

Industrial Polymer Effluent Treatment by Chemical Coagulation and Flocculation

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ABSTRACT

Polymer industries generate significant amounts of effluent which has to be treated before being discharged into water stream. So far, very little attention has been paid towards polymer effluent treatment by physio-chemical process. In the present study, chemical coagulation-flocculation process was used to separate solids from industrial polymer effluent in order to make the effluent dischargeable with suitable characteristics. Aluminium Sulphate $[Al_2(SO_4)_3]$ and Anionic Polyacrylamide (Magnafloc155) were used as coagulant and flocculant respectively. Sulphuric Acid (H_2SO_4) and Lime solution $[Ca(OH)_2]$ were used to adjust the pH values during the treatment process. A series of jar tests were conducted with different values of pH and dosing amounts of coagulant and flocculant. After each test, the supernatant layer of treated effluent was analysed for Chemical Oxygen Demand (COD), Suspended Solids (SS), colour and Turbidity. The process efficiency varied between 10 and 98% in COD removal, between 23 and 91% in suspended solids removal and between 37% and 99% reduction in turbidity. The optimal working pH value for coagulation was found to be 6 and that for flocculation was 8. The optimal doses of coagulant and flocculant were 7.5 mL per litre of effluent. These jar testing results have

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24 been further proved by a successful pilot scale trial at the polymer plant with 1000 L effluent in
25 an Intermediate Bulk Container (IBC) using the same optimal values of the jar tests, which
26 indicates that the chemical coagulation and flocculation process is a feasible solution for the
27 treatment of effluent generated at polymer industry.

28 **Keywords**

29 Polymer effluent, water-based emulsion, effluent treatment, chemical treatment, coagulation and
30 flocculation.

31 **1 Introduction**

32 Polymer industry is the world's fastest growing sector due to ever increasing demand of its
33 products. Polymer-based products have become an essential part of every day's life. Due to their
34 unique mechanical and thermo-physical properties, they are replacing wood, metal and many
35 other products. The high demand for polymers has resulted in a large quantity of polymer
36 effluent that needs to be treated in order to protect the environment and aquatic life.

37

38 The industrial polymer effluent contains residual polymers in water or caustic solution and has
39 higher level of suspended solids and organic materials. This effluent is usually milky in colour
40 containing finely dispersed solids particles called colloids which are stabilised by negative
41 electric charges on their surface, causing them to repel each other. The repulsion between these
42 particles prevents them from settling and keeps them in suspension. These particles cannot be
43 easily separated with conventional physical methods such as filtration or settling and therefore,
44 require the addition of chemicals to neutralise the charges on colloidal particles.

45

46 There are a number of processes available for water and wastewater treatment such as chemical
47 coagulation-flocculation, electro-coagulation, electro-floatation, sedimentation precipitation,
48 extraction, evaporation, membrane filtration, adsorption on activated carbon, ion-exchange,
49 oxidation and advanced oxidation, incineration, bio-degradation and electrochemical treatment
50 etc. However, complete treatment of wastewater usually require number of steps and it is often
51 appropriate to combine more than one method of treatment and purification before the maximal
52 efficiency/purity can be obtained, knowing that each method has its advantages and its
53 disadvantages. [1-6].

54
55 Coagulation-flocculation is one of the most practised technologies extensively used on industrial
56 scale wastewater treatment [7-12]. The removal mechanism of this process is mainly due to the
57 charge neutralization of negatively charged colloids by cationic hydrolysis products which
58 allows the Van der Waals force of attraction to encourage initial aggregation of colloidal
59 particles to form microflocs [13]. The efficiency of coagulation-flocculation process depends on
60 the coagulant type, dosage, pH value, temperature, ionic strength, nature and concentration of
61 organic matter, total dissolved solids, size and distribution of colloidal particles in suspensions
62 and several other factors [14, 15]. Coagulation-flocculation is an important unit operation in
63 wastewater treatment of many industries such as pulp and paper, pharmaceutical, petrochemical,
64 cosmetics, food, mineral processing, metal working and textile [16]. This technique has been
65 successfully employed for the treatment of the effluents from tannery [17], yeast wastewater[18],
66 textile [19, 20], petroleum refinery [8], dyebath and dye house [21], aquaculture [13], vinasse
67 [22], municipal [23, 24] , landfill leachates [25], pulping [26, 27], olive mill [28] and many other.
68 These multitudes of applications on the examination of coagulation–flocculation for the

69 industrial effluents treatment aim mainly at the performance optimisation. Although chemical
70 coagulation and flocculation may be a feasible solution for the treatment of effluent from
71 polymer industry, few studies have been carried out to investigate the polymer effluent treatment
72 using coagulation and flocculation processes. In fact, the studies on the polymer effluent
73 treatment are also quite limited. *Araya et al.* investigated the anaerobic treatment of effluents
74 from an industrial polymers synthesis plant and were able to reduce the COD value by 75% by
75 using the anaerobic treatment process [29].

