Investigate the optimal dose for COD and TSS removal using chemical treatment

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***Abstract*— Water is one of the most valuable resources in the world; but they are constantly threatened by climate change, massive population growth, and sewage. One of the most promising efforts to reduce the world water crisis is river pollution, water reclamation and reuse. Water samples have been collected from “Sorkheh Hesar Canal” of the east Tehran- Iran and analyzed for various water quality parameters during research project period. In this study, the coagulation process is evaluated in treatment of river water on the basis of organic material (e.g. chemical oxygen demand, COD) and suspended solids (TSS) removal efficiency by use lime Ca(OH)2, Ferric chloride FeCl3.6H2O, Aluminum sulphate Al2 (SO4)3.16 H2O. The sample treated water was taken to determine of chemical oxygen demand (COD), total suspended solid tests. The spectrophotometer has been used in the laboratory experience for measure COD. The vacuum pump device has been used for measure total suspended solids TSS. Experiments show dose of aluminum sulphate 60 ppm has a great potential for efficient removal of COD, TSS up to 80, 90% respectively.**

***Index Terms*— chemical treatment, chemical oxygen demand, total suspended solid, optimal dose**

I. Introduction

Natural surface waters contain organic molecules and inorganic. Inorganic molecules, including mud, and metal oxides, usually enters surface water through natural erosion [1]. Organic molecules may include bacteria, algae, viruses as well as waste that have come from the water source. In addition, surface waters will contain dissolved organic compounds and very fine colloidal such as humic acids, it is result of decomposition and filtration of organic debris [2]. The purpose is therefore to provide the physical and chemical basis for the phenomena that occur in coagulation and flocculation processes [3]. Coagulation is the most popular process in treating water and wastewater. They are effective in removing particles as well as organic matter [4].

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Coagulation processes are primarily to reduce turbidity, and then the limit of organic matter has become a target of coagulation, given the impact of organic components on the biological stability of water [6]. The critical steps in water treatment are Coagulation, flocculation. At recent days, the focus has been on organic matter which could be used by microorganisms as a source of nutrients, the biodegradable element consisting mainly of non-humic material, research has been shown in recent years, which10 to 20% of the humic material in rivers and lakes could be biodegradable [7, 8]. Reduction natural organic matter depends on several factors, are: - temperature, nature of organic material, water treatment process, like coagulation, flocculation reagents [9]. The dissolved organic matter is removed from coagulants by complex reactions, followed by removal by solid formation or by solid adsorption [10]. Coagulation destabilizes particle charges. Coagulants are added to the water to neutralize negative charges on dispersed solids such as clay and organic material [11]. Excessive mixing does not affect coagulation, but insufficient mixing leave this step incomplete. The appropriate contact time in the quick mix chamber is usually 1 to 3 minutes [12]. Most coagulants are cationic in water and include chemicals for water treatment such as alum, ferric sulfate, lime [13]. The chemical has been achieved in the water and sewage treatment by coagulation as the most important physicochemical operation [14]. Physical - chemical treatment is an advanced method for the removing contaminants that not been removed by conventional biological treatment processes. These contaminants include (TSS), (BOD) and (COD) or (TOC) [15, 16]. Flocculation is the agglomeration of instability particles and colloids toward settle able particles (flocs.) or it is the particles have a neutral charge and can stick together. Water samples were mixed with coagulation in the beaker then put paddles that provide slow mixing and bring the small particles together to form larger particles called flocs. Mixing is done quite slowly and gently in the flocculation step. The contact times for flocculation from 15 or 20 minutes to an hour or more. This separation is usually achieved by sedimentation and filtration [17]. Aluminum sulfate has been used in water treatment, the most commonly known as coagulant used and does not normally contain any impurities of concern [18]. Recommended alum dosage rates ranges from 5 to 150 mg/L [19]. The most widely used coagulants are: Aluminum Sulphate, Ferric Sulfate, Ferric Chloride, Lime, Silicon Derivatives, Poly-aluminum

