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INDUSTRIAL WASTEWATER TREATMENT AND ITS IMPACT ON WATER QUALITY"CASE STUDY"

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Abstract

Ceramic industry wastewaters not only contain high total suspended solids but also significant amounts of dissolved organics resulting in high BOD or COD loads. Suspended solids can be removed from the wastewater by chemical precipitation. However, dissolved BOD/COD compounds can only be removed by biological or chemical oxidation.

Effluent wastewater from chemical sedimentation stage of ceramic industry was characterized and subjected to biological treatment in a laboratory scale activated sludge unit. Experiments were conducted at different conditions and solids retention times. The best results were obtained with mixed liquor suspended solids 3000 MLSS and 6 hrs. of solids retention times (sludge age) resulting in effluent COD and BOD concentration of 0 mg/l from a feed wastewater of 4000 mg/l COD and 150 mg/l BOD contents.

***Keyword**:* Ceramic industry, wastewater treatment, aerobic and anaerobic techniques.

Introduction

There are numerous processes that can be used to clean up waste waters depending on the type and extent of contamination. Most wastewater is treated in industrial-scale wastewater treatment plants (WWTPs) which may include physical, chemical and biological treatment processes. However, the use of septic tanks and other On-Site Sewage Facilities (OSSF) is widespread in rural areas, serving up to one quarter of the homes in the U.S.[1-6]. The most important aerobic treatment system is the activated sludge process, based on the maintenance and recirculation of a complex biomass composed by micro-organisms able to absorb and adsorb the organic matter carried in the wastewater. Anaerobic processes are widely applied in the treatment of industrial wastewaters and biological sludge. Some wastewater may be highly treated and reused as reclaimed water. For some waste waters ecological approaches using reed bed systems [7-9] such as constructed wetlands may be appropriate. Modern systems include tertiary treatment by micro filtration or synthetic membranes. After membrane filtration, the treated wastewater is indistinguishable from waters of natural origin of drinking quality. Nitrates can be removed from wastewater by microbial denitrification, for which a small amount of methanol is typically added to provide the bacteria with a source of carbon. Ozone wastewater treatment is also growing in popularity [10-12] and requires the use of an ozone generator, which decontaminates the water as Ozone bubbles percolate through the tank.

Disposal of wastewaters from an industrial plant is a difficult and costly problem. Most petroleum refineries, chemical and petrochemical plants [13-18] have onsite facilities to treat their wastewaters so that the pollutant concentrations in the treated wastewater comply with the local and/or national regulations regarding disposal of wastewaters into community treatment plants or into rivers, lakes or oceans. Other Industrial processes that produce a lot of wastewaters such as paper and pulp production has created environmental concern leading to development of processes to recycle water use within plants before they have to be cleaned and disposed of.[19-22]

The aim of this study is to investigate the most effective methods for ceramic industrial wastewater treatment ; The study includes : 1- Identifying the pollutants of industrial wastewater from ceramic industrial in Egypt and determining its concentration (heavy metals such as, Pb, Al, Cu, Zn, Fe and Ni and monitoring the nitrogen and phosphorus compounds besides physical parameters such as pH, conductivity, TDS and chemical parameters such as dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, anions, alkalinity, hardness and some organic substances as phenol, oil and grease, total organic carbon and protein). 2- Using pilot plant for biological treatment (aerobic and/or anaerobic) via varying some essential parameters (as activated sludge concentration, time) and others constants (as temperature, flow rate) to give the optimum conditions to get the best results of treatment. 3- Using jar test for chemical treatment by using different coagulants with varying concentrations to get the optimum concentration of each one and identify the best coagulant which gives the best results.

Experimental

Materials

All chemicals used are of analytical grade and used as purchased with further purification.

Collection of industrial wastewater sample from subsurface out flow effluents of Ceramic industry (at 6 th October city) in the Summer 2007.

Techniques used in treatment process Biological treatment

Anaerobic digestion Anaerobic digestion is a bacterial process that is carried out in the absence of oxygen. The process can either be thermophilic digestion,[23-26] in which sludge is fermented in tanks at a temperature of 55°C, or mesophilic, at a temperature of around 36°C. Though allowing shorter retention time and thus smaller tanks. Thermophilic digestion is more expensive in terms of energy consumption for heating the sludge.