76
77 The effectiveness of coagulation depends on the coagulating agent used, the dosage, the solution
78 pH, the concentration and the nature of the organic compound present in the water [30]. The
79 widely used coagulants are iron and alum salts. These coagulants promote particles
80 agglomeration by reducing the electrostatic particle surface charges in the acidic pH region
81 prominently where hydrolysed metal species are abundant [8]. The aluminium salts are
82 commonly used coagulants for water and wastewater treatment [31]. One of the most widely
83 used coagulant is Aluminium Sulphate (alum), due to its low cost, ease of use, handling, storage
84 and mixing properties [32].

85
86 The flocculant adsorbs destabilised colloidal particles with loop and tails extending into the
87 solution for bridging with other particles [33]. The long chain polymers attach at a relatively few
88 sites on the particles, leaving long loops and tails which stretch out into the surrounding water.
89 Flocculation is usually more effective with higher molecular weight polymers. Adding excessive
90 amount of polymer results in entire particle surface becoming coated with polymer, such that no
91 sites are available to 'bridge' with other particles [34]. The flocs structure may differ as a

92 function of physical-chemical conditions, as the flocs formed at the lower pH and dose are
93 reported to be denser and less porous than those formed at higher pH and dose [35].

94

95 In the present study, an investigation on the treatment of effluent generated from an industrial-
96 scale polymer plant was conducted by the chemical coagulation-flocculation. The polymer
97 manufactured at the plant was water based, mainly consisting of Acrylic Acid, Methylacrylic
98 Acid, Maleic Acid and their derivatives. A series of jar tests were conducted in order to
99 determine the optimal dosage and pH for coagulation and flocculation. The experimental results
100 were evaluated using major ecological parameters, like Chemical Oxygen Demand (COD),
101 Suspended Solids (SS), colour and turbidity values.

102 **2 Materials and methods**

103 **2.1 Materials**

104 Aluminium Sulphate [$\text{Al}_2(\text{SO}_4)_3$] and Magnafloc155 (Anionic polyacrylamide) were used as
105 coagulant and flocculant respectively. Sulphuric acid (H_2SO_4) and Lime solution [$\text{Ca}(\text{OH})_2$] were
106 used for regulating the pH value of effluent during the treatment processes. The details of used
107 materials are described in Table 1.

108

Table 1. Materials characteristics.

Chemicals	Formula	Physical Form	Molecular Weight (g/mole)	Concentration (%)	Purpose
Sulphuric Acid	H ₂ SO ₄	Liquid	98.01	77	pH adjustment
Aluminium Sulphate	Al ₂ (SO ₄) ₃	Powder	342.15	26	Coagulant
Lime	Ca(OH) ₂	Powder	74.093	12	pH adjustment
Magnafloc155	-C ₃ H ₅ NO-	Powder	5x10 ⁶	0.16	Flocculant

110 2.2 Sampling

111 The effluent samples were collected from the polymer manufacturing plant at Scott Bader
112 Company Limited situated in Northamptonshire, UK. The samples were collected from the outlet
113 of the holding tank where the effluent is stored before it is sent to the effluent treatment plant.

114
115 The initial solid contents in the effluent samples collected were 1.0% on dry basis. Various
116 characteristics of the effluent were determined according to the Standard Methods [36] and are
117 summarised Table 2. The target values are defined for Scott Bader as the discharge consent
118 limits by Anglian Water (regulated under the Water Industry Act 1991).

119

120

Table 2. Physico-chemical characteristics of the pre-treated effluent.

Parameters	Units	Initial Values	Target Values
Temperature	°C	45	<40
PH	–	13	6–10
COD	mg/L	>20,000	<6000
SS	mg/L	3500	<1000
Turbidity	NTU	750	<20

121 2.3 Jar tests

122 The jar test has been the standard technique used to optimise the addition of coagulants and
123 flocculants used in the water and wastewater treatment industry from more than half a century.
124 The scope of this practice is to evaluate the treatment to reduce the suspended, colloidal and non-
125 settable matter from the effluent by chemical coagulation-flocculation. The same standard was
126 utilized to evaluate the variables normally encountered in the coagulation-flocculation process
127 [13].

