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Greywater Characterization and Treatment Using Chemical Coagulation

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Abstract:

The main problem in treating grey water is the large variation in quality observed over short timescales. Different treatment schemes have been used such as physical, chemical and biological processes to treat this effluent. However they have some problems like adjusting shock loading of organic matters and chemicals. Therefore, in the present study chemical coagulation process was tested to treat grey water. Coagulants (alum and ferric chloride) were used in the present work to treat both real and synthetic grey water. The findings showed that at a dose of 30 mg/L of ferric chloride, 90% of the solution's turbidity and 80% of the TDS could consistently be removed. These findings were well matched with biological active filter system that reported 85% of COD removal from grey water. In addition, the effects of pH and alkalinity on the removal performance were also investigated. Overall, the present study showed that both traditional and proposed novel chemical process could treat grey water to the required level which can further be re-used for agricultural activities.

Keywords: Grey water, Coagulants, Aluminium Sulphate, Ferric Chloride, Coagulation, characterization, Removal performance

Introduction

While the supply of global freshwater becomes increasing the scarce, increased consideration towards alternative water resources has become compulsory. Once Pakistan was a water left-over country is now a water lacking country. The availability of water has reduced from 1299 m3 per capita in 1996-97 to 1100 m3 per capita in 2006 and it is expected to less than 700 m3 per capita in 2025. (Ghulam Murtaza et al., 2014) The worldwide population is projected to surpass nine billion by 2050 and total water consumption of urban will surge by 62% from 1995 (International water Management Institute, 2002; UN, 2010). Rapid population growth has led to increase the water scarcity. Meanwhile the mainstream of freshwater is consumed for the production of food (FAO, 2007), Shortage of water in an area can also directly influence the food safety. Main portion of water consume in the home is probable greywater, so it swears into the streams of wastewater. The characteristic home with elder persons may produce 35,000 gallons (132.5 m3) of greywater in a year although a fresher more effective home may produce 25,000 gallons (94.6 m3) of greywater in a year (Aquacraft, inc. 1999, 2004, 2008). Domestic wastewater may be categories into two parts, namely blackwater and greywater. Blackwater water is defined in this way the waste water that is generated from toilet flushing and Greywater is the wastewater that includes the water from laundry, bath, kitchen sink, washing machine, hand basins, showers and exclude the water from toilet. (Jefferson *et al*., 2004; briks and hills 2007). Greywater contains 55-75% of total wastewater of household (Shaikh et al., 2015). In terms of quality, greywater is predictable to have lesser organic and nutrients contents and lower pathogens load when compared to blackwater. Wastes of toilet is most polluted water from the household wastewater. If such potion of wastewater removed from the streams, the remaining waste have the protentional to reuse less requirement for treatment process. Greywater without treatment contains large number of bacteria, microbial pollutants, high difference in organic amount, it is warm and rich in nutrients that make it a perfect medium for microbial activity and bacterial growth (Birks et al., 2004; Lazarova et al., 2003; Leggett, 2001; Surrendran and Wheatley 1998; Rose et al., 1991). On the previous research the concentration of organics in greywater is like as settled household wastewater but concentration of suspended solids is much lesser as wastewater from toilets which are not included (Jefferson et al, 2004). Greywater is produced for the outcomes of the standards of living of the concerned people. Consequently, characteristics of greywater are highly flexible and affected by lifestyle, cultural and social conduct of the inhabitants, the consumption and water availability (Eriksson *et al.*, 2002; Jefferson *et al*., 2004; Uddin et al., 2015). Untreated greywater contains huge number of bacteria, microbiological contamination, high inconsistency in concentration of organics, greywater is rich in nutrients and warm that make it perfect medium for microbiological development and movement of microbial (Birks *et al*., 2004; Lazarova *et al*., 2003; Leggett, 2001; Surrendran and Wheatley 1998; Rose *et al*., 1991).