Anaerobic mesophilic digestion is the most common treatment of domestic sewage in septic tanks, which normally retain the sewage from one day to two days, reducing the BOD by about 35 to 40 percent, [27-30]. This reduction can be increased with a combination of anaerobic and aerobic treatment by installing Aerobic Treatment Units (ATUs) in the septic tank.

One major feature of anaerobic digestion is the production of biogas with the most useful component being methane which can be used in generators for electricity production and/or in boilers for heating purposes.

Aerobic digestion Aerobic digestion is a bacterial process occurring in the presence of oxygen. Under aerobic conditions, bacteria rapidly consume organic matter and convert it into carbon dioxide. The operating costs used to be characteristically much greater for aerobic digestion because of the energy used by the blowers, pumps and motors needed to add oxygen to the process.

Aerobic digestion can also be achieved by using diffuser systems or jet aerators to oxidize the sludge [31-33]. Fine bubble diffusers are typically the more cost-efficient diffusion method; however, plugging is typically a problem due to sediment settling into the smaller air holes. Coarse bubble diffusers are more commonly used in activated sludge tanks (generally a side process in waste water management) or in the flocculation stages. A key component for selecting diffuser type is to ensure it will produce the required oxygen transfer rate.

Chemical treatment

Coagulation results from the addition and rapid mixing of coagulant with the wastewater to neutralize surface charges, collapse the surface layer around the particles and allow the participles to come together and agglomerate. The resulting formulation, called a floc, can more readily settle. As the floc settles, it interacts with more particles, and allows the floc to grow in size [34-35]. A number of coagulants are in common use. The most popular coagulants are alum, ferric chloride and polyacrylamide was added incrementally the lowest dosage that provides good turbidity removal in jar test is considered the first trial dosage in plant operation.

Instruments

Ion chromatography DX -120 using Dionex ion Pac. As 14 columns was used to measure the liberated ions (Chloride- nitrate, nitrite, fluride, bromide and sulphate.). Using eluent consisted of 2:7 sodium carbonate: sodium bicarbonate mixture and the flow rate was 1.2ml/min .

Multimeters WTW (wissen shftlich- technicke- werkstatten Gmbh) inolab multi was used for measuring pH, salinity, conductivity, dissolved solids and total dissolved solids. The pH electrodes were standardized under controlled parameter using a standard buffer solution of pH 4 before measurement of the water sample. Electrical conductivity was determined using special electrodes. The conductivity measurement was carried out several times with distilled water and then a standard potassium chloride solution used as a reference. Dissolved oxygen was determined using another electrode.

Spectrophotometer UV-9200 UV-VIS spectrophotometer was used in wavelength range 330-990 nm to measure the total phosphate at $\lambda = 690$ nm. Where's a series of different concentrations of standard phosphate were prepared and used for the construction of calibration graph measurement at $\lambda = 690$ nm. Cecil 7200 diffuse reflectance spectrometer at scanning speed 4000nm/mm and a band width of 2 nm was used to measure the total phosphate at $\lambda = 690$ nm

Turbidity meter TW (Wissenshaftlich- Technische werkst atten GmbH) was used. The turbidity cell was rinsed several times with distilled water before sample analysis. Before that the instrument was standardized with a standard solution.

Atomic absorption spectrophotometer (AAS) The samples solution was measured using atomic absorption spectro-photometer model (Aurora AA110 – Canada). The nitrous oxide and acetylene flame were used in the determination. the metal concentrations

The jar test Effectiveness of chemical coagulation .The jar test is stirring device. Which consists of six paddles capable of variable speed operation between 0 and 100 rpm. **, Fig (1).**