128
129 Considering the number of possible jar tests and total effluent volume of 15 L available for all
130 these tests, it was decided to use 200 mL sample for each jar test. The resulting optimal pH and
131 dose of chemicals was then applied to 500 mL and 1000 mL of the remaining sample and the
132 same results were observed as those for 200 mL. The equipment used was a laboratory
133 flocculator model JLT-4 VELP by Scientifica, Italy equipped with four parallel beakers. A
134 volume of 200 mL of the polymer effluent was placed in each beaker. The desired pH for
135 coagulation was adjusted using Sulphuric Acid (H_2SO_4) and for flocculation using Lime solution
136 $[(Ca(OH)_2]$. Inorganic coagulant Aluminium Sulphate $[Al_2(SO_4)_3]$ and anionic polyacrylamide
137 flocculant (Magnafloc155) were used in different combinations.

138
139 For coagulation, vigorous mixing at 200 rpm was used for 5 minutes whereas for flocculation,
140 slow mixing at 40 rpm was used for 5 minutes followed by settling time of 30 minutes. Two
141 series of jar tests were conducted according to the standard test methods [37]. In the first series,
142 the dose of coagulant and flocculant was varied from 0.5 to 2.5 mL. In the second series, the pH

143 for coagulation was varied from 4 to 8 and for flocculation 6 to 10. The final pH, COD, SS,
 144 colour and turbidity of the supernatant were then measured.

145 2.4 Analysis

146 The methods and equipment used for determining the pH, COD, SS, TS and Turbidity are shown
 147 in Table 3. All analyses were performed according to the Standard Methods [36].

148

149 **Table 3.** Analytical methods and equipment used in the study.

Parameter	Method	Apparatus	Range	Brand/Model	Reference
pH	Electrometry	pH Meter	0–14	HANNA Instruments HI2212	Standard Methods [36] APHA 4500-H
COD	Spectroscopy	Photometer	20–20,000 mg/L	PALINTEST 8000	Standard Methods [36] APHA 5520-B
Turbidity	Nephelometry	Turbid meter	0.01–1100 NTU	HANNA Instruments TB200	Standard Methods [36] APHA 2130
Total Solids	Evaporation	Moisture Analyser	0–36 %	OHAUS MB35	Standard Methods [36] APHA 2540

150 3 Results and Discussion

151 3.1 The coagulation-flocculation process

152 The coagulation-flocculation process was completed in four steps. In the first step, the pH of
 153 effluent was adjusted to 6 as the optimum pH for Aluminium Sulphate is between the range of
 154 5.8 to 6.5 [38]. The second step was the addition of coagulant (Aluminium Sulphate) to
 155 destabilise the colloidal particle of emulsion. In the third step, pH was adjusted to 8 using lime
 156 as Magnafloc155 tends to work best in the pH range of 6 to 10 [39] which was also suggested by
 157 the manufacturer, Goldcrest Chemicals Limited, UK. In the final step, flocculant (Magnafloc155)

158 was added to bridge the destabilised colloidal particles together to develop larger flocs. The same
159 procedure was repeated for the second series of the experiments in which the concentration of
160 the coagulant and flocculant were kept constant but pH values for coagulation and flocculation
161 were changed. The effects of coagulant-flocculant concentration and pH were analysed on the
162 removal of COD, suspended solids, colour and turbidity.

163 **3.2 Effects of coagulant and flocculant doses on the removals of COD, suspended** 164 **solids, colour and turbidity**

165 The effects of coagulant and flocculant doses on the removals of COD, SS and turbidity were
166 investigated at constant pH values of 6 for coagulation and 8 for flocculation with varying doses
167 of the reagents. pH is a measure of the acidity or alkalinity of water and is one of the stable
168 measurements. pH is a simple parameter but is extremely important, since most of the chemical
169 reactions in aquatic environment are controlled by any change in its value. Anything either
170 highly acidic or alkaline would kill marine life. Aquatic organisms are sensitive to pH changes
171 and biological treatment requires pH control or monitoring. The toxicity of heavy metals also
172 gets enhanced at particular pH. Thus, pH is having primary importance in deciding the quality of
173 wastewater effluent. Waters with pH value of about 10 are exceptional and may reflect
174 contamination by strong base such as NaOH and Ca(OH)₂ [40]. The range of desirable pH of
175 wastewater prescribed for discharge purpose by Anglian water was 6.0 to 10.0. The pH value of
176 effluent samples collected was observed as 13.0, well above from the permissible limit.