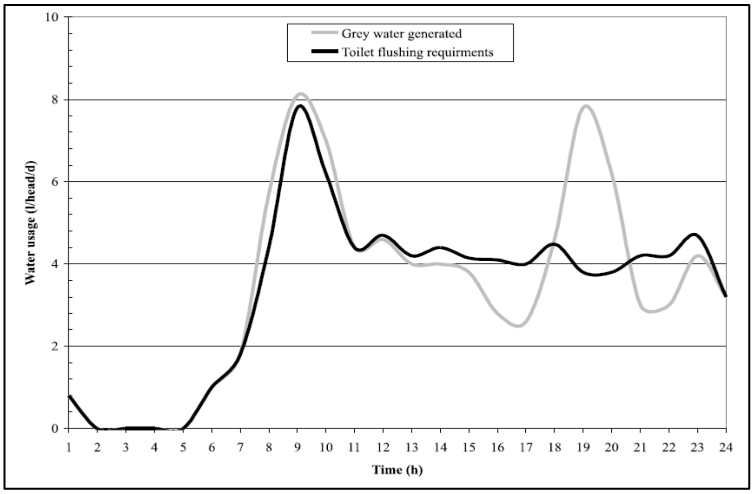

Fig. 1: typical greywater generation and toilets flushing requirement in college (Surrendran & Wheatley 1998)

Materials & Methods

Chemicals and Reagents

Different types of coagulants used for the chemical coagulation which are compounds of Aluminum (Aluminum sulphate and Aluminum chloride) and Iron (iron chloride and iron sulphate). Aluminum sulphate and ferric chloride are used for the treatment of greywater as a coagulant. Calculation of percentage removal efficiency of both coagulants. Compare the both coagulants removal efficiencies.

Greywater Sampling

Greywater is collected from the 5 households of Multan. Greywater can be defined as water from laundry, bating, washing machines, kitchen and showering excluding the toilets waste. Sampling is taken twice a week. After sampling greywater can be transfer in the water quality lab. Store the sample and analyses it.

Preparation of Coagulants

Coagulant of Aluminum sulphate is prepared by adding 2.5 mg/l, 5 mg/l and 7.5 mg/l of Aluminum sulphate into the 500 ml of distilled water in three different chemical jars. For checking the effective coagulant, put these different dosages of coagulant into the jar which have greywater and run the setup. From this check the effectiveness of different coagulants which is prepared. The 7 mg/l dose of coagulant have the good results in the jar test for the preparation of flocculants. Coagulant of ferric chloride is formed by putting 2.5 mg/l, 5 mg/l and 7.5 mg/l of ferric chloride into the three jars which have 500 ml of each jars. To check the effectiveness of coagulant, add these different concentration of coagulants in to the jar which contain the greywater in it. By analyzing the results 7 mg/l of coagulants dose have effective in the floc formation.

Experimental Setup and Working

The coagulation process should be done by Jar Test Experiment. 1000 ml of grey water will be taken in a beaker having the jar capacity of 1L. Coagulants of Different concentrations is used which varies from 1 mg/l to 200 mg/l. For coagulation processes we took a mixed sink and bathwater water as starting effluent, which contain the greywater samples from 10 different households. Through the experimentation aluminum sulphate ($Al_2(SO_4)_3.14H_2O$) ferric chloride (FeCl3) can be used as hydrolyzing salts of metal, put the different concentration of coagulants into the sample. For the chemical coagulation experiment, one liter of the water which you want to treat put into the jar test apparatus. Two different types of speeds should be used, initially a rapid mix for 90 s at 200 rpm, the coagulants either aluminum sulphate ($Al_2(SO_4)_3.14H_2O$) or ferric chloride (Fecl3) should be medicated in each individual jar and adjusted pH to the designated value (4.5, 6 and 7). The sample is then flocculated at 30 rpm for 15 minute and permissible to settle down the particles for extra 15 minute. The jar test is adjusted for 10 min at 150 RPM, after particles dropping period the treated water is filtered. The filtered water after then analyses the different parameters which we want to examine. All test should be taken on the room temperature.