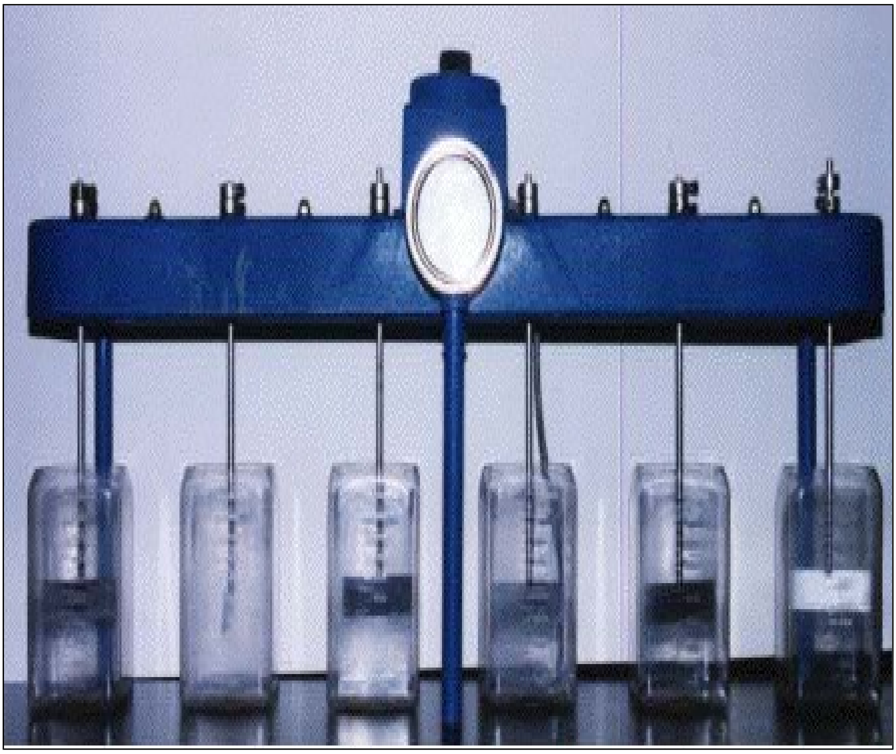


Fig (1): Stirring device used in a jar tests for chemical coagulation

The pilot plant For biological treatment**.,** It consists generally of the bioreactor aeration tank, anaerobic tank, pumps ,valves .The big container has the influent wastewater has a large pump with certain rate of pumping to a first column (primary settling tank) with constant flow rate can be adjusted by a valve to this column to settle about 2 hours then the effluent to the following tank by certain rate adjusted to aeration tank to stay about 2-8 hours with certain volume A.S (MLSS) in two periods with different aeration tanks operation respectively treating the same wastewater influent. The plant contains an aerating device to ensure sufficient dissolved oxygen concentration in the aeration tank needed for the biological degradation. **Fig (2)**.

Fig. (2) Pilot plant device as large scale

Results and discussion

Biological treatment

Biological treatment of ceramic industry wastewater is carried out by using aerobic and/or anaerobic techniques. The experimental results reveal that the crude sample shows the highest value of the studied parameters due to the existence of high organic content which will be degraded via the using of some organisms. On the other hand, their values after the using of aerobic and/or anaerobic techniques at different experimental conditions involving the variation of mixed liquor suspended solids contents (1500, 2000, 2500, 3000 and 3500 MLSS) and different times (0-8 hr) at constant flow rate and adjusting pH to 7 to be suitable for the working of microorganisms.The results obtained indicate that the variation of MLSS dosage increase treatment efficiency within 1500 – 3500 range with time for the removal of these parameters. Then chose the optimum condition to progress it, aerobic and anaerobic to reach to zero values of all parameters. But it must take inaccount that DO in aerobic condition be not lower than 2 and not above 3 by aeration and in anaerobic equal to 2 by agitation these values are necessary to microorganisms to life and works [36]

The results obtained and represented in **Fig (3)** reveal that, the maximum removal (100%) of TSS has been attained at 3500 MLSS and 6 hrs. beyond which the TSS removal was approximately constant. The behaviour of the treatment samples was the same using aerobic or anaerobic condition in treatment of TSS.

The removal of BOD illustrated in **Fig (4)** indicate that, highest value of BOD was 150 ppm. The maximum removal was at 1500 MLSS and 6 hrs, with a similar trend of degradation with aerobic and anaerobic. **Fig (5)** shows the removal of COD (4000 ppm). The efficiency of the treatment in which the value of COD reach to 0 ppm in case of aerobic and anaerobic condition were observed at 3000 MLSS value after 4 hrs. The concentration of chloride was 1598 ppm before treatment and reduced to 98 ppm with 3000 of MLSS at 6hrs. and the same behavior was obtained with aerobic and anaerobic process, **Fig (6)**.

