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Research article

Use of Alum for Removal of Total dissolved Solids and Total Iron in High Rate Activated Sludge System

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ABSTRACT

Industries discharge wastewaters, which carry high concentrations of dissolved solids and iron can be treated by high rate activated sludge stage of the multiple-stage sludge treatment plant. This system is characterized by high treatment efficiency, optimal, low prices, and small areas compared with conventional activated sludge treatment plants. A pilot plant with an influent industrial discharge flow of 135L/hrs was designed according to the activated sludge plant to simulate between the biological and chemical treatment with the addition of dosages 100, 150, 200 and 250 mg/L alum salt to the aeration tank with. The concentrations of Total Dissolved Solids (TDS) and Iron (Fe) in industrial discharge flow had an average range of 140000, 4.5mg/L respectively. The results clearly indicate that the highly-loaded activated sludge (A-stage) has a high elimination efficiency of inorganic matters compared with the mechanical stage of the conventional treatment plants. Without adding alum salt, the removal efficiency of the total dissolved solids (TDS) and the total iron (Fe) were approximately 28.91% and 45.07% respectively. The optimization of the chemical-biological process using 200mg/L Alum dosage had succeeded in improving the removal efficiency of TDS and Total Iron to 48.15% and 68.11% respectively.

KEYWORDS: Activated sludge, Industrial Wastewater, Total Dissolved Solids, Total Iron, Alum salt

1. INTRODUCTION

In these days, the increasing of industrial activities such as food industries, palm oil industry, mining industries, steel industry, dye industry, etc. has contributed pollution to our environment (S. N. B. JAMIL, 2010). These industries discharge wastewaters which carry high concentrations of dissolved solids. These effluents should be treated for safe disposals which meet the regulations imposed on industrial sectors. Industrial wastewaters often have high concentrations of total dissolved solids can exceed 100000mg/L. High amounts of TDS are associated with different types of industries such as tanning, textile, milk, cheese, yogurt, butter milk, distillery and etc. (S. Shabani M. Mortula, 2012).

Total Dissolved Solids (TDS) combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal solution) suspended form. Generally, the operational definition is that the solids (often abbreviated TDS) must be small enough to survive filtration through a sieve size of two micrometers (E. Pearce J. Camerata, et al., 2011). This material can include total hardness, carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, iron, alkalinity, and organic ions. A certain level of these ions in water is necessary for aquatic life. Changes in TDS concentrations can be harmful because the density of the water determines the flow of water into and out of an organism's cells. However, if TDS concentrations are too high or too low, the growth of many aquatic lives can be limited, and death may occur (S. Halsor B. Oram, et al,, 2010).

Metals play important roles in the life processes of microbes. Some metals, such as Fe are of vital importance for many microbial activities when occur at low concentrations. These metals are often involved in the metabolism and redox processes as parts of enzyme cofactors or participators in the electron transfer in microbial. However, metals at high concentrations are inhibitory or even toxic to living organisms (S. Teng S. Wang, et al,, 2010).

Many techniques have been tried out to remove heavy metals from wastewater. Physicochemical methods, such as chemical precipitation, ion exchange, adsorption, electrolysis, chemical oxidation/reduction and membrane technologies are found to be ineffective or rather expensive or generate toxic slurries. Biological treatment is considered a promising technique for bioremediation of metals wastewater, since it can degrade organic pollutant in the wastewater and simultaneously transform heavy metals. Electrons extracted from the oxidation of organic compounds or hydrogen are used to reduce Fe(III), Mn(IV), and SO_4^{2-} to Fe(II), Mn (III), and H_2S (S. Teng S. Wang, et al,, 2010). Iron (II) or also known as ferrous is one of the metal potential hazards toward human body. According to the Engineering Services Division, maximum concentration of iron is 0.3mg/L (The Ministry of Health Malaysia, 1979). The activated sludge is used as biological material to absorb the iron (II) in the contaminate wastewater. The result show 77.5% of iron (II) removal efficiency was attained in the Polymer Industry dried activated sludge with 45µm size and 200 minutes of contact time. Meanwhile, Food Industry and Palm Oil Mill Effluent are 66% and 72% respectively (S. N. B. JAMIL, 2010).

In the activated sludge process, the microorganisms are kept suspended either by blowing air in the tank or by the use of agitators. Oxygen is used by the microorganisms to oxidize organic matter. To maintain the microbiological population, the sludge from the settler is recirculate to the aerated tank, In order to keep the sludge concentration constant despite of the growth of the microorganisms, sludge is withdrawn from the process as excess sludge (Lindberg C. F. Bengt C., 1998; C. F. Lindberg, 1997).

There are five categories of these activated sludge "bugs". The predominance of one or more of these groups over the others can give an indication of the age and condition of the sludge. They are listed as: Amoeboids, Flagellates, Free Swimming Ciliates, Stalked Ciliates and Rotifers (F. Ragsdale, 2013).

The basic activated sludge system consists of a number of interrelated components. These components include a single reactor basin or multiple basins designed for completely mixed flow or plug flow, each reactor basin with sufficient size to provide hydraulic retention times of at least 0.5hrs to maximally 24h, An oxygen source, a device for mixing the reactor basin contents, A settling basin to separate the mixed liquor solids from the treated wastewater, A device for collecting the sludge in the settling basin and recycling them to the reactor basin (Mamdouh Y. Saleh, 1994).

The Adsorption/Bio-oxidation technique (AB-system) was invented and patented as a two-stage activated sludge plant without primary sedimentation. In this process the excess sludge of the second stage is not transferred to the first stage (R. Kayser, 2005). The sludge load (F/M) in the high-load stage (A-stage) approximately ranges from 0.6 to 1.5 kg BOD_5/kg MLSS.d, and for the low-load stage (B-stage) F/M ranges from 0.1 to 0.2 kg BOD_5/kg MLSS.d (Mamdouh Y. Saleh, 1994).

