Treatment of effluent generated from engine manufacturing by coagulation flocculation method using poly aluminum chloride (PAC) and ferric chloride (FeCl3)

Sunil S. Shaha* and Kalyani Patake**

*Research Guide ** Research Student

Department of Environmental Engineering, KIT's College of Engineering (Autonomous), Kolhapur

Abstract

This study aims at studying physico-chemical treatment as a method of treatment of effluent generated from an engine manufacturing industry. The effluent mostly comprises of machining coolant and hence contains high level chemical oxygen demand (COD). Experiments were carried out using poly aluminum chloride (PAC), ferric chloride (FeCl3) aided by anionic polyelectrolyte as the coagulant aid to determine the effectiveness of coagulation method for removal of COD. The results obtained prove that PAC was found comparatively more effective in removing COD as compared to FeCl3. At optimum pH and coagulant dose, PAC shows COD reduction by 89.2 % while FeCl3 shows COD reduction by 81.9 %.

Key words: coagulation, flocculation, effluent, poly aluminum chloride, ferric chloride

1. Introduction

Effluent with high COD levels is harmful to the environment if disposed untreated and is regulated by pollution control board norms. Hence, COD should be maintained within permissible limits.

Coagulation and flocculation is physico-chemical treatment used for effluent with high COD content. The removal mechanism of this coagulation & flocculation process includes charge neutralization of negatively charged colloids by cationic hydrolysis products. The efficiency of treatment is highly dependent on optimum pH and coagulant dosage. Commonly used chemicals for coagulation are iron salts such as ferric chloride, ferrous sulphate and alum as well as aluminum salts such as poly aluminum chloride. The key objective of this study is to optimize pH and coagulant dose and compare effectiveness of PAC versus FeCl3 in terms of COD reduction.

2. Literature review

Abdul Fattah Abu Bakarhas et al (2013) have explained the procedure of determination of optimum pH for the coagulants and have demonstrated that pollutant removal efficiency was found highest while using PAC as a coagulant. The results obtained proved that PAC was comparatively more efficient to FeCl3 and alum. At defined optimum experiment condition (coagulant dose: 70 mg/L, coagulant aid dose: 2 mg/L and pH 7), PAC showed 70% removal for (chemical oxygen demand) COD and 98% of (total suspended solid) TSS. For FeCl3 and alum, the maximum removal for COD were 64% and 54%, meanwhile TSS removal were 91% and 94%. [1]

Debabrata Mazumder et al (2011) have explored the pollution potential of automobile service station wastewater and to treat the same. The wastewater samples were collected from different servicing points of a typical automobile garage and then characterized for parameters like pH, Total solids, Total Suspended Solids, Chemical Oxygen Demand (COD) as well as Oil and Grease. A composite sample was also prepared on the basis of wastewater generation pattern. The characterization results revealed that oil and grease and COD were two major pollution parameters of concern. The composite oily wastewater was firstly treated using coagulants like alum, $FeSO_4$ and $CaCl_2$. The results showed that removal is feasible for initial oil concentration in the range of 300 – 600 mg/L for the alum dose of 100 - 400 mg/L, alum + bentonite dose of 20 - 250 mg/L and $FeSO_4$ dose of 50 - 200 mg/L. Subsequently, treatment of the composite wastewater with acclimated suspended biomass (activated sludge) resulted about 18 – 68% removal efficiency for initial oil and grease concentration of 300 – 600 mg/L under the batch period of 18 – 30 hours. [2]

Nasir et al (2014) have adopted coagulation as a mode treatment for biodiesel waste water. In their research work, they have demonstrated effect of pH and coagulant dose on coagulation and subsequent pollutant removal efficiency. The effects of pH and coagulant dosage were examined at 150 rpm of rapid mixing and 20 rpm slow mixing and 30 min settling time. Higher removal of suspended solids (SS), colour, oil and grease (over 90%), and COD (over 80%) were achieved at pH 6. PAC was found to be superior to aluminium sulphate, yielding a lower amount of coagulation, i.e., 300 mg/L. [3]

3. Materials and methodology

Effluent from the all sources (7 sources in all) was collected in proportioned quantity as per the COD values and the quantity of effluent generated from each source.
Physico-chemical treatment is provided to settle suspended and colloidal solids by using coagulants and thereby reduce COD. For this study Poly Aluminium Chloride (PAC) and Ferric Chloride ($FeCl_3$) were used as coagulants along with Polyelectrolyte (PE) as coagulant aid.
Coagulation is highly effective only at particular pH with particular coagulant dosage. Hence, studies were carried out to determine optimum pH and dose for above mentioned coagulants. Methodology used for optimum pH and optimum coagulant dose is as follows.