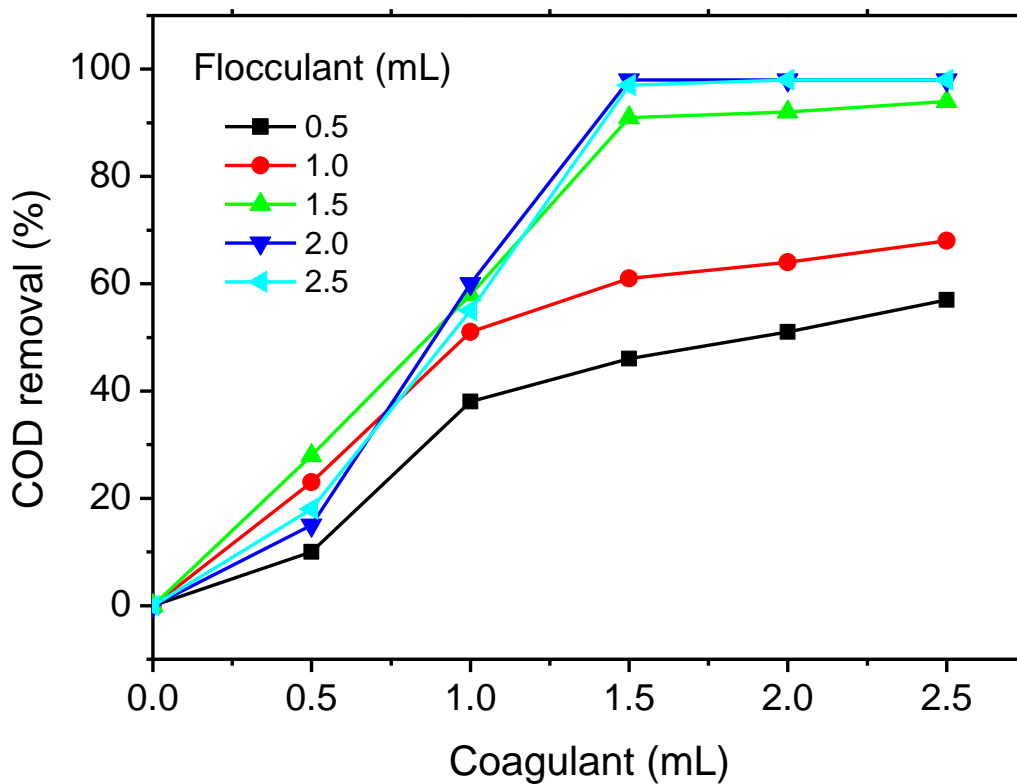
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178 Chemical Oxygen Demand value is useful in specifying toxic condition and presence of
179 biologically resistant substances. It is an important, rapidly measured parameter for industrial
180 wastewater studies and control of waste treatments. The COD value is a measure of the relative

181 oxygen-depletion effect of a waste contaminant and has been widely adopted as a measure of
182 pollution effect [41].

183

184 The COD value in collected effluent was observed to be greater than 20,000 mg/L whereas the
185 discharge consent limit allowed by Anglian Water authorities is only 6000 mg/L. The effects of
186 the coagulant and flocculant doses on the removal of COD are shown in Fig. 1.



187

188 **Fig. 1.** COD removal with different coagulant and flocculant doses.

189

190 It can clearly be seen that the COD removal increased with the increase in coagulant and
191 flocculant doses until the maximum values were obtained. When the doses of coagulant and

192 flocculant were 0.5 mL (in 200 mL sample), the removal of COD was about 10% but it increased
193 to 51% which is still not sufficient for the required standard (<6000 mg/L) when both doses
194 increased to 1.0 mL; however, when the coagulant dose was increased from 1.0 to 1.5 mL
195 combined with the addition of 1.5mL of flocculant, a significant improvement in COD removal
196 efficiency was achieved with the COD removal of 91% with the corresponding COD value (1800
197 mg/L) much smaller than the required standard value. At the coagulant dosage of 1.5 mL and
198 flocculant dose of 2.0 mL, the COD removal was at the highest level, 98%. With a further
199 increase in the coagulant dose up to 2.5 mL, no further significant COD reduction was observed.

200

201 Both the scientific literature and international water quality guidelines relating to SS are
202 dominated by the implicit assumption that the concentration-response model applies to SS effects
203 on aquatic biota (i.e. increase in SS = increase in effect on aquatic biota) [42]. Indeed, numerous
204 authors have reported that the magnitude of the effects of SS on aquatic organisms generally
205 increases with SS concentrations. However, other factors such as the duration of exposure,
206 particle-size distribution and chemical composition of the SS, and the presence of other
207 contaminants on the solids also appear to have an important control over the effect of SS on
208 aquatic biota. Suspended solids can harbour opportunistic pathogens and speed up the growth of
209 bacteria. They are associated with environmentally-induced disease problems, and have been
210 reported to cause sub-lethal effects such as fin rot and direct gill damage [43]. The effects of the
211 coagulant and flocculant doses on the removal of SS are shown in Fig. 2.