2. MODEL DESCRIPTION AND OPERATION

2.1. Aim of Study

The aim of this research is to increase the elimination efficiency of high concentration TDS and Fe salts in the influent industrial wastewater by adding chemical precipitants such as $A1_3^+$ salts. The study was carried out in the first biological stage (the A-stage), which is classified as the highly-loaded activated sludge stage of the multiple-stage plant (AB-system).

2.2. Model Description and Operation

The work in this study was carried out on a scaled pilot plant. The used model system consisted of two rectangular tanks: an aeration tank and sedimentation tank which were designed to act dependently as the A-stage. The two tanks were made of galvanized tin sheets. The total volume of the aeration tank was 135L with a detention time of 30 minutes. The influent flow was 135L/hrs with an average returned sludge of 135L/hrs. The sedimentation tank had a total volume of 270L with a detention time of 1 hour. The water flow was 135L/hrs with the temperature ranging from 19ºC to 40ºC, as shown in Fig.(1).

2. 3. Sample collection points

There were four sample collection points in the pilot plant. These points were very important in order to examine the characteristics of wastewater and sludge. The four positions to collect the sample were first, the influent of the pilot plant; second, the effluent of the pilot plant downstream from the settling tank; third, the influent of the recycling sludge upstream from the aeration tank; and the fourth point was at the middle of the aeration tank (i.e. the mixed liquor in the aeration tank).

2.4. Chemicals Used for Precipitation (Alum salt)

Alum is acidic in nature while sodium aluminate is alkaline, which may be an important factor in choosing between them. Alum was more effective than sodium aluminate based on the molecule ratio. The commercial product for alum (aluminum sulfate), $Al_2(SO_4)_3.18H_2O$ (Mamdouh Y. Saleh, 1994). In this study, the alum dosages used ranged from 100 to 250mg/L.

2.5. Wastewater and sludge analysis method

Biochemical oxygen demand (BOD_5), Total Dissolved Solids and Total Iron were the parameters determined for the influent wastewater to the aeration tank and the effluent from the settling tank. The influent and effluent samples were mixed samples, collected during the 24hrs of the day in a refrigerator. The samples were taken at regular intervals 3 times a day. Samples of the returned sludge and mixed liquor were taken once a day in the morning.

PH-value, mixed liquor suspended solids (MLSS), suspended solids in the returned sludge (SSRS) and sludge load rate (F/M) were the parameters determined for the returned sludge (RS) to the aeration tank and the mixed liquor in the aeration tank (A-tank). The sludge as well as the mixed liquor samples was taken 3 times per day at 9.00a.m., 11.00a.m. and 1.00p.m. All the parameters were determined in accordance with the American standards methods for the examination of water and wastewater (American Public Health Association, 1999).

3. RESULTS AND DISCUSSIONS

The experimental work for this study was subdivided into two groups. The first group (with zero additive) was carried out in one run without salt addition with 12 days as a retention time, to describe the natural performance of the pilot plant for the high-loaded activated sludge stage (A-stage). The working properties for the pilot plant, TDS and Fe were determined with a mixed sludge sewage water recirculation ratio of 89%.

The second group (with Alum Salts Addition) was carried out in four runs with Alum salt addition (100, 150, 200 and 250mg/L) during retention time 7 days each to describe the natural performance of the pilot plant for the high-loaded activated sludge stage (A-stage). The working properties for the pilot plant, TDS and

Fe were determined, with a mixed sludge sewage water recirculation ratio were ranged from 93.3%, 89.38%, 95.55 and 92.5% respectively.

3. 1. BOD_5, MLSS and F/M parameters

Table (1) illustrates average influent and effluent concentrations and elimination efficiencies of the BOD_5, aeration tank MLSS and F/M for all of trials. As shown in Table (1) the average F/M ratios which were ranged between 2.55 and 4.19 kg BOD_5/ kgMLSS.d (F/M ratio must be equal or larger than 1.5kg BOD/kg MLSS.d (Mamdouh Y. Saleh, 1994)). This means that the pilot plant was working as highly-loaded activated sludge at all trials.

3. 2. Total Dissolved Solids Results (TDS)

Experimental results indicated that, the high rate activated sludge system were effective in removing TDS from the samples. Fig.(2, 3, 4) illustrates the influent and the effluent TDS average concentration values when adding 0, 100, 150, 200, 250mg/L Alum salt. The average TDS concentrations at influent were 206783, 311200, 201875, 91343 and 139343mg/L and the average TDS concentrations at effluent were 143167, 19648, 112629, 47357 and 71029mg/L respectively.

The TDS elimination efficiency values with 0, 100, 150, 200, 250mg/L Alum. Salts were represented at Fig.(5,6), the TDS elimination efficiency were 28.91%, 32.25%, 44.2%, 48.15% and 49.03%respectively. This means that increased by using more dosage of Alum Salts until reach to 200mg/L after that the efficiency were constant. But all effluent TDS gave higher than the allowable values range (2000mg/L) (The Egyptian Ministry of Health, 1982).

3. 2. Total Iron Results (Fe)

The studies were carried out with Alum salt additive 0, 100, 150, 200 and 250mg/L and for each run the influent/effluent concentration illustrated in Fig.(7,8,9). The average Fe concentrations at influent values were 6.15, 6.49, 8.09, 2.9 and 3.18mg/L, the average Fe concentrations at effluent were 3.36, 3.3, 2.87, 0.90 and 0.98mg/L respectively.

The removal efficiencies are presented in Fig.(10,11), The Fe elimination efficiency values with 0, 100, 150, 200, 250mg/L Alum. Salts were 45.07%, 49.14%, 64.48%, 68.88% and 69.11% respectively. Which means that the Fe elimination efficiency increased by using more dosage of Alum Salts until reach to 200mg/L after that the efficiency were constant. Only the effluent values with 200 and 250 Alum Salt were approximately had Fe less than the allowable value (1mg/L) (The Egyptian Ministry of Health, 1982).