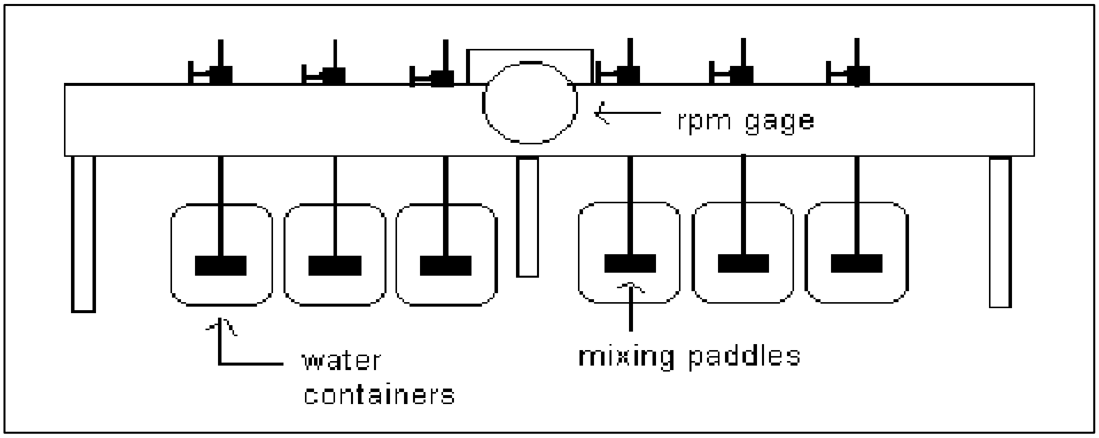

Fig. 2 : Jar test experiment

RESULTS

Characteristics of Greywater

Greywater generated from households washing actions. That sources includes waste from kitchen sinks, hand basins, washing machines and showers, but greywater exclude black water causes (urinals, bidets and toilets).

Table 1. Greywater Characteristics

Parameters	(Min)	Average	(Max)
pH	7.9	8.17	8.63
TSS(mg/l)	2.6	3.31	4
TDS(mg/l)	1584	2038	2700
Turbidity(NTU)	20	30.66	41
COD(mg/l)	1113	1190	1280
TP (mg/l)	4	7.5	11

Table 1 is described the characteristics of greywater. It indicated that the greywater samples have an average pH values in the range of 8.17, a minimum 7.9 and it has maximum value of 8.63. Table also shows about the total suspended solids which have an average TSS value is 3.31 mg/L, minimum value of 2.6 mg/L and it has maximum value of 4 mg/L. Greywater characteristics indicated that total dissolved solids have the range of 2038 mg/L, minimum value 2700 mg/L. It was also observed from the above table that value of turbidity lies in the range of 21-42 NTU. Greywater characteristics described that chemical oxygen demand (COD) can be lies in between the value of 1113-1280 mg/L. Table 4.1 also indicated that the value of total phosphorous varied from 4-11 mg/L.

Table 2. Chemical coagulation experiment with Aluminum sulphate.

Parameters	Units	Greywater before treatment	Greywater after treatment
pH	-	8.17	6.50
Turbidity	NTU	30.66	3.28
TDS	mg/l	2038	520
TSS	mg/l	3.31	0.89
COD	mg/l	1190	183
TP	mg/l	7.5	1.9

Table 2 shows that the performance of Jar test using Aluminum sulphate as a coagulant. It shows that raw water has turbidity value of 30.66 NTU and 6.50 NTU after treatment, and have TDS, TSS, COD and TP value of raw water was 2038 mg/L, 3.31 mg/L, 1190 mg/L and 7.5 mg/L respectively. After treatment with chemical coagulation the values of TDS, TSS,COD and TP have 520 mg/L, 0.89 mg/L, 183 mg/L and 1.9.

