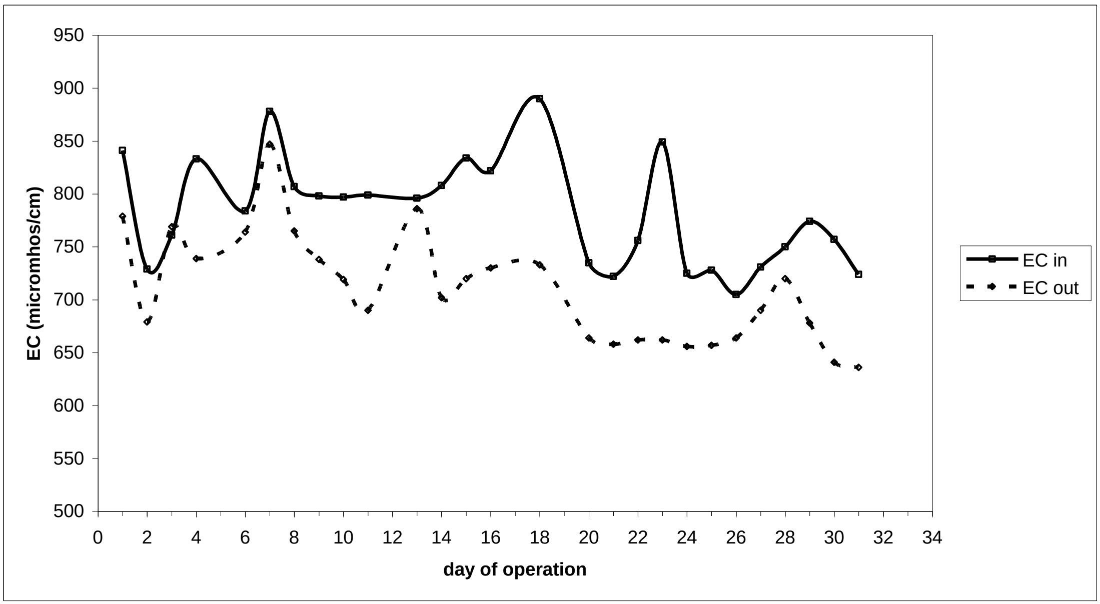


Fig. (8): Electrical conductivity variation through aeration tank during startup conditions.

Conclusion:-

1- The startup work has been done successfully in the studied plant as it can be seen from aeration tank behavior (proportion of treatment happened and sludge grow up) .

2- The activated sludge units need to more than 45 days to reach the designated efficiency, and may need to 60 days when treating wastewater containing inhibitors like wastewater coming from hospitals.

3- The life mass in the aeration reactor can be created and grow up to reach the target MLSS (2000-2500mg/L) without use activated sludge seeds. This may take about 25 days in the case of municipal wastewaters without seed.

Table 1: The general characteristics of hospital wastewater (the studied site after equalization tank).

Characteristic	range	average
Total Solids(mg/L)	750-1200	900
Total dissolved solids(mg/L)	450-800	550
Suspended solids (mg/L)	150-400	260
COD (mg/L)	110-300	150
BOD_5 (mg/L)	80-150	120
pH (unitless)	6.3-7.8	-
EC (µS/cm)	700-1400	850
Nitrate –N (mg/L) (NO_3)	0.4-1.0	-
Phosphate-P (mg/L) (PO_4)	5-15	8.0
Sulfate-S (mg/L) (SO_4)	70-150	80
Alkalinity (mg/L)as $CaCO_3$	250-400	320
Chloride (Cl^-)(mg/L)	70-180	120
Phenol (mg/L)	0.05-0.3	-
D.O (mg/L)	0.6-3.5	-

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