212

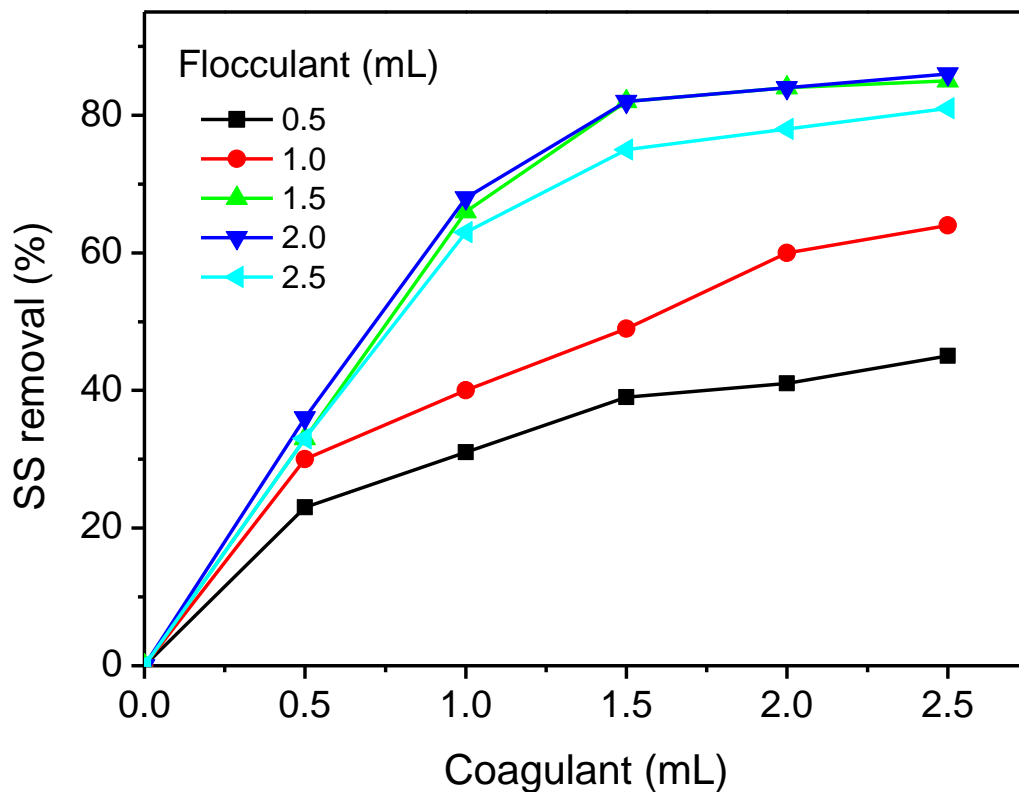
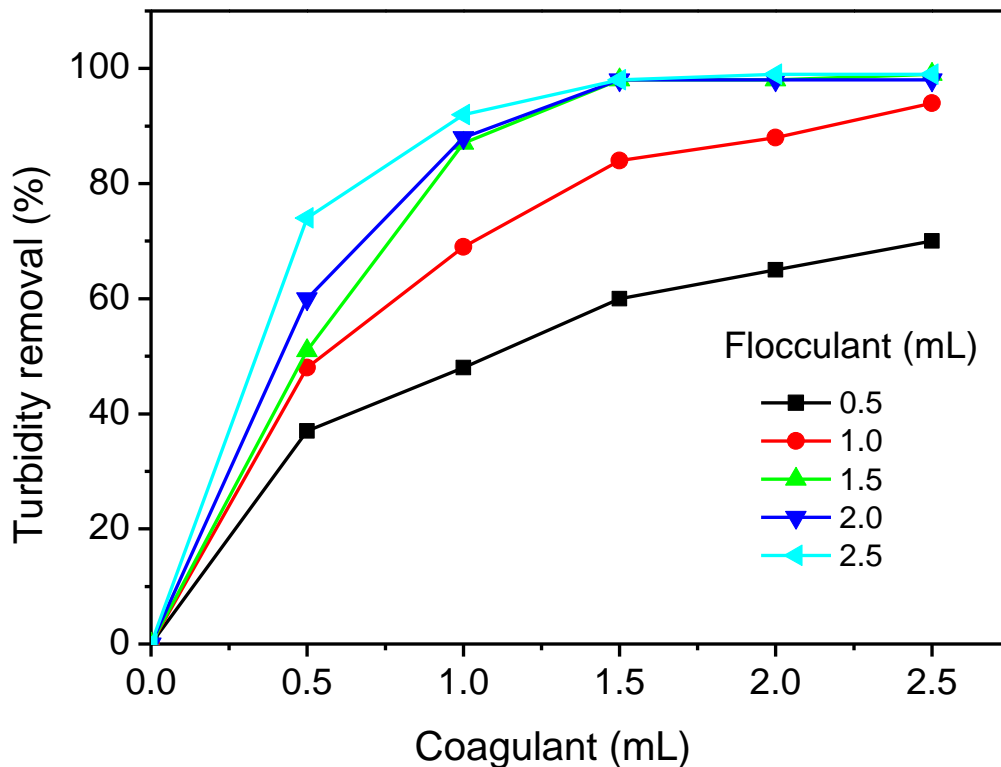