Percentage Removal Efficiency

The percentage removal efficiency is calculated by the following formula.

$$\% \text{ Removal } = \frac{\text{Co}-\text{Ce}}{\text{Co}} * 100$$

Here,
CO = Effluents concentration before treatment
Ce = Effluents concentration after treatment

Table 3: Chemical coagulation experiment with Aluminum sulphate.

Parameters	Units	Percent removal efficiency (%)
Turbidity	NTU	89.30
TDS	mg/L	74.48
TSS	mg/L	74
COD	mg/L	85
TP	mg/L	74.66

Table 4. Chemical coagulation experiment with Ferric Chloride

Parameters	Units	Greywater before treatment	Greywater after treatment
pH	-	8.17	6.80
Turbidity	NTU	30.66	5 .5
TDS	mg/l	2038	610
TSS	mg/l	3.31	1.01
COD	mg/l	1190	235
TP	mg/l	7.5	2.20

Table 4 indicated the performance of jar test using ferric chloride as a coagulant. The raw greywater has turbidity, TDS, TSS, COD and TP vales are 30.66 NTU, 2038 mg/L, 3.31 mg/L, 1190 mg/L and 7.5 respectively. After treating the raw water with chemical coagulation, ferric chloride as a coagulant turbidity, TDS, TSS, COD and TP vales are 5.5 NTU, 610 mg/L, 1.01 mg/L, 235 mg/L and 2.20 mg/L.

Table 5. Chemical coagulation experiment using Aluminum sulphate as a coagulant.

Parameters	Units	Percent removal efficiency (%)
Turbidity	NTU	82.06
TDS	mg/L	70.06
TSS	mg/L	70
COD	mg/L	80.25
TP	mg/L	70.66

Effect of Coagulant dosage

Dosage was utmost vital parameter which was considered to measure optimum situation for the working of flocculation and coagulation. Every kind of coagulants has different characteristics at range of optimum dosage. Mostly, inadequate or overdosing will show poor results in the coagulation or flocculation. Consequently, it was vital to measure ideal dosage in command to diminish the cost of coagulant and attained optimal performance for treatment. The effect of coagulant dosage was examined at 250 rpm for 10 minutes and 45 minutes settling time at 30 rpm for a dosage of coagulant which varies from 12-66 mg/L

Table 6. Effect of coagulant dosage on percentage removal efficiency

parameters	Turbidity (NTU)	TDS (mg/l)	TSS (mg/l)	COD (mg/l)	TP (mg/l)
15 (mg/l)	18.62	1498	2.15	870	5.6
30 (mg/l)	14.90	1280	1.4	670	4.42

45 (mg/l)	10.15	920	1.01	450	3.80
60 (mg/l)	7	520	0.99	190	2.20
75 (mg/l)	7	520	0.90	190	2.20

Fig. 3 Percentage Removal efficiencies of different parameters using Aluminium sulphate as a Coagulant

Jar test experiment was accomplished to establish the ideal coagulant concentration. So, the amount of coagulant has a great influence on the removal COD, TDS, TSS and TP. Graph 4.1 indicated the removal efficiencies of different parameters (i.e. COD, TDS, TSS and TP). COD curve showed that initially there are no removal and at 15 mg/L coagulant dosage there is almost 24% removal of COD. Curve also indicated that coagulant dosage and removal efficiency is directly proportional at 60 mg/L, because Aluminum sulphate coagulant is optimum in between the 12-66 mg/L (Moosavirad *et al*., 2016). Curve showed that above 60 mg/L coagulant dosage the removal efficiency is constant. TDS curve indicated that primarily there are no removal of TDS. At 15 mg/L coagulant dosage the removal efficiency is almost 25 %. From 15 mg/L the coagulant dosage and removal efficiency is directly proportional at 60 mg/L. Behind the 60 mg/L the curve showed that the removal efficiency is constant because Aluminium sulphate have the optimum coagulant dosage from 12 mg/L to 66 mg/L (Moosavirad *et al*., 2016).