5. Summary of Results

The principal target of this research work is not to develop the entire treatment system, but to develop the highly loaded activated sludge stage (A-stage) of the multiple-stage plant (AB-system) which is characterized by the high treatment efficiency, optimal and low prices and small areas compared to the conventional activated sludge treatment plants.

The results clearly indicate that the highly-loaded activated sludge (A-stage) has a high elimination efficiency of inorganic matters compared with the mechanical stage of the conventional treatment plants. Without adding alum salt, the removal efficiency of the Total Dissolved Solids (TDS) and the total Iron (Fe) were approximately 28.91% and 45.07% respectively. Adding alum salt improved the elimination efficiency of TDS and the total Iron (Fe) in the first treatment stage.

The aim of this research is to examine, if by adding the chemical precipitants such as $A1_3^+$ salts in the influent of the activated sludge system, the elimination efficiency of TDS and the total Iron (Fe) in the treatment system can be improved.

A pilot plant with an influent discharge flow of 135L/hrs was designed according to the highly loaded activated sludge stage (A-stage) of the multiple-stage plant (AB-system) to simulate between the biological and chemical treatment with the addition of alum sulfate to the aeration tank with dosages in of 100, 150, 200 and 250mg/L. The average F/M ratios increased incrementally as the dosage of the aluminum salt increased. In addition, the ratios were higher than the values of the conventional activated sludge unit. The average F/M ratio with 100, 150, 200 and 250mg/L aluminum salt added were found to be 2.553, 3.516, 3.645 and 4.158 Kg BOD_5

/ KgMLSS.d, respectively. Aerated mixed liquor classified as highly-loaded activated sludge because all over (F/M) ratios was larger than 1.5kg BOD_5/kgMLSS.d (Mamdouh Y. Saleh, 1994).

The Effluent TDS elimination efficiencies were increased and then became constant as possible. And the TDS elimination efficiency values with 0, 100, 150, 200, 250mg/L Alum. Salts were 28.91%, 32.25%, 44.2%, 48.15% and 49.03% respectively. Which means that, the TDS elimination efficiency was increased by using more dosage of Alum Salts until the efficiency reaches to 200mg/l and after that the efficiency had low increment.

The Influent and Effluent Fe elimination efficiencies were increased with time. The Fe elimination efficiency values with 0, 100, 150, 200, 250mg/L Alum salt were 45.07%, 49.14%, 64.48%, 68.88% and 69.11% respectively. The iron elimination efficiency was increased by using more dosage of Alum Salts until the efficiency reaches to 200mg/L and after that, the efficiency had low increment. Also, the effluent values with 200 and 250 Alum Salt were approximately had Fe less than the allowable value (1mg/L) (The Egyptian Ministry of Health, 1982).

6. Conclusion

Referring to the observations and the results obtained, the following points are included:

1- It can be stated that the detention time of 30 minutes in the A-tank was sufficient for mixing and flocculation of the mineral salt.
2- Adding alum salt in the influent of the highly-loaded activated sludge stage (A-stage) of the multiple-stage plant (AB-system) improved the elimination efficiency of TDS as well as; Total Iron
3- The optimization of the chemical-biological process using 200mg/L Alum dosage compared with the biological process in the A-stage has a number of advantages :
    - Improvement of TDS removal efficiency from 28.91% without additive to 48.15% with 200mg/L Alum Salt.
    - Improvement of Total Iron removal efficiency from 45.07% without additive to 68.11% with 200mg/L Alum Salt.

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LIST OF TABLES

Table (1): Average values of influent BOD_5, MLSS in Aeration Tank and F/M ratio

Alum Salt (mg/L)	BOD_5 mg/L	MLSS g/L	F/M
Zero additives	107.1	0.93	3.27
100	135.4	1.48	2.55
150	131.61	1.07	3.15
200	182.8	1.3	3.65
250	179.57	1.21	4.19