Fig. 2. SS removal with different coagulant and flocculant doses.

213
 214
 215
 216 It can clearly be seen that SS removal increased with the increases in coagulant and flocculant
 217 doses until the maximum removal values were obtained, similar to what have been shown in Fig.
 218 1. For example, when the initial doses of coagulant and flocculant were 0.5 mL, the removal
 219 efficiency of SS was about 23% but it increased to 40% when both doses increased to 1.0 mL,
 220 which is still not sufficient for the required standard value (<1000 mg/L). When both the
 221 coagulant doses were increased to 1.5 mL, the SS removal efficiency was significantly high at 82%
 222 with the SS value (674 mg/L) being well below the required standard value. At the coagulant
 223 dosage of 2.5 mL and flocculant dose of 2.0 mL, the SS removal was at its highest level of 86%.

224 No significant SS reduction was observed for further increases in the coagulant and flocculant
225 doses beyond 1.5 mL.
226
227 Turbidity diffuses sunlight and slows photosynthesis. Plants begin to die, reducing the amount of
228 dissolved oxygen and increasing the acidity (decaying organic material produces carbonic acid,
229 which lowers the pH level), both of these effects harm aquatic life. Turbidity as sedimentation
230 can also affect ecosystem functions [44,45]. Fig. 3 shows the removal of turbidity with different
231 coagulant and flocculant doses at constant pH values of 6 and 8 for coagulation and flocculation
232 respectively.



233

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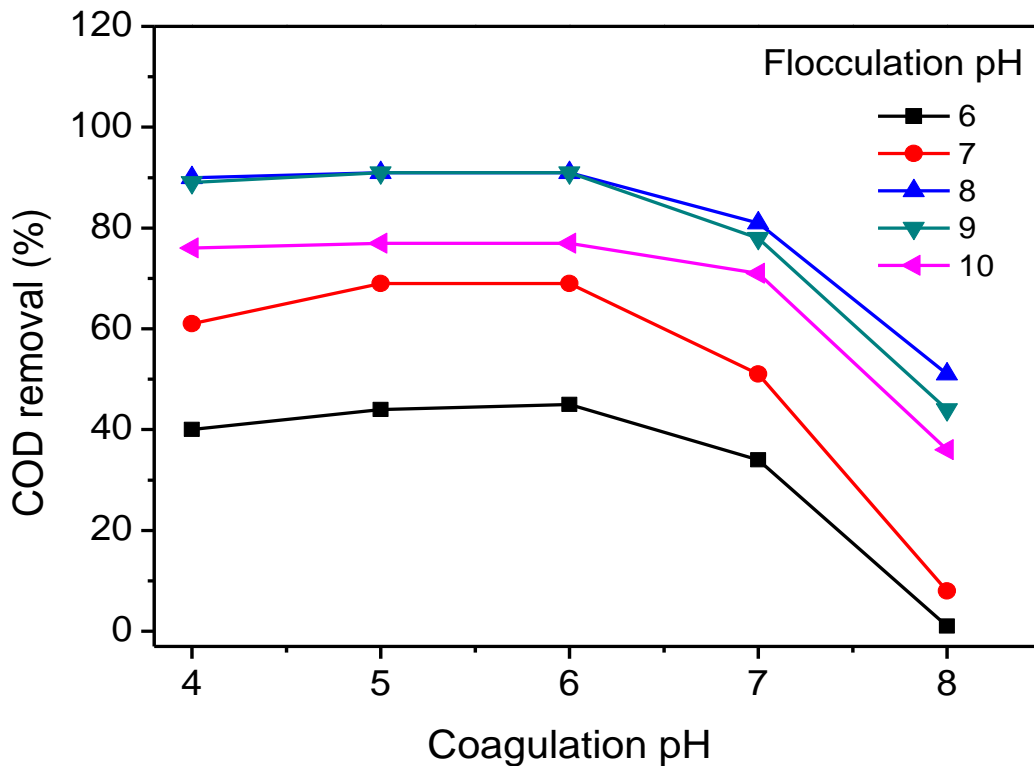
Fig. 3. Turbidity removal with different coagulant and flocculant doses.