Chloride (PAC), Al2(OH)3Cl3 [20]. The chemical oxygen demand (COD) test is usually used to measure the amount of organic compounds in water [21, 22]. COD reduction is the most important parameter when evaluating filter performance in water treatment. COD is the most significant contaminant in surface water. Therefore, its effective reduction is particular importance [23, 24]. Total suspended solids are the water quality parameter used such as of wastewater quality assessment after treatment, Environmental waters may contain a variety of solid or dissolved impurities. In measuring the levels of these impurities, suspended solids are the term used to describe particles in water. TSS is the most common contaminants in the world in the form “dirt”. TSS can include a wide range of materials, such as silt, decomposing plant and animal matter, industrial wastes, and wastewater [25]. When considering water for human consumption or other uses, both suspended and dissolved solids are important concentrations that you must know, it is the dry weight of particles trapped by the filter, they are also known as molecules large enough not to pass through a filter used to separate them from the water [26, 27]. The primary purpose of the coagulation/flocculation process was for reducing of water contaminants content to find the effective treatment process of “Sorkheh Hesar Canal” water. Physical & chemical properties of water were measured before and after treatment and these water parameter tested were: Chemical Oxygen Demand (COD), Total suspended solid (TSS).

II. MATERIALS & METHODS

A. Study Area

This study has been conducted in the Sorkheh Hesar canal during the summer August 2015, which is situated in east of Tehran. This canal runs from Alborz Mountains, through areas of 7, 14 and 20 of Tehran municipality within the city limits which also called as "Abazar canal" (as Figure 1). Water from Alborz Mountain, flow through this canal that collects rainwater and surface waters. During the session of water flow, sewage and polluted water run into the canal causing wide spread contamination.

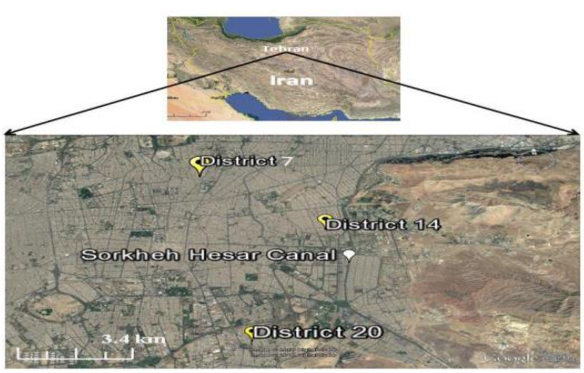

Figure 1: Map of Tehran City illustrates the study sites on Sorkheh Hesar Canal

B. Sampling

Water samples were collected from Sorkheh Hesar Canal water in east Tehran at different times. Where they were collected in plastic bottles and transferred to the laboratory. Parameters such as chemical oxygen demand (COD), total suspended solid (TSS) have been measured. These parameters have been selected for their spread in wastewater and industrial water. Samples were subsequently analyzed to determine physical and chemical variables. All measurements and analysis were conducted based on standard methods of water and wastewater testing. [28].

C. Analysis

- Chemical oxygen demand: - is an inexpensive and quick way. They are widely used to determine the amount of organic contaminants present in surface water or wastewater which are subject to oxidation by strong chemical oxidation, making COD a useful measure of water quality. This is expressed in milligrams per liter (mg / L). COD removal was measured by using spectrophotometer wavelength (420nm) is manufactured by UNICO America, model UV-2100. Moreover, hot COD meter HACH model DRB 200 used in Sharif University of Technology/ Iran.
- The vacuum pump device was used to measure the total suspended solids in in water samples and measurement of TSS concentration is essential to characterize polluted waters. The unit of measurement was expressed in milligrams per liter (mg / L). TSS removal was measured by using vacuum pump device used in Sharif University of Technology/ Iran.

Experiments were conducted for the purposes of finding the percentage of pollution removal efficiency (R %) calculated using the following Equation.