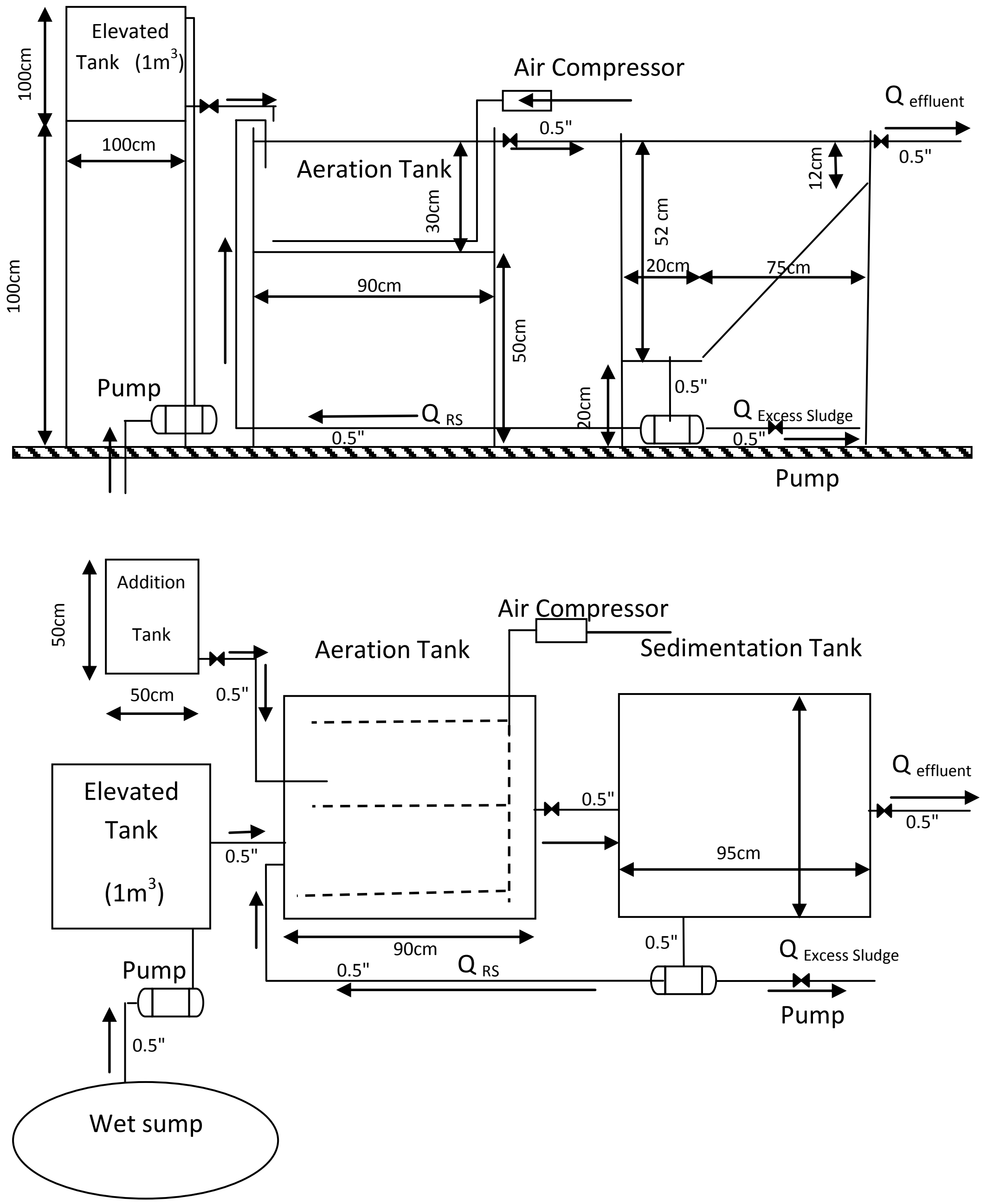

Fig.(1): A-stage process

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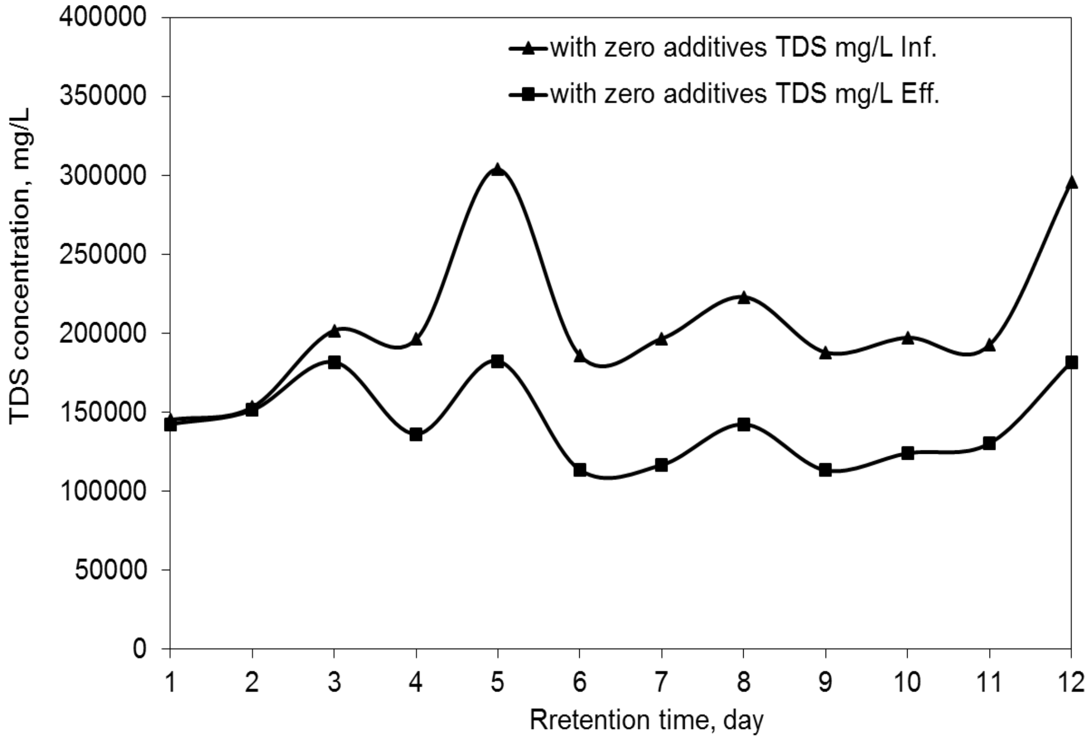

Fig. (2): Influent and Effluent TDS during the first group (zero additives)