3.1 Experimental set-up:

- 500 ml beakers
- pH meter
- Glass stirrer

Chemicals used:

- PAC
- $FeCl_3$
- Lime
- Poly-electrolyte

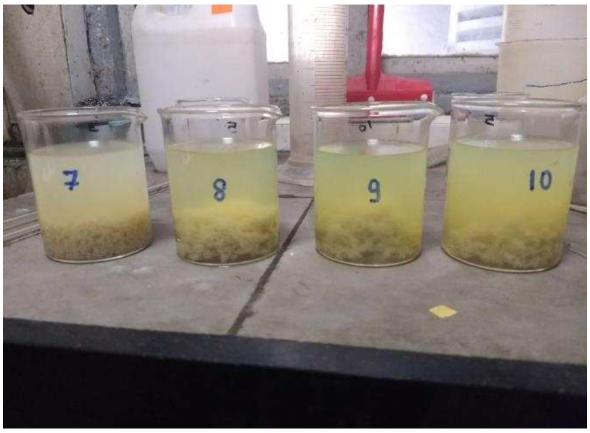
3.2 Procedure

3.2.1 Proportioning

- Qualitative and quantitative parameters of all sources analyzed
- Average COD and average quantity per day of each source calculated
- Total COD expected calculate using following formula
  (Source1 COD x quantity) + (Source 2 COD x quantity) / total quantity
- Proportioning options derived by permutations and combinations

3.2.2 pH standardization:

- Take proportioned sample in 4 beakers
- Adjust pH using lime in all 4 beakers (pH 7,8,9 and 10)
- Add 1000 mg/l of PAC in each beaker
- Add 5 ml of poly-electrolyte solution
- Rapid mix for 4 minutes and slow mix for 20 minutes
- Allow the flocs to settle down completely by giving a detention time of 30 minutes
- Collect the supernatant 2 ml above the settled sludge from the beakers and calculate COD of all 4 samples
- Select the pH that results in highest COD reduction.



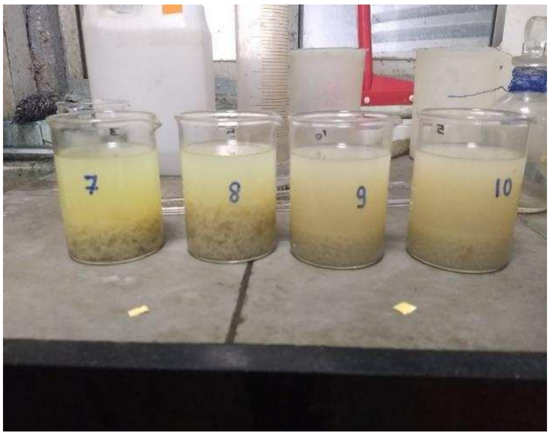


Figure 1: pH standardization for PAC

Figure 2: pH standardization for FeCl3

3.2.3 Coagulant dose standardization:

- Take proportioned sample in 4 beakers
- Adjust pH to standard level as per the results of pH standardization
- Add 4 different doses in 4 beakers (PAC dose of 1000 mg/l, 1500 mg/l, 2000 mg/l and 3000 mg/l)
- Add 5 ml of PE in each beaker
- Rapid mix for 4 minutes and slow mix for 20 minutes
- Allow the flocs to settle down completely by giving a detention time of 30 minutes
- Collect supernatant 2 ml above the settled sludge from the beakers and calculate COD of all 4 samples.
- The dose resulting in highest COD reduction is the optimum coagulant dose.

Repeat the same process using FeCl3.

3.2.4 Analytical Methods

The experimental procedure for COD analysis was done as per IS 3025.

4. Results and discussion

4.1 Proportioning results

Based on above mentioned procedure following results were obtained.