$$R\% = \frac{(COD_i - COD_f)}{COD_i} * 100$$

$$R\% = \frac{(TSS_i - TSS_f)}{TSS_i} * 100$$

Where: - $COD_{i,}$ TSS_i : Initial concentration

COD_f ,TSS_f : The final concentration

III. EXPERIMENTAL WORK

The jar test procedure is initially found to the best coagulant performing and dose rate and then to determine the chosen coagulant and optimum dose rate for removal efficiency COD, TSS. The experimental plan of this study was as follow: Study the effects of different coagulation doses on river water by using jar test device. A jar test device consists of 4 jars of one liter each with multiple stirrer units. Each test was performed on sample several times and the results were then recorded. One liter of river water sample was put on each jar with a different doses of coagulation such as lime Ca(OH)2. Operate the multiple stirrers are during this fast mix procedure; for period 15 min, observe floc particles uniformly suspended. After mixture period, pulling paddles and observe settling of floc particles. After 30 min of settling, and by pipette, pull an adequate sample volume, to conduct COD measuring, TSS and the optimum dose were determined. Repeat steps using other coagulants such as $Al_2(SO_4)_3.16H_2O$ and $FeCl_3.6H_2O$ alone and in combination with others using different doses. Estimate the effect of different doses of coagulants on the COD, TSS.

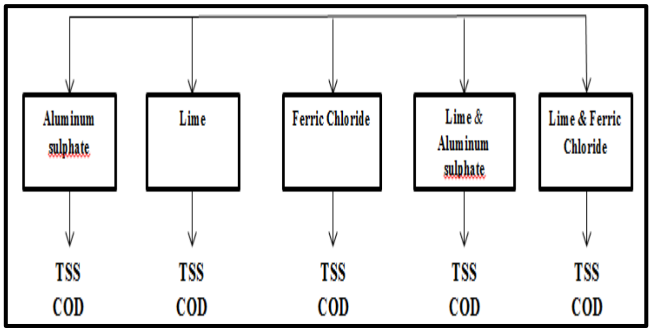

Fig.2 Experimental diagram in the jar test process

TABLE I
INITIAL CHARACTERIZATION OF THE SORKHEH HESAR CANAL WATER SAMPLE

S. No.	Parameters	Concentration (mg/l)
1	COD	43
2	TSS	40

IV. RESULTS AND DISCUSSION

Laboratory results were made using jar tests to evaluate the effect of performance of the three types of coagulants; lime $Ca(OH)_2$, ferric chloride $FeCl_3.6H_2O$ and aluminum sulphate $Al_2(SO_4)_3.16H_2O$ individually and in combination; lime $Ca(OH)_2$ with aluminum sulphate $Al_2(SO_4)_3.16H_2O$ and ferric chloride $Fecl_3.6H_2O$ with lime $Ca(OH)_2$ and determination of optimum coagulant dose and removal ~~efficiency COD, TSS for "Sorkheh Hesar Canal" water.~~

A. Effect of lime on removal efficiency COD, TSS

The effect of lime on the chemical oxygen demand (COD) and total suspended solid (TSS) was studied for river water. The selected dose was added from a specific coagulation directly to the river water sample. The coagulation dose was important in reducing the concentration of pollutants in river water. Experimental results indicated that the dose of coagulant (lime) was effective at concentrations ranging from 8 mg/L to 2 mg/L to remove COD, TSS. The amount of pollutants present in river water has decreased after treatment. The reduction of COD, TSS was from 43, 40 mg/L (raw water) to 10.5, 6 mg/L (treated water) with a mean removal efficiency of 75.5, 85 %. A series of jar test experiments were run for 20 minutes and 30 minutes to settle. River water samples have been analyzed for COD, TSS. The optimal dose of lime was to reduce the COD, TSS at a dose of 4 mg/L and also most favorable. During different doses 8, 6, 4, 2 mg/l, Note COD, TSS will decrease as a result of lime. The declines were up to 67.8, 73.2, 75.5, 70.7 % for COD and 70, 85, 85, 80 % for TSS respectively. The jar test experiments provided evidence that the coagulation process could provide COD, TSS efficiency of removal in the lime dose of 4 mg/l. Reduction of COD, TSS is the most important parameter when evaluating the performance of a chemical treatment process in the "Sorkheh Hesar Canal" water. Chemical oxygen demand and total suspended solid is the most important pollutant in surface water. This effectively detects our treated by lime. The Chemical oxygen demand and total suspended solid showed a significant reduction after treatment by this type of coagulant. Therefore, their effective reduction is of particular importance. Moreover, this study showed that the coagulation process can assure efficiency of removal for COD, TSS. The graph shows doses of lime and the highest removal percentage for chemical oxygen demand, total suspended solid as seen from Figure 3. This makes the chemical treatment using lime effective in the water treatment process "Sorkheh Hesar Canal ". The study results agree with those of [29, 30].