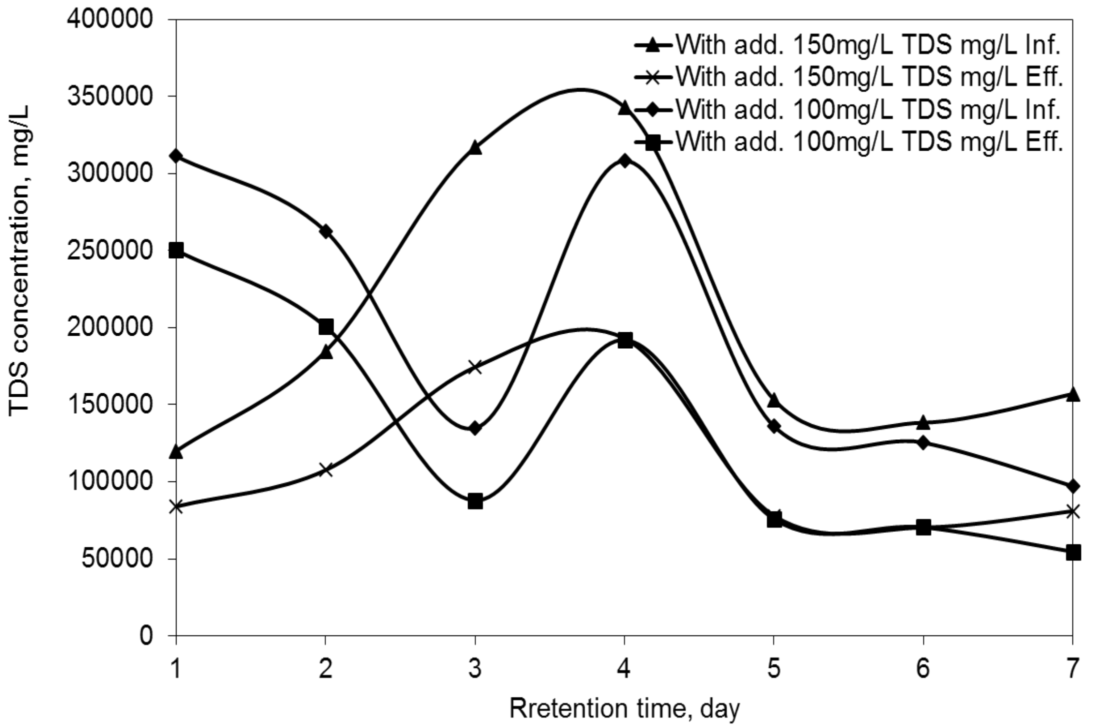

Fig. (3): Influent and Effluent TDS during the second group (with 100 and 150mg/L Alum. salts addition)

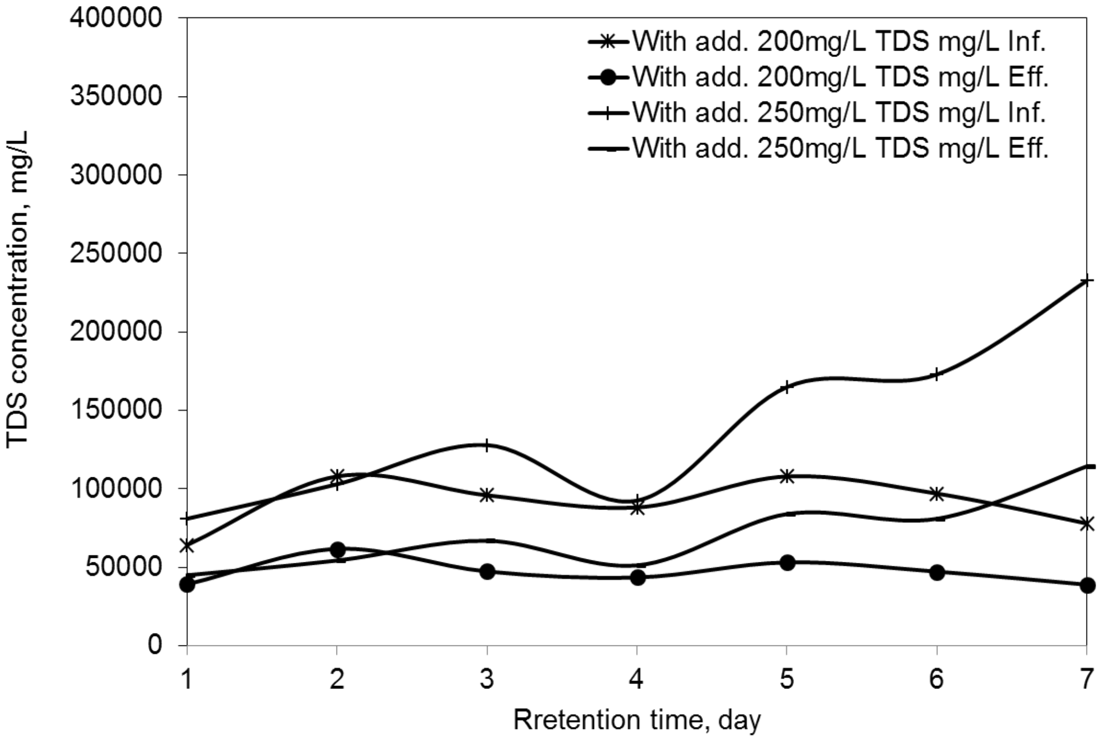

Fig. (4): Influent and Effluent TDS during the second group (with 200 and 250mg/L Alum. salts addition)