The results obtained and represented in **Fig (7)** reveal that, the maximum removal (100%) of nitrate has been attained at 1500 MLSS and 6 hrs. beyond which the nitrate removal was constant. In addition, complete removal for nitrate have been observed upon the using of anaerobic treatment wherease, increase nitrate concentration with the aerobic treatment to reach the maximum value (30.73 ppm) at 3500 MLSS**Fig (8).** The results indicate also that, the concentration of nitrate increase with increasing treatment time: as nitrate is the final stage in the oxidation of nitrogenous compounds in aerobic condition. The concentrations of the investigated trace metals are given in **Table (1).**

Table (1): trace metals concentrations before and after biological treatment

Trace metal	Before treatment	After aerobic treatment	After anaerobic treatment
Cu	2.44 ppm	0.61 ppm at 3000 MLSS and 6 hrs.	0.63 ppm at 3000 MLSS and 6 hrs.
Al	1.71 ppm	0.13 ppm at 3000 MLSS and 8 hrs.	0.13 ppm at 3000 MLSS and 8 hrs.
Pb	12.1 ppm	1.7 ppm at 3000 MLSS and 8 hrs.	1.61 ppm at 3000 MLSS and 6 hrs.
Ni	3.72 ppm	0.7 ppm at 3000 MLSS and 8 hrs.	0.7ppm at 3000 MLSS and 8 hrs.
Zn	6.35 ppm	0.56 ppm at 3000 MLSS and 10 hrs.	0.56ppm at 3000 MLSS and 10 hrs.

From the above results, the optimum condition (0%) in biological treatment **was** reached at 3000 MLSS at 6 hrs. in the sequence; aerobic, anaerobic then aerobic.