Fig. 4 showed that percentage removal efficiency of coagulant dosage at optimum dosage. At zero coagulant dosage there was no removal efficiency of turbidity. At 15 mg mg/L the removal efficiency increases from zero to the almost 40 %. The curve trend showed that there is direct relation between coagulant dosage and removal efficiency. At the 60 mg/ L dosage of coagulant the removal efficiency has been 79%, behind that point the removal efficiency has been decreasing or constant (M.Pidou *et al.,* 2008).

Fig. 5 indicated the percentage removal efficiencies of different parameters (i.e. TDS, COD, TSS and TP). COD curve showed the percentage removal of COD against the coagulant dosage. It also showed that initially when there was low coagulant dosage removal of COD are less. By increasing the coagulant dosage, the removal efficiency has been increasing slowly and there was a point come when it is maximum, above that point the removal efficiency going to be decreasing. At 15 mg/L of coagulant dosage the removal efficiency was almost 20%. From 15 mg/L to 60 mg/L of coagulant dosage the removal efficiency showed that there was a direct relation between coagulant dosage and removal efficiency. Behind 60 mg/L the removal efficiency was going to be decreasing or constant. Because the coagulant optimum dosage is varying in the range of 12-66 mg/L (Vinitha *et al.*, 2018). TDS curve indicated removal efficiency of TDS against the coagulant dosage. Trend of TDS curve indicated that firstly when there was less coagulant dosage the removal efficiency was less and vice versa. At 15 mg/L of coagulant dosage the removal efficiency was almost 20%. The trend of curve showed that from 15 mg/L to 60 mg/L, there is a direct relation in between coagulant dosage and removal efficiency of TDS. Above that point the removal efficiency going to be constant or decreasing (Moosavirad et al., 2016). TSS curve specified that the removal efficiency of TSS against the coagulant dosage. Primarily there was less removal because firstly coagulant dosage is low. By increasing the coagulant dosage, the removal efficiency has been increasing slowly and there was a point come when it is maximum, above that point the removal efficiency going to be decreasing. The TSS curve indicated that there is a direct relation between coagulant dosage and removal efficiency of TSS from 15-60 mg/L of coagulant dosage. Because the optimum coagulant dosage differs from 12-66 mg/L (Vinitha et al., 2018).

Jar test was accomplished to establish the best amount of dosage of coagulant. So, the concentration of coagulant has a prodigious influence on the turbidity removal. Figure 4.7 indicated that the removal efficiency of turbidity against the dosage of coagulant. Primarily there are no removal of turbidity because in the starting there are less concentration of coagulant. The ferric chloride coagulant has just removed less percentage removal of turbidity, and with increasing amount of coagulant, minor change has been decrypted in the turbidity removal. The ferric chloride coagulant at an amount of 15 mg/L could remove 35% of turbidity. Thus, the turbidity removal efficiency with ferric chloride cannot minimize the turbidity effectively (Ustun et al., 2011). From 15 mg/L to 60 mg/L the removal efficiency and the coagulant dosage have the direct relation, increasing the coagulant dosage the removal efficiency also increased up to a point. Behind that point the removal efficiency decreased by adding more coagulant there is no effect on the removals