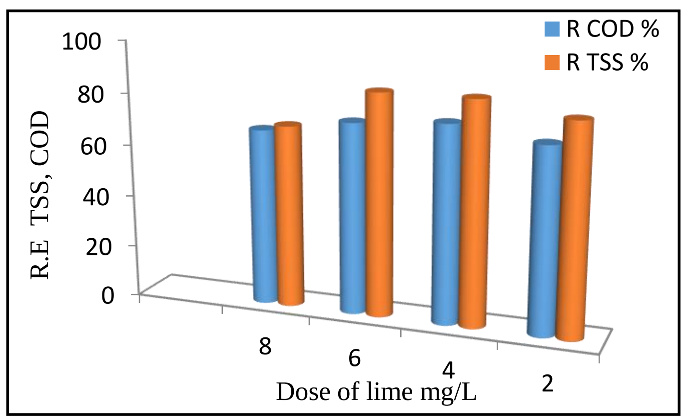

Fig. 3 Effect of different doses of lime on removal efficiency of COD, TSS

B. Effect of aluminum sulphate on removal efficiency COD, TSS

The effect of aluminum sulphate on the chemical oxygen demand (COD) and total suspended solid (TSS) was studied for river water. The selected dose was added from a specific coagulation directly to the river water sample. The coagulation dose was important in reducing the concentration of pollutants in river water. Experimental results indicated that the dose of coagulant (aluminum sulphate) was effective at concentrations ranging from 5 mg/L to 60 mg/L to remove COD, TSS. The amount of pollutants present in river water has decreased after treatment. The reduction of COD, TSS was from 43, 40 mg/L (raw water) to 8.5, 4 mg/L (treated water) with a mean removal efficiency of 80, 90 %. A series of jar test experiments were run for 20 minutes and 30 minutes to settle. River water samples have been analyzed for COD, TSS. The optimal dose of aluminum sulphate was to reduce of COD, TSS at a dose of 60 mg/L and also most favorable. During different doses 5, 10, 15, 20, 30, 40, 50, 60 mg/l, Note COD, TSS will decrease as a result of aluminum sulphate. The declines were up to 71.1, 62.4, 67.4, 70.3, 73.9, 76.5, 78.3, 80 % for COD and 83.5, 75, 78, 85, 80, 83, 82, 90 % for TSS respectively. Note that gradual increases of coagulation doses (aluminum sulphate) increase the removal efficiency of COD, TSS. The jar test experiments provided evidence that the coagulation process could provide COD, TSS efficiency of removal in the aluminum sulphate dose of 60 mg/l. Reduction of COD, TSS is the most important parameter when evaluating the performance of a chemical treatment process in the "Sorkheh Hesar Canal" water. Chemical oxygen demand and total suspended solid is the most important pollutant in surface water. This effectively detects our treated by aluminum sulphate. The Chemical oxygen demand and total suspended solid showed a significant reduction after treatment by this type of coagulant. Therefore, their effective reduction is of particular importance. Moreover, this study showed that the coagulation process can assure efficiency of removal for COD, TSS. The graph shows doses of aluminum sulphate and the highest removal percentage for chemical oxygen demand, total suspended solid as seen from Figure 4. This makes the chemical treatment using aluminum sulphate effective in the water treatment process “Sorkheh Hesar Canal ". The study results agree with those of [22, 23].

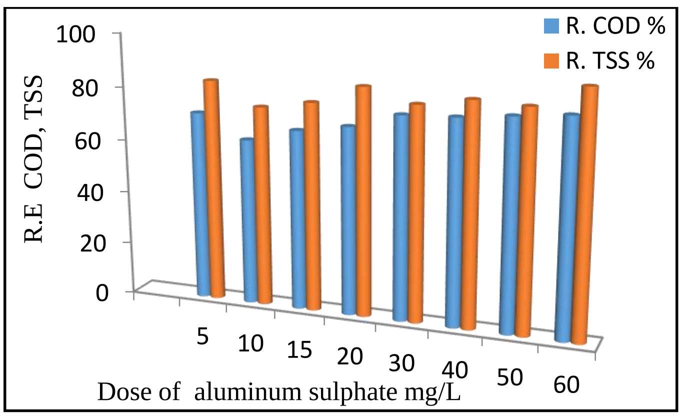

Fig. 4 Effect of different doses of aluminum sulfate on removal efficiency of COD, TSS