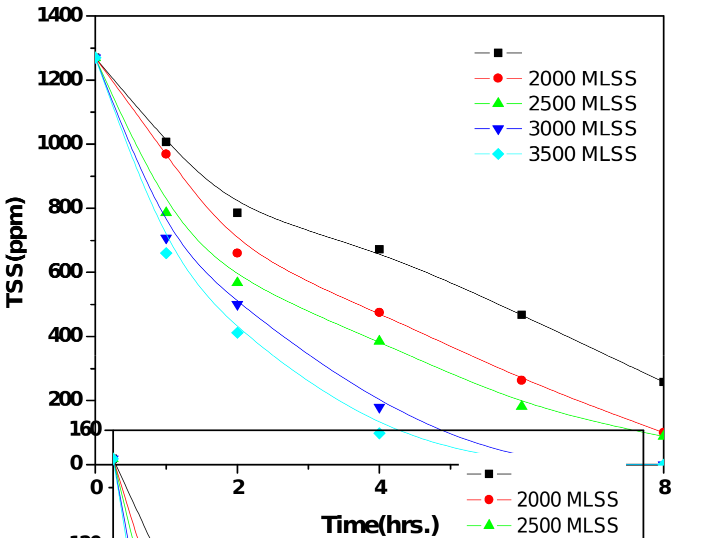


Fig (3): TSS concentrations for aerobic or anaerobic treatment

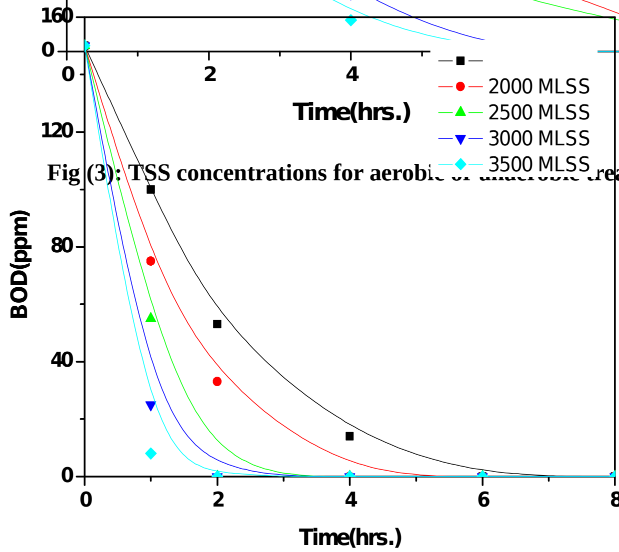


Fig. (4): BOD concentrations for aerobic or anaerobic treatment

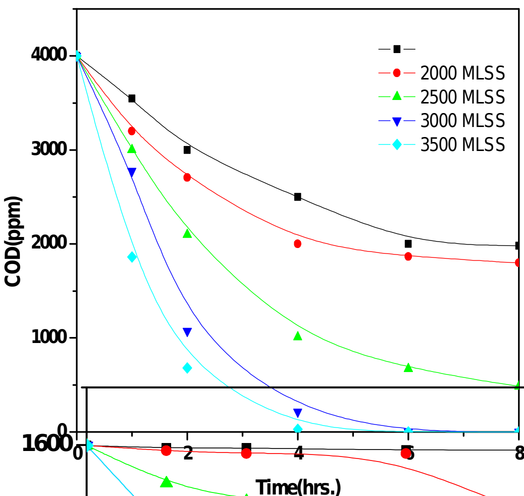
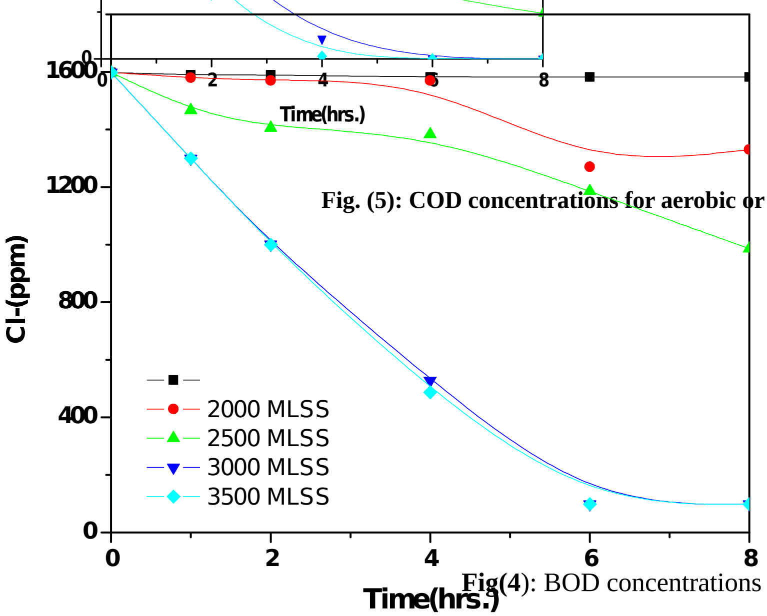