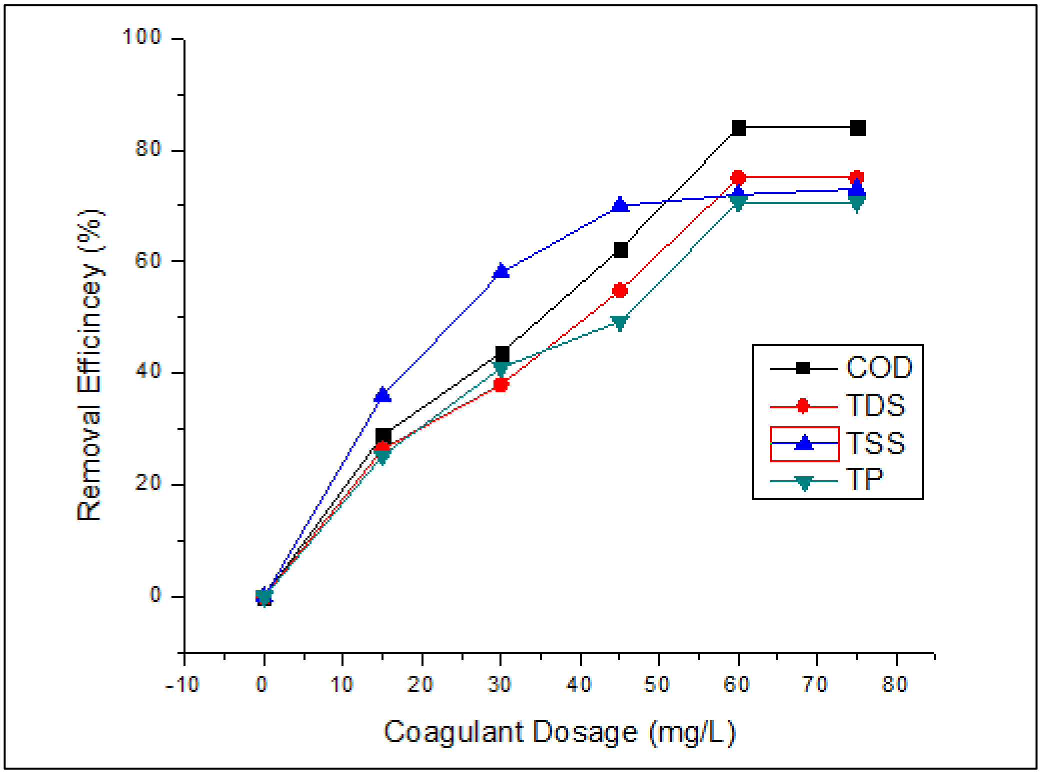

Figure 3: Percentage Removal Efficiencies of Different Parameters Using Aluminim Sulphate as a Coagulant Agent