C. Effect of aluminum sulphate & lime on removal efficiency COD, TSS

The effect of aluminum sulphate with lime on the chemical oxygen demand (COD) and total suspended solid (TSS) was studied for river water. The selected dose was added from a specific coagulation directly to the river water sample. The coagulation dose was important in reducing the concentration of pollutants in river water. Experimental results indicated that the dose of coagulant (aluminum sulphate with lime) was effective at concentrations ranging from 5 mg/L to 20 mg/L to remove COD, TSS. The amount of pollutants present in river water has decreased after treatment. The reduction of COD, TSS was from 43, 40 mg/L (raw water) to 10.4, 4 mg/L (treated water) with a mean removal efficiency of 75.8, 90 %. A series of jar test experiments were run for 20 minutes and 30 minutes to settle. River water samples have been analyzed for COD, TSS. The optimal dose of aluminum sulphate with lime was to reduce of COD, TSS at a dose of 15 mg/L and also most favorable. During equal doses of aluminum sulphate with lime 5, 10, 15, 20 mg/l, Note COD, TSS will decrease. The declines were up to 68.7, 70.5, 75.8, 74.7 % for COD and 72.5, 85, 90, 80 % for TSS respectively. The jar test experiments provided evidence that the coagulation process could provide COD, TSS efficiency of removal in the aluminum sulphate with lime dose of 15 mg/l. Reduction of COD, TSS is the most important parameter when evaluating the performance of a chemical treatment process in the "Sorkheh Hesar Canal" water. Chemical oxygen demand and total suspended solid is the most important pollutant in surface water. This effectively detects our treated by aluminum sulphate with lime. The Chemical oxygen demand and total suspended solid showed a significant reduction after treatment by this type of coagulant. Therefore, their effective reduction is of particular importance. Moreover, this study showed that the coagulation process can assure efficiency of removal for COD, TSS. The graph shows doses of aluminum sulphate with lime and the highest removal percentage for chemical oxygen demand, total suspended solid as seen from Figure 5. This makes the chemical treatment using aluminum sulphate with lime effective in the water treatment process “Sorkheh Hesar Canal ". The study results agree with those of [22, 23].

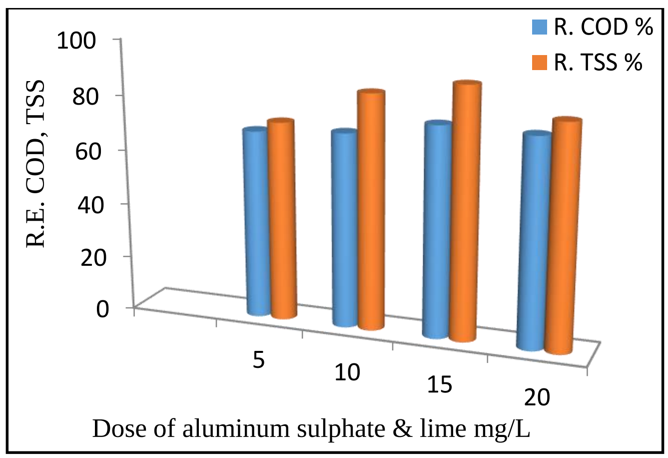

Fig. 5 Effect of equal doses of aluminum sulfate with lime on removal efficiency of COD, TSS