Source	Quantity	Avg COD	Total COD (Avg COD*Quantity)
S1	7	54933	384533
S2	3	88960	266880
S3	7	16107	112747
S4	1.2	82233	98679
S5	7	5868	41074
S6	2	19627	39253
S7	3	8695	26085

Table 1: Total COD for all sources

	Combination	Total COD	Total Quantity	Avg COD expected
Option 1	S6+S1+S7	449871	12	37489
Option 2	S3+S5	153820	14	10987
Option 3	S4+S5+S7	165838	11.2	14807
Option 4	S1+S5	425607	14	30401
Option 5	S2+S5+S7	334038	13	25695
Option 6	S4+S5+S7+S6	116422	13.2	8820
Option 7	S4+S5+S1+S6	563540	17.2	32764
Option 8	S2+S3+S7	405711	13	31209

Table 2: List of proportioning options

Out of the above proportioning options, option 8 was used for experimentation.

Option	Source	Lit
8	S2	6
	S3	14
	S7	6

Table 3: Selected proportioning option

4.2 pH optimization

The coagulation-flocculation process is highly pH sensitive. The coagulation occurs during a specific pH range and the range changes with change in the coagulant used. During the study, pH was varied from 7 to 10 for a fixed coagulant dose of 1000 mg/l of both PAC and FeCl3. Here, only COD removal was considered for organic content removal as TSS removal is not quite affected by the pH range.

For PAC, optimum pH calculated based on maximum COD removal was found to be 8. While for FeCl3, optimum pH based on similar considerations was found to be 9.

For initial COD of 25241 mg/l, maximum COD reduction of 91.11 % was obtained by PAC at pH 8 whereas maximum COD reduction of 75.9 % was obtained by FeCl3 at pH 9.

PAC	pH	7	8	9	10
	Dose	1000	1000	1000	1000
	COD	5248	2246	3369	4118

Table 4: pH optimization results for PAC

FeCl3	pH	7	8	9	10
	Dose	1000	1000	1000	1000
	COD	7996	6473	6092	7113

Table 5: pH optimization results for FeCl3

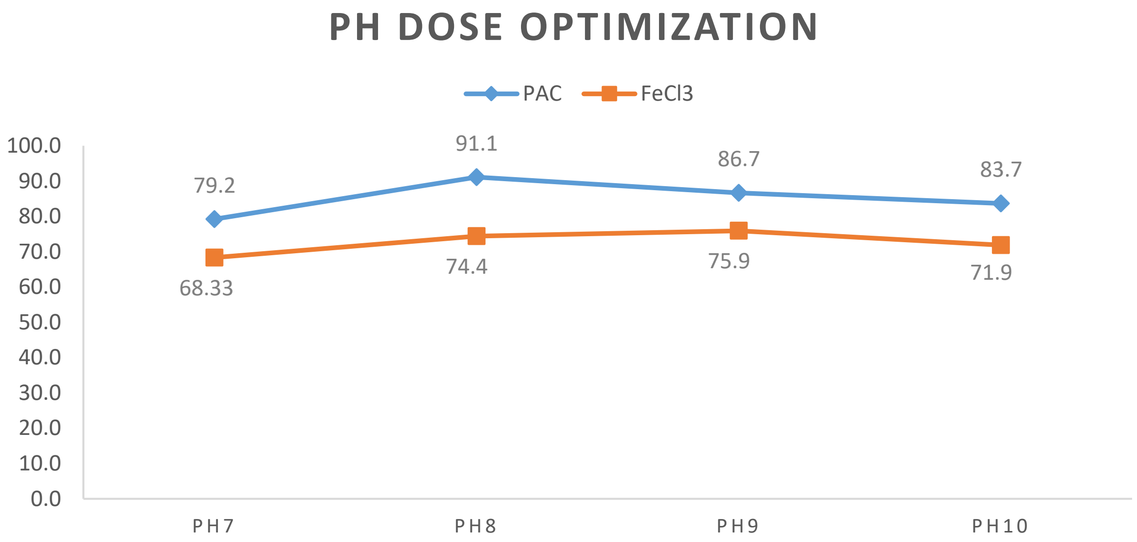


Figure 3: COD reduction in % through pH optimization for PAC and FeCl3.

4.2 Coagulant dose optimization

Coagulant dose used is a key parameter in determining optimum conditions for coagulation flocculation. Optimum dose varies for with the coagulant selected. If less or more than optimum dose is used, it may result in poor efficiency of COD removal.

Hence, post pH optimization, the coagulant dose was standardized by varying it from 1000 mg/l to 3000 mg/l for both PAC and FeCl3. A fixed anionic poly electrolyte dose of 5 ml was added in each beaker as coagulation aid.