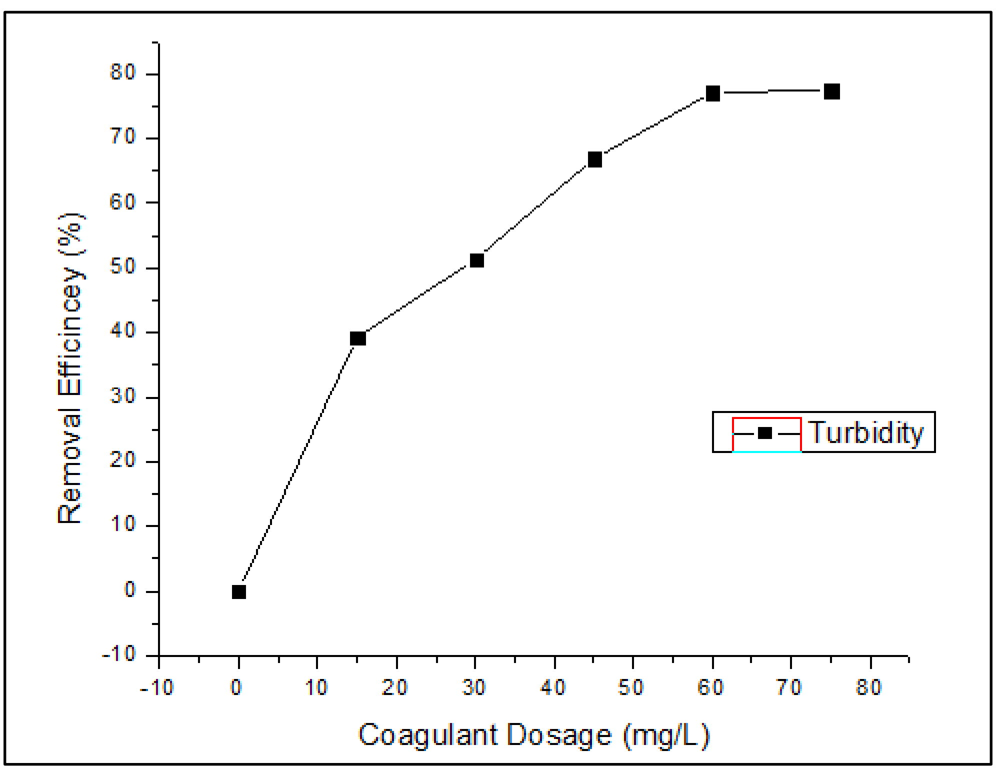

Fig. 4 Percentage Removal efficiency of Turbidity using Aluminium sulphate as a Coagulant

Table 7. Effect of coagulant dosage on percentage removal efficiency

Parameter	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	COD (mg/L)	TP (mg/L)
15 (mg/l)	19.62	1640	2.35	990	6.6
30 (mg/l)	15.90	1420	1.70	845	5.34
45 (mg/l)	11.15	1080	1.4	568	3.20
60 (mg/l)	7.5	855	1.35	295	2.20
75 (mg/l)	7.5	855	1.31	295	2.20

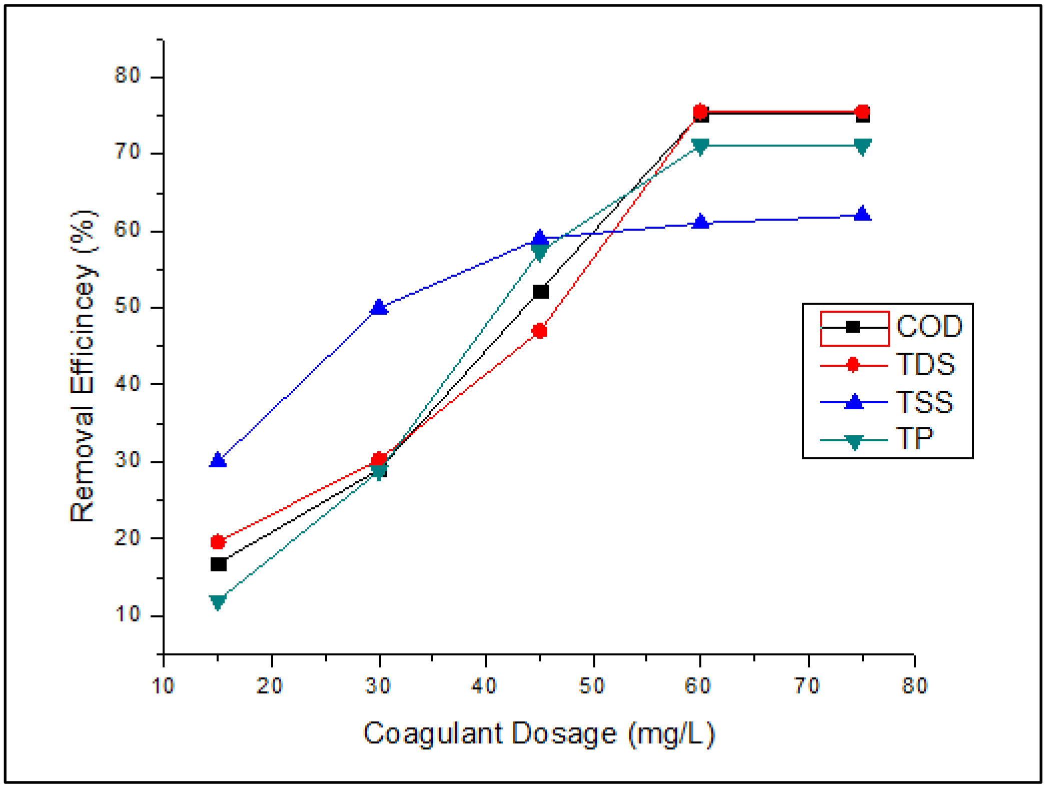

Fig. 5 Percentage Removal efficiencies of different parameters using Aluminium Ferric Chloride as a Coagulant