D. Effect of ferric chloride on removal efficiency COD, TSS

The effect of ferric chloride on the chemical oxygen demand (COD) and total suspended solid (TSS) was studied for river water. The selected dose was added from a specific coagulation directly water sample for the river. The coagulation dose was important in reducing the concentration of pollutants in river water. Experimental results indicated that the dose of coagulant (ferric chloride) was effective at concentrations ranging from 5 mg/L to 40 mg/L to remove COD, TSS. The amount of pollutants present in river water has decreased after treatment. The reduction of COD, TSS was from 43, 40 mg/L (raw water) to 12.4, 6 mg/L (treated water) with a mean removal efficiency of 71.1, 85 %. A series of jar test experiments were run for 20 minutes and 30 minutes to settle. River water samples have been analyzed for COD, TSS. The optimal dose of ferric chloride was to reduce of COD, TSS at a dose of 40 mg/L and also most favorable. During different doses 5, 10, 15, 20, 30, 40 mg/l, Note COD, TSS will decrease as a result of ferric chloride. The declines were up to 65.3, 67.4, 68.9, 69.7, 70.5, 71.1 % for COD and 75.5, 80, 81, 83, 85, 85 % for TSS respectively. The jar test experiments provided evidence that the coagulation process could provide COD, TSS efficiency of removal in the ferric chloride dose of 40 mg/l. Reduction of COD, TSS is the most important parameter when evaluating the performance of a chemical treatment process in the "Sorkheh Hesar Canal" water. Chemical oxygen demand and total suspended solid is the most important pollutant in surface water. This effectively detects our treated by ferric chloride. The Chemical oxygen demand and total suspended solid showed a significant reduction after treatment by this type of coagulant. Therefore, their effective reduction is of particular importance. Furthermore, this study showed that the coagulation process can assure efficiency of removal for COD, TSS. The graph shows doses of ferric chloride and the highest removal percentage for chemical oxygen demand, total suspended solid as seen from Figure 6. This makes the chemical treatment using ferric chloride effective in the water treatment process “Sorkheh Hesar Canal ". The study results agree with those of [22, 23].

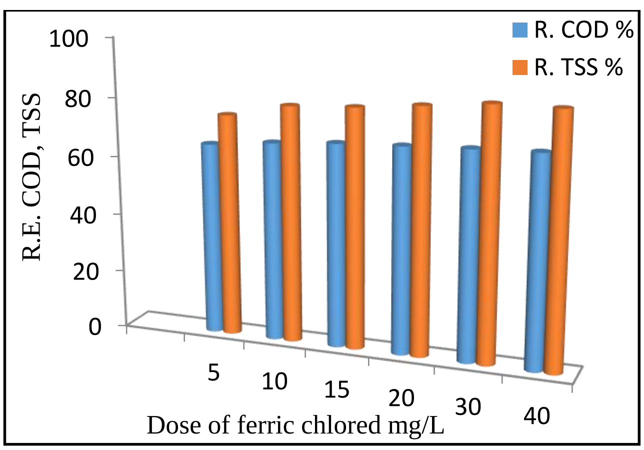

Fig. 6 Effect of different doses of ferric chloride on removal efficiency of COD, TSS

E. Effect of ferric chloride & lime on removal efficiency COD, TSS

The effect of ferric chloride with lime on the chemical oxygen demand (COD) and total suspended solid (TSS) was studied for river water. The selected dose was added from a specific coagulation directly to the river water sample. The coagulation dose was important in reducing the concentration of pollutants in river water. Experimental results indicated that the dose of coagulant (ferric chloride with lime) was effective at concentrations ranging from 5 mg/L to 20 mg/L to remove COD, TSS. The amount of pollutants present in river water has decreased after treatment. The reduction of COD, TSS was from 43, 40 mg/L (raw water) to 12.8, 6 mg/L (treated water) with a mean removal efficiency of 70.2, 85 %. A series of jar test experiments were run for 20 minutes and 30 minutes to settle. River water samples have been analyzed for COD, TSS. The optimal dose of ferric chloride with lime was to reduce of COD, TSS at a dose of 20 mg/L and also most favorable. The river water samples were analyzed for COD, TSS. During equal doses of ferric chloride with lime 5, 10, 15, 20 mg/l, Note COD, TSS will decrease. The declines were up to 63.4, 65.8, 69.5, 70.2 % for COD and 75, 78, 80, 85 % for TSS respectively. The jar test experiments provided evidence that the coagulation process could provide COD, TSS efficiency of removal in the ferric chloride with lime dose of 20 mg/l. Reduction of COD, TSS is the most important parameter when evaluating the performance of a chemical treatment process in the "Sorkheh Hesar Canal" water. Chemical oxygen demand and total suspended solid is the most important pollutant in surface water. This effectively detects our treated by ferric chloride with lime. The Chemical oxygen demand and total suspended solid showed a significant reduction after treatment by this type of coagulant. Therefore, their effective reduction is of particular importance. Furthermore, this study showed that the coagulation process can assure efficiency of removal for COD, TSS. The graph shows doses of ferric chloride with lime and the highest removal percentage for chemical oxygen demand (COD), total suspended solid (TSS) as seen from Figure 7. This makes the chemical treatment using ferric chloride with lime effective in the water treatment process “Sorkheh Hesar Canal ". The study results agree with those of [22, 23].