235 Similar to the COD and SS removals, the turbidity removal increased with the increase in
236 coagulant and flocculant doses until the maximum values were obtained. With the doses of
237 coagulant and flocculant at 0.5 mL, the removal efficiency of turbidity was about 37%. When
238 both doses increased from 0.5 to 1.0 mL, the removal of turbidity increased to 69% but still not
239 up to the required standard value (<20 NTU). When both the coagulant dose and the flocculant
240 dose were 1.5 mL, the total turbidity removal reached 98% with the turbidity value (18 NTU)
241 being well below the required standard value. At the coagulant dosage of 2.5 mL and flocculant
242 dose of 1.5 mL, turbidity removal was at its highest level of 99%.

243
244 This series of tests showed that it was possible to achieve the maximum removal efficiency of 98%
245 for COD, 86% for SS and 99% for turbidity. When both the coagulant and the flocculant doses
246 were increased from 1.0 mL to 1.5 mL remarkable improvements in removal efficiencies were
247 observed. Visual inspection also showed that with the increase in coagulant and flocculant
248 dosage, the supernatant became clearer as shown in Fig. 1. On the other hand, the targeted values
249 of COD, SS and turbidity were well within the range of 91%, 82% and 98% removals
250 respectively which are quite close to the best values. Therefore it can be concluded that the
251 coagulant dose of 1.5 mL and flocculant dose of 1.5 mL are optimal doses for the targeted values
252 of the all three parameters.

253 **3.3 Effects of pH on the removal of COD, suspended solids, colour and turbidity**

254 The effects of pH values on the removals of COD, SS and turbidity were investigated at a
255 constant dose of 1.5 mL (in 200 mL sample) of coagulant and 1.5 mL (in 200 mL sample) of
256 flocculant whereas the pH values for both steps were varied. The removal percentage of COD
257 with varying pH values for coagulation and flocculation is shown in Fig. 4.



258
259 **Fig. 4.** COD removal with varying pH values for coagulation and flocculation.

260

261 Divergent from the series one tests where the pH value for coagulation and flocculation were

262 fixed at 6 and 8 respectively, the pH values for the series two tests were changed from 4 to 8 for

263 coagulation and from 6 to 10 for flocculation., Fig. 6 shows that the percentage of COD removal

264 increases up to the maximum level of 98% then starts to decrease with an increase in the pH

265 value for either coagulation or flocculation. At an initial pH value of 4 for coagulation and 6 for

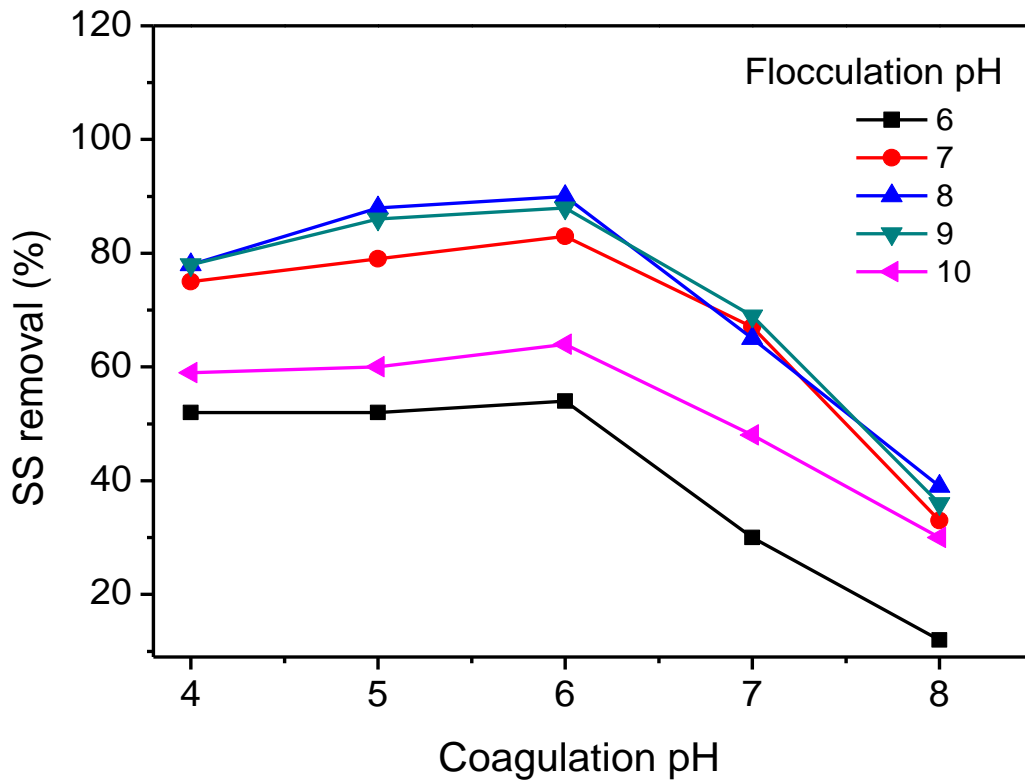
266 flocculation the removal percentage of COD was 40% while changing pH value to 5 for

267 coagulation and 6 for flocculation led to the COD removal percentage of 69%, which is still not

268 sufficient for the required standard value (<1000 mg/L). Further increases in pH value to 6 for

269 coagulation and 8 for flocculation resulted in the COD removal to the highest level of 91%.

270 Further increases in the pH value for coagulation to 8 and for flocculation to 10 resulted in a
271 decrease in the COD removal efficiency (down to 36%).

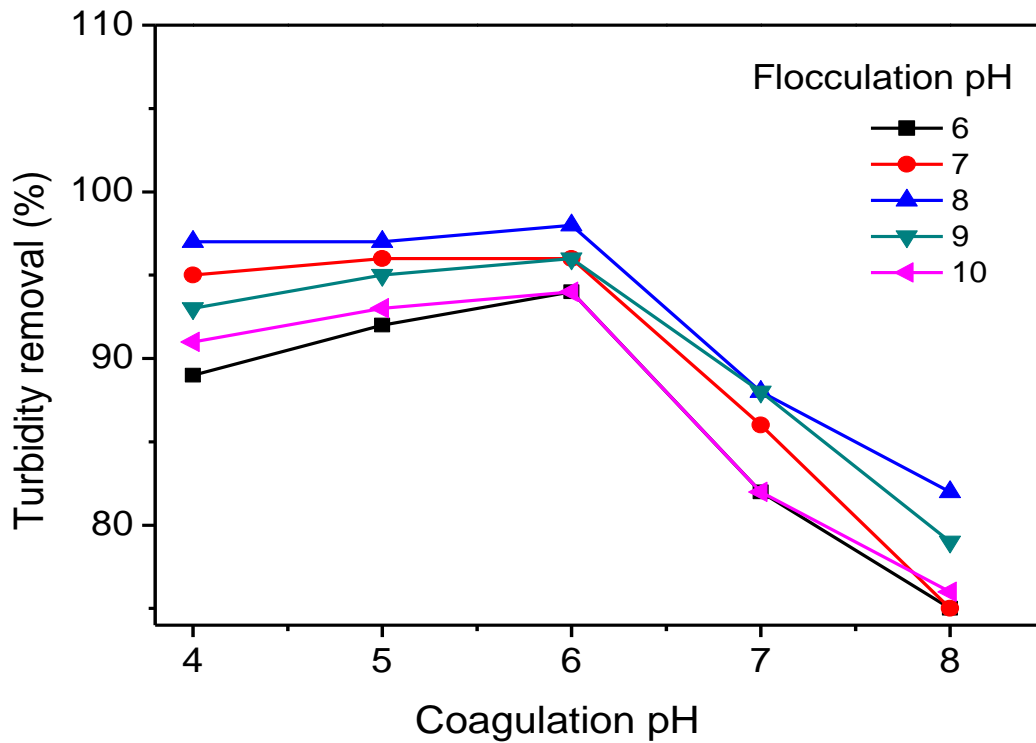


272 **Fig. 5.** SS removal with varying pH values for coagulation and flocculation.
273

274

275 Fig. 5 shows the variation of the removal percentage of SS with the pH values for coagulation
276 and flocculation. It is clear that when the pH values for coagulation were changed from 4 to 8
277 and for flocculation from 6 to 10, the percentage of SS removal increases up to a certain level
278 then starts decreasing. At the pH value of 4 for coagulation and 6 for flocculation the removal
279 percentage of SS was 52%. Changing the pH value from 4 to 5 for coagulation and from 6 to 7
280 for flocculation, the removal percentage of SS increased to 79% which is still not sufficient to
281 achieve the standard value (<1000 mg/L). A further increase in the pH value to 6 for coagulation

282 and to 8 for flocculation resulted in the maximum SS removal efficiency of 90% SS. Any further
283 increase in the pH values for coagulation and flocculation lead to a reduction in SS removal. The
284 effects of pH values on the removal of turbidity are shown in Fig. 6.