The optimum dose selected for PAC and FeCl3 both was such that maximum COD removal was achieved at that particular coagulant dose. Based on the study, for PAC the coagulant dose of 1000 mg/l was found optimum while for FeCl3 it was found to be 1500 mg/l. Maximum COD reduction achieved by 1000 mg/l dose of PAC was 89.4 % and for 1500 mg/l dose of FeCl3 was 81.8 %

PAC	pH	8	8	8	8
	Dose	1000	1500	2000	3000

	COD	2683	6283	6092	6741

Table 6: Coagulant dose optimization for PAC

FeCl3	pH	9	9	9	9
	Dose	1000	1500	2000	3000
	COD	6473	4569	5331	5792

Table 7: Coagulant dose optimization for FeCl3

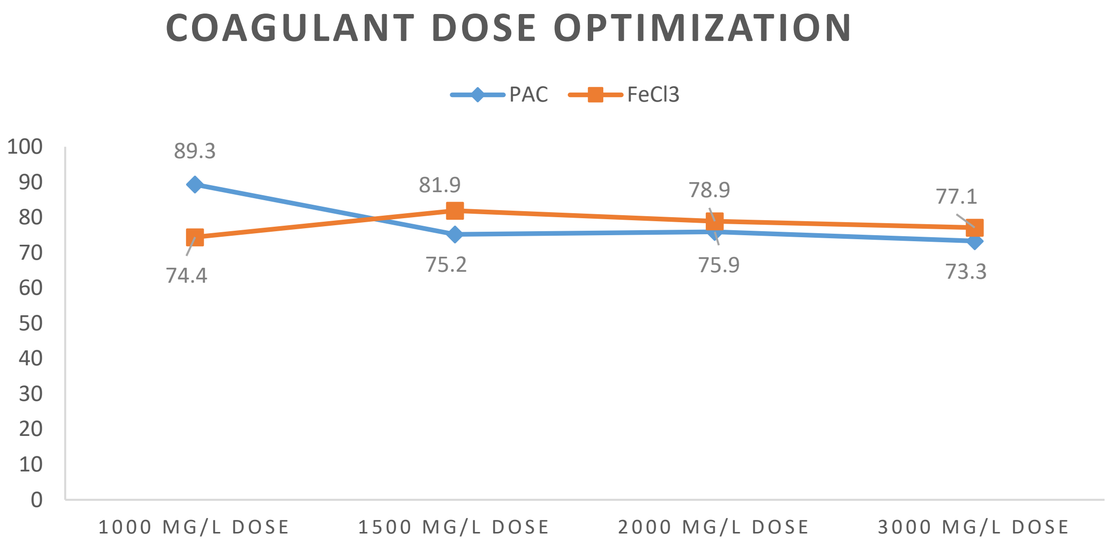


Figure 4: COD reduction in % through coagulant dose optimization

5. Conclusion

The study concludes that coagulation-flocculation process is highly sensitive to pH and coagulant dose. Optimum pH and coagulant dosage helps in achieving maximum COD removal for the selected industrial effluent.

While comparing performance of PAC to that of FeCl3, PAC was found to be more efficient in COD removal. At optimum pH of 8, and optimum dose of 1000 mg/l, PAC was able to achieve COD reduction by 89.3 % while FeCl3 at optimum pH of 9 and optimum dose of 1500 mg/l was able to achieve COD reduction by 81.9%

Influence of other conditions such as temperature and mixing process can be considered for future study on this topic.

6. References

i. Abdul Fattah Abu Bakar,Azhar Abdul Halim, "Treatment of automotive wastewater by coagulation-flocculation using poly-aluminium chloride (PAC),ferric chloride (FeCl3) and aluminium sulphate (alum)", School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia (2013)

ii. Debabrata Mazumdar, Somnath Mukherjee, “Treatment of Automobile Service Station Wastewater by Coagulation and Activated Sludge Process, International Journal of Environmental Science and Development, Vol.2, No.1 (2011)

iii. N. Nasir, Z. Daud, “Performance of aluminium sulphate and poly aluminium chloride in biodiesel waste water”, Journal of Mechanical Engineering and Sciences (JMES), Universiti Malaysia Pahang, Malaysia,ISSN (Print): 2289-4659; e-ISSN: 2231-8380; Volume 7, pp. 1189-1195 (2014)