Fig. (5): COD concentrations for aerobic or anaerobic treatment



Fig(4): BOD concentrations for aerobic or anaerobic treatment

Fig (6): Cl^- concentrations for aerobic or anaerobic treatment

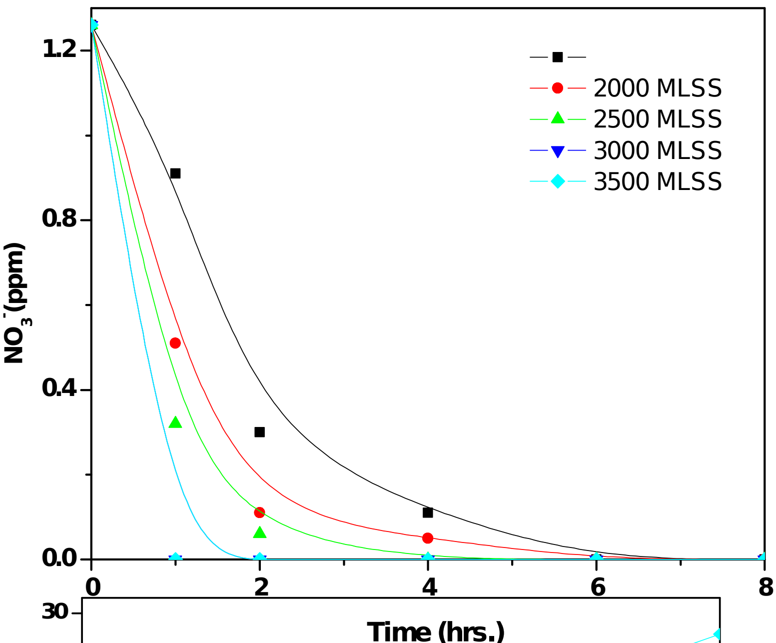


Fig (7): NO_3^- concentrations for anaerobic treatment

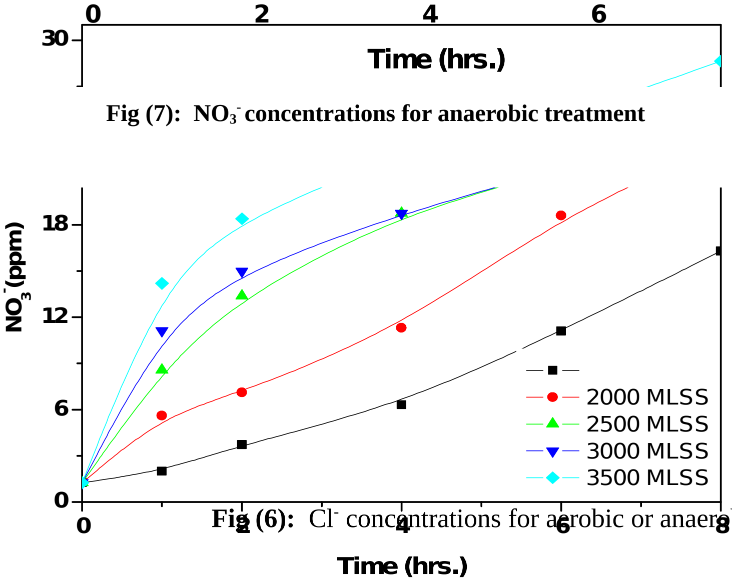


Fig (6): Cl^- concentrations for aerobic or anaerobic treatment

Fig (8): NO_3^- concentrations for aerobic treatment

Chemical treatment.

Chemical treatment by simple effective coagulation treatment method was used throughout this study. The jar test apparatus used for chemical coagulation treatment. Three different coagulants, ferric chloride, aluminum sulphate and poly acryl amide polymer and one by-pass dust as adsorbant was used. The effect of increasing coagulant doses on the treatment was studied.

The studied parameters were temperature, pH, salinity, TSS, TDS, DO, Conductivity, BOD, COD , Turbidity, T-P, T-H, alkalinity, O/G, protein, TOC, Org-N , K-N, Amm., Ca, Mg ions, phenol, settling time some anions and trace metals. Form this study the following observations were recorded:

The removal of TSS using 1 % polymer increase with increasing the polymer concentration to be 23.6 ppm at about 100 ppm polymers as given in **Fig(9)** . However, the use of alum and $FeCl_3$ in the treatment show a relatively lower removal at the initial periods when compared with polymer then their minimum values reach to 111 ppm and 38.11 ppm concentration with 150 ppm alum and 150 $FeCl_3$ respectively. Furthermore, the using of by-pass dust for the removal of TSS indicate that the increasing of this material strongly affects TSS removal. The results obtained indicate that the maximum removal was observed with about 9 ppm adsorbent. the the removal of BOD **Fig(10)** which reach to maximum removal 100% by using 5 ppm adsorbent, 90 ppm polymer, 90 ppm of $FeCl_{3,}$ and 100 ppm of alum. Complete removal for COD **Fig(11)** ,in case of 5 ppm adsorbent , 100 ppm polymer, , 150 ppm $FeCl_{3,}$ and 200 ppm of alum. The removal of Nitrate processes using coagulants 1 % alum, 1 % $FeCl_3$ and 1 % polymer and by-pass dust adsorbent exhibit the same behavior at the start of the adsorption process NO_3^- concentration was 1.26 ppm at first then reach to zero after treatment. The experimental results represented in **Fig(12)** indicate that, the removal of Cl^- using 1 % alum increase with increasing the alum concentration to be 30 ppm at about 150 ppm alum this decreasing may be due to adsorption on the flocks occurred . However, the using of polymer and $FeCl_3$ show a relatively lower pollutants removal at the initial periods when compared with alum but reach to 80 ppm concentration at 90 ppm polymer and 93.91 ppm with 100 ppm $FeCl_3$.On the other hand, the use of by-pass dust Indicates that the increasing of this material strongly affect the pollutant removal. The results obtained indicate that maximum removal was observed with about 7 ppm adsorbent which considered as a relatively very small amount when compared with coagulants. This finding may be due to the large surface area and active sites which play the important role in the process of adsorption and may be absent in case of coagulants . While, the results in **Table(2)** indicate that in case of by-pass dust the trace metals remain constant without any change during the process of treatment due to the fact that, by-pass consists of a mixture of several oxides which may be responsible for the obtained constant value of trace metal**s** readings.