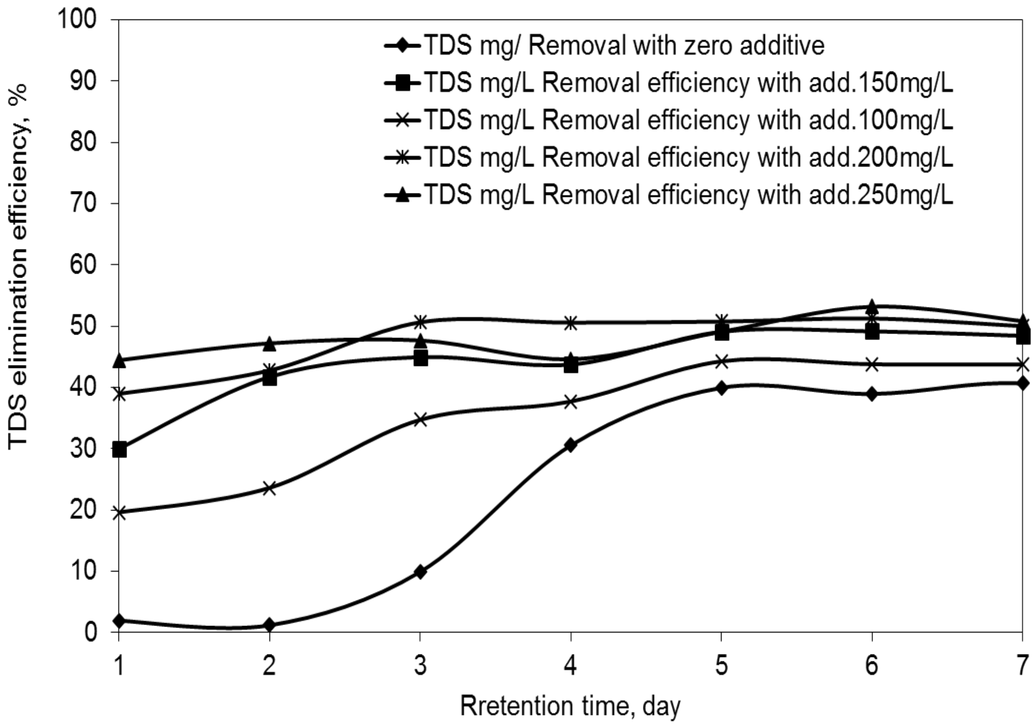

Fig. (5): TDS Elimination values during Alum. Salts addition for dosages from 0 to 250mg/L

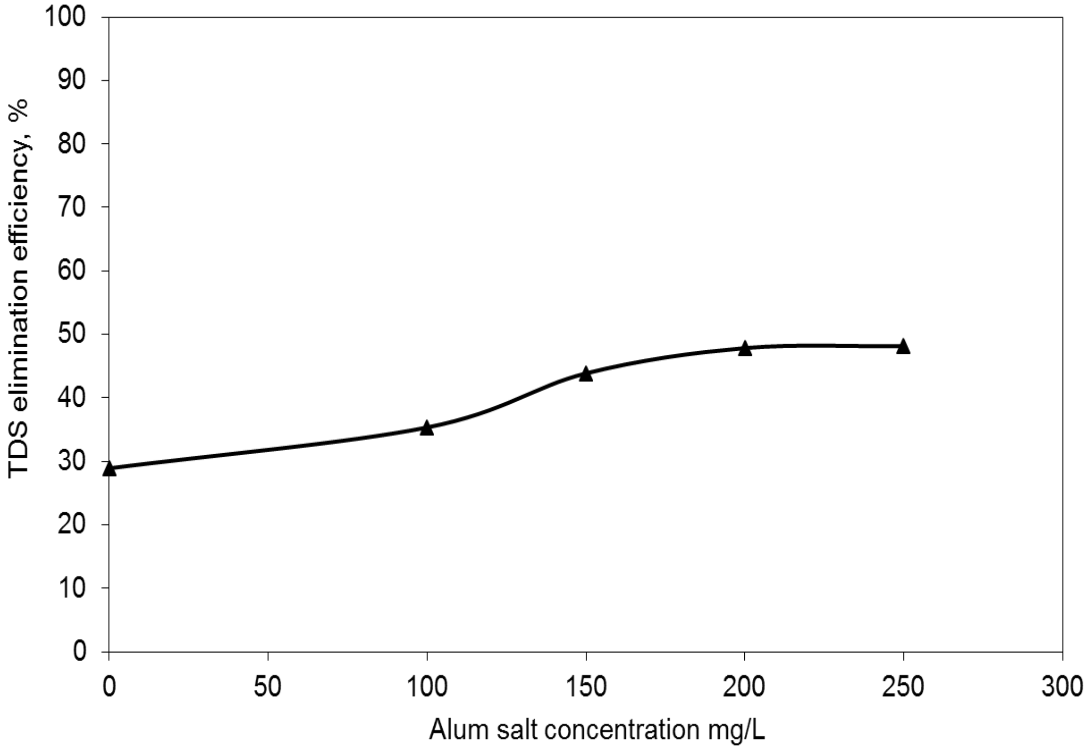

Fig.(6): Average TDS Elimination Efficiency values during Alum. Salts addition for dosages from 0 to 250mg/L