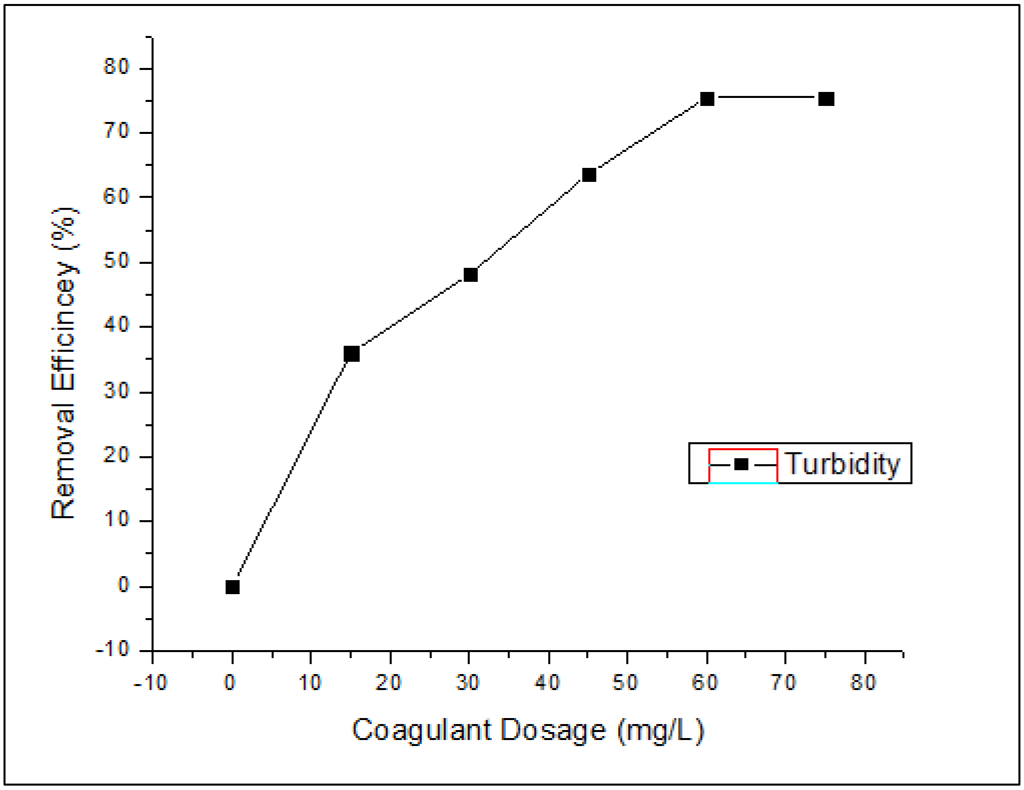

Figure 6 Percentage removal efficiency of Turbidity using ferric chloride as a coagulant

Conclusions

The method of chemical coagulation for grey water is best for the following reasons:

- Ferric chloride and alum at the concentrations used can remove a high percentage of turbidity. But ferric chloride could not remove any optimal turbidity with any tested concentrations.
- All coagulants utilized in this study have the capability to remove a high percentage of COD at concentration of 30 mg/L, which displays the highest removal percentage. alum and ferric chloride could remove 90.42% and 89.14% of COD respectively.
- To remove TSS in superb condition, Aluminium sulphate could remove 77.25% of the TSS, while the percentages obtained were 66.35% for ferric chloride

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