Table (2): trace metals concentrations before and after chemical treatment

Trace metal	Before treatment	After treatment with coagulants		
		1 % polymer	**1 %$FeCl_3$**	**1 % alum**
Cu	2.44 ppm	1 ppm at 90 ppm polymer	1 ppm at 100 ppm $FeCl_3$	1.11 ppm at 150 ppm alum
Al	1.71 ppm	0.67 ppm at 70 ppm polymer	0.51ppm at 100ppm $FeCl_3$	0.63 ppm at 150 ppm alum
Pb	12.1 ppm	6.71 ppm at 90 ppm polymer	6.12 ppm at 100ppm $FeCl_3$	6.51 ppm at 150 ppm alum
Ni	3.72 ppm	1.36 ppm at 150ppm polymer	1.38 ppm at 100ppm $FeCl_3$	1.56 ppm at 90 ppm alum
Zn	6.35 ppm	3.11 ppm at 90 ppm polymer	3 ppm at 150 ppm $FeCl_3$	3.11 ppm at 150 ppm alum

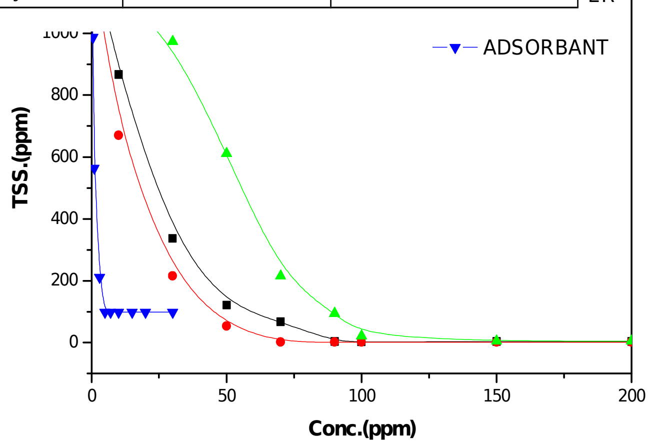
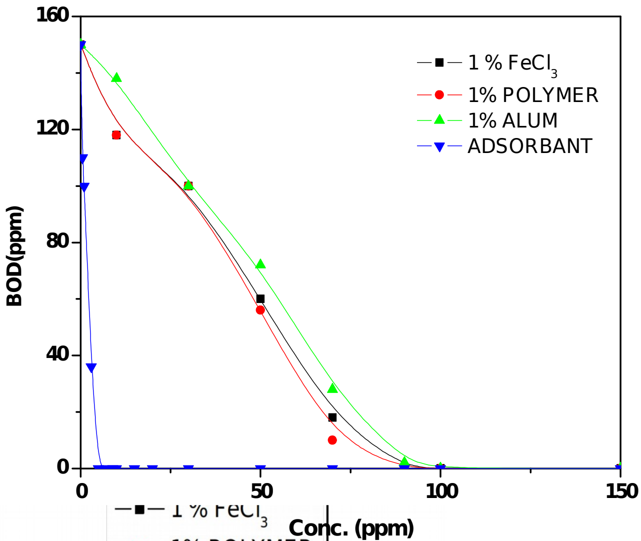
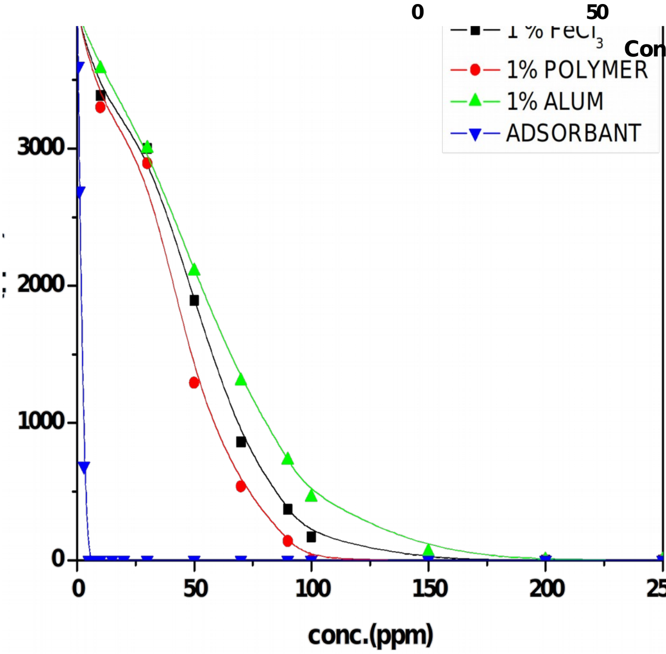