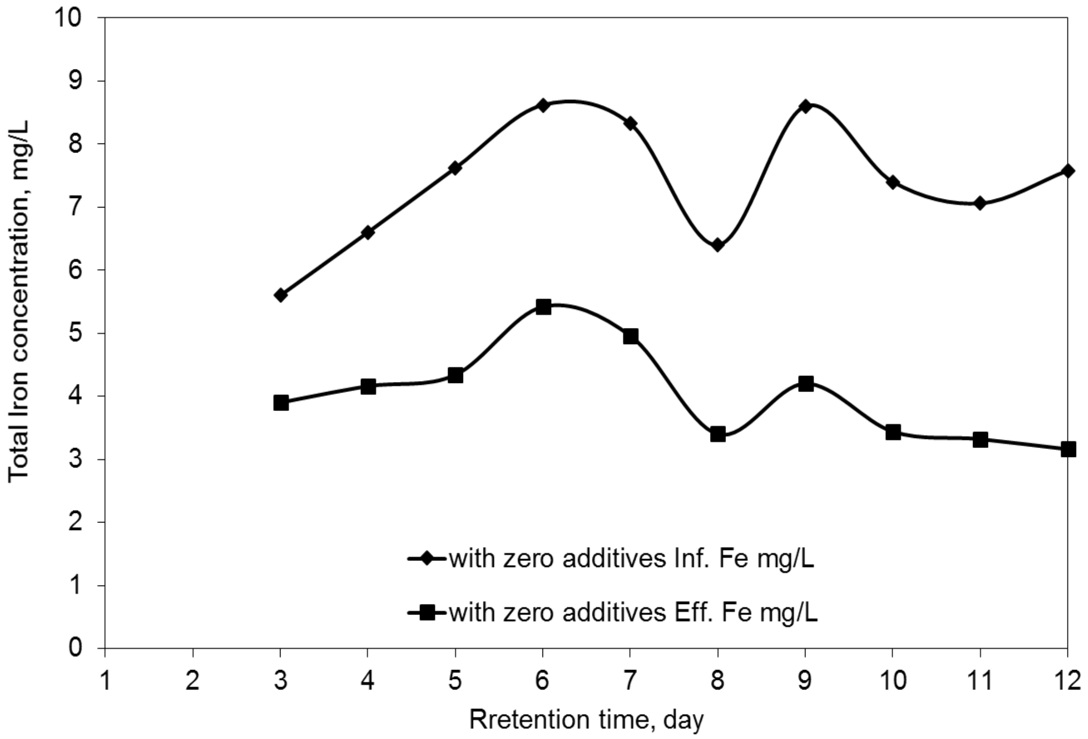

Fig. (7): Influent and Effluent Fe during the first group (zero additives)

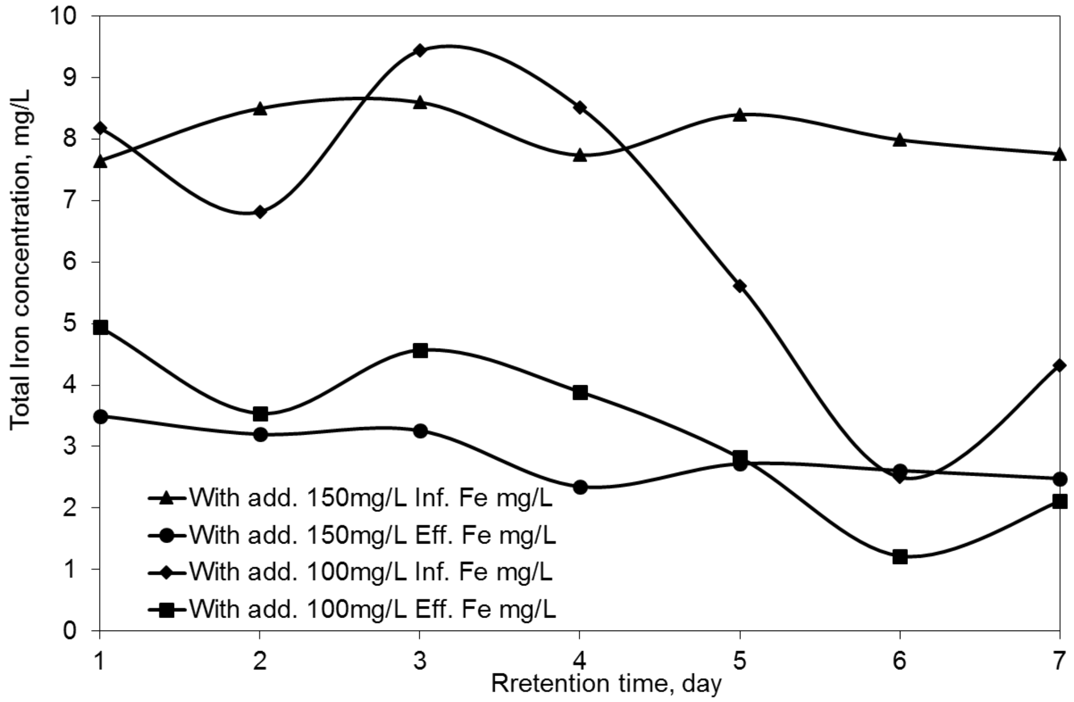

Fig. (8): Influent and Effluent Fe during the second group (with 100 and 150mg/L Alum. salts addition)

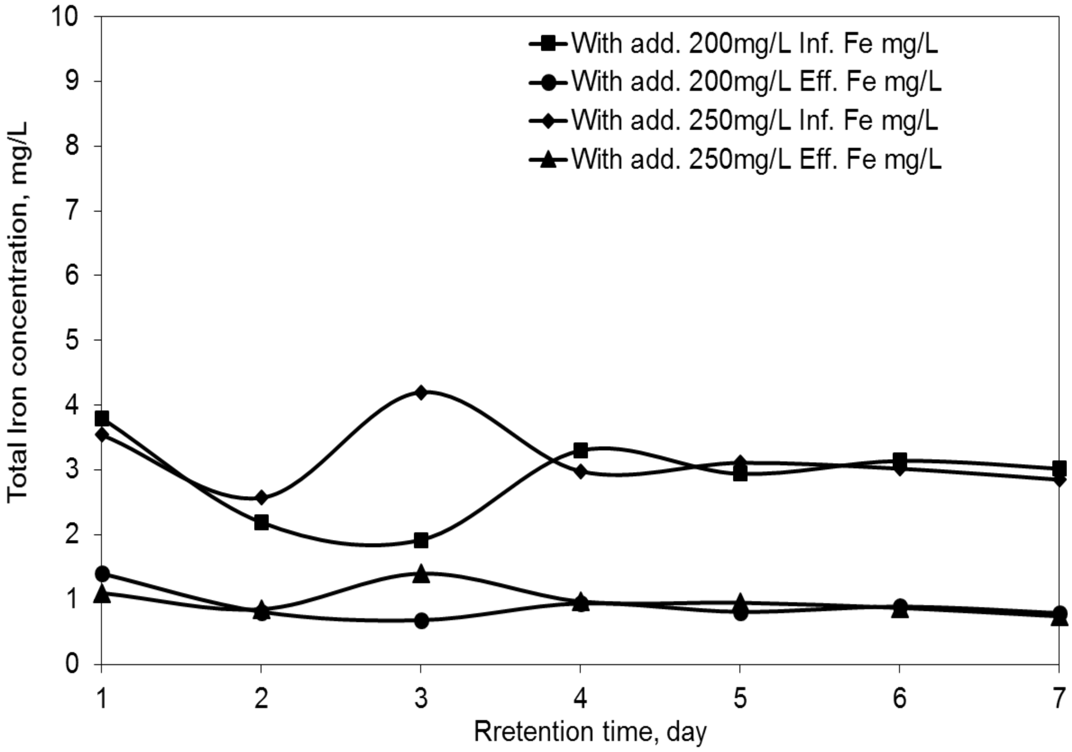

Fig. (9): Influent and Effluent Fe during the second group (with 200 and 250mg/L Alum. salts addition)