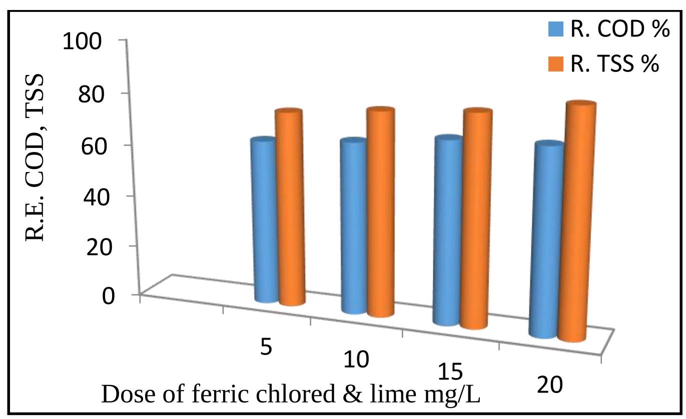

Fig. 7.Effect of equal doses of ferric chloride with lime on removal efficiency of COD, TSS

V. Comparison of Different Coagulants

Comparison of performances of the three coagulants of Ca(OH)2, FeCl3.6H2O, Al2 (SO4)3.16 H2O. Ca(OH)2 with Al2 (SO4)3.16 H2O and FeCl3.6H2O with Ca(OH)2. It was found that aluminum sulfate; aluminum sulfate with lime and lime had more efficiency in removing COD, TSS compared to that of ferric chloride. Different doses were the most important to determine optimal dose for coagulation performance. Thus, it is necessary to determine the optimal dose to reduce the cost of dose and obtain the optimum performance in treatment. The results presented in Figure 8 shows the effect of aluminum sulfate dose on removal efficiency COD, TSS. For the optimum aluminum sulfate dosage of 60 mg/l, aluminum sulfate recorded the highest reduction of parameters, which were the reduction of 80% and 90 % for COD and TSS respectively. Therefore, the optimum aluminum sulfate dosage in this research was 60 mg/l. The comparison of the used coagulants shows that there is a very significant effect on the elimination of the levels of pollution by the aluminum sulphate.

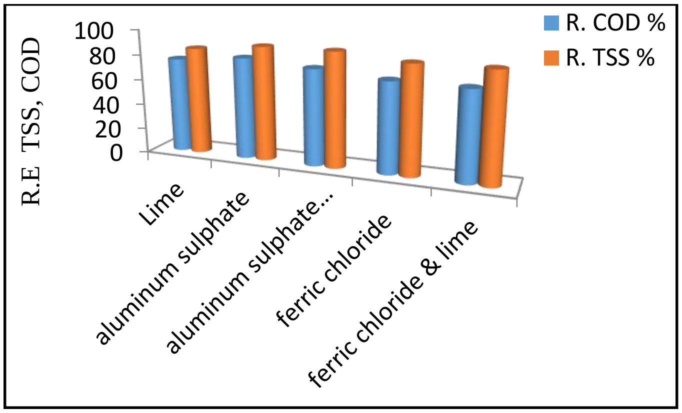

Fig. 8 Comparison of Different Coagulants on removal efficiency of COD, TSS

VI. Conclusions

The aim of this work is to treat river water and optimizing the coagulation process for this treatment. Coagulation has an important impression on water treatment and sewages, special for organic matter and suspended solid of treated water. According to the results obtained we conclude the following: The results of the current study indicate that the river water is polluted and contains (TSS), (COD). Source of pollution is generated by various chemicals such as industrial waste as well as domestic wastewater, which are released into river's water that has caused widespread pollution and this in turn affects human health and the environment. Coagulation is a key factor necessary to take into account for the good progress of the process of coagulation/flocculation at the water treatment level; elimination of pollution using chemical treatment is very effective. Chemical oxygen demand was correlated with total suspended solid value. However, the decrease of total suspended solid level leads to reduced chemical oxygen demand of treated water. Treatment by aluminum sulfate was more advantageous and convincing

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