Fig (9): TSS variations for chemical treatment





emical treatment

chemical treatment

Fig (11): COD concentration for chemical Treatment

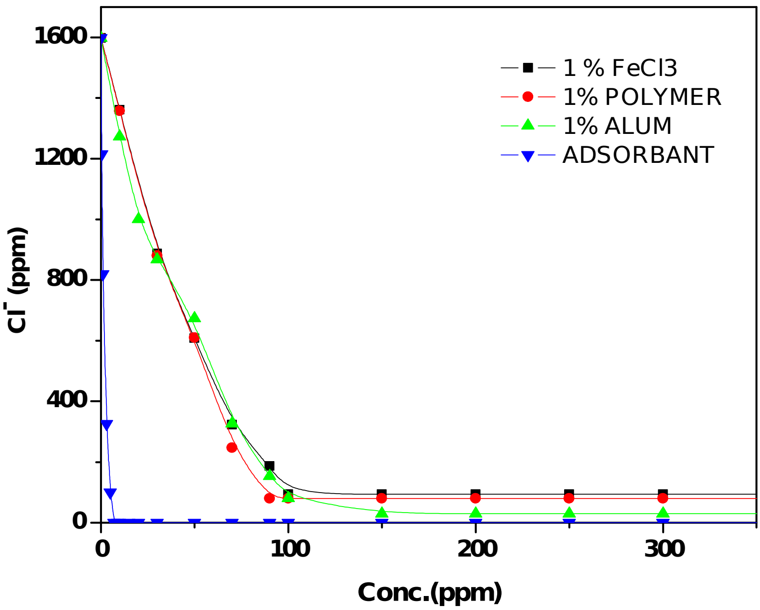


Fig (12): Cl- ion concentrations for chemical treatment

From the above results, The optimum Coagulants concentrations are 90, 100 and150 ppm for Polymer, $FeCl_3$ and alum respectively but the poly acryl amid polymer is more efficient in many treatments although it is the most expensive one so $FeCl_3$ is considered as the most applicable.

However, the by-pass dust adsorbent the optimum concentration is 5 ppm. Insipid of its efficiency with small amount, it is not effective at all in some cases as in treatment of metals, hardness and alkalinity.

Recommendations

Fig (12): Cl- ion concentrations for chemical treatment

The recommendations suggested from this study are as follows:

1- Industrial development projects have to continue to receive top priority and at the same time such projects have to take into consideration the prevention of pollution .also, consider giving priority to the execution of pollution control projects. Like all countries Egypt's natural resources particularly its water supplies are limited and will become increasingly more valuable in the future, therefore, projects that control the positive economic impact should be given priority.

2- Water pollution protection can be achieved better through control of pollution at the sources

3- Detailed studies should be carried out for each industry to minimize the quantity and improve the quality of wastewater discharged. This could achieve by plant measures and/or treatment of wastes.

4- The chemicals used for the treatment of water for different purposes should be minimized and added under supervision of experts for sawing budged and improve the environment. This study determined the optimum condition for each treatment .

5- In the light of pervious results , it is fair to **conclude** that the biological treatment is more efficient to get the best results but it has high costs (power , time , and large places for aeration and anaerobic tanks) although the chemical treatment less efficient but more cheap

6- The pollutants in treated wastewater reached to the permissible limits in law 44/2000, so it can be discharged into Underground Reservoir or can be used in cultivation of ornamental plants or plant trees for wood

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