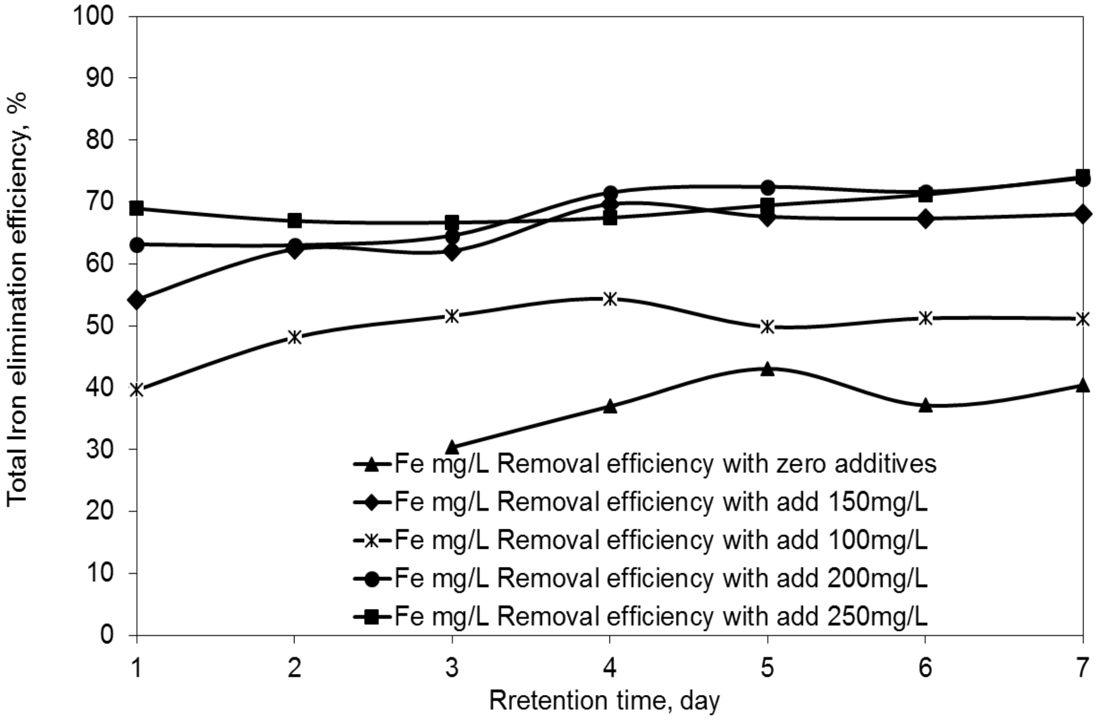

Fig. (10): Fe Elimination values during Alum. Salts addition for dosages from 0 to 250mg/L

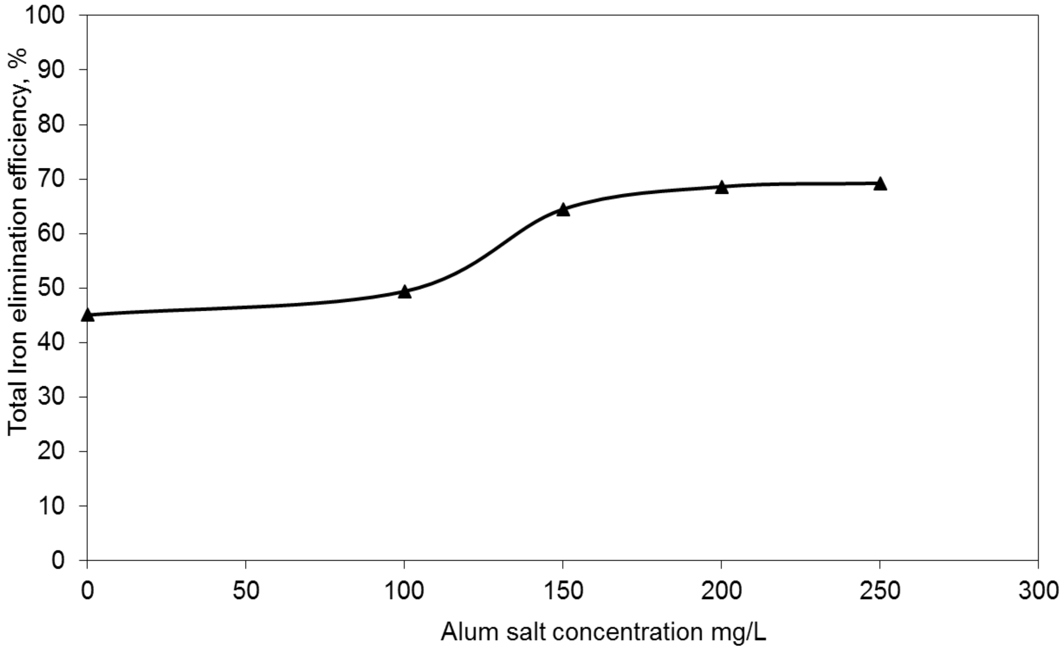

Fig.(11): Average Fe Elimination Efficiency values during Alum. Salts addition for dosages from 0 to 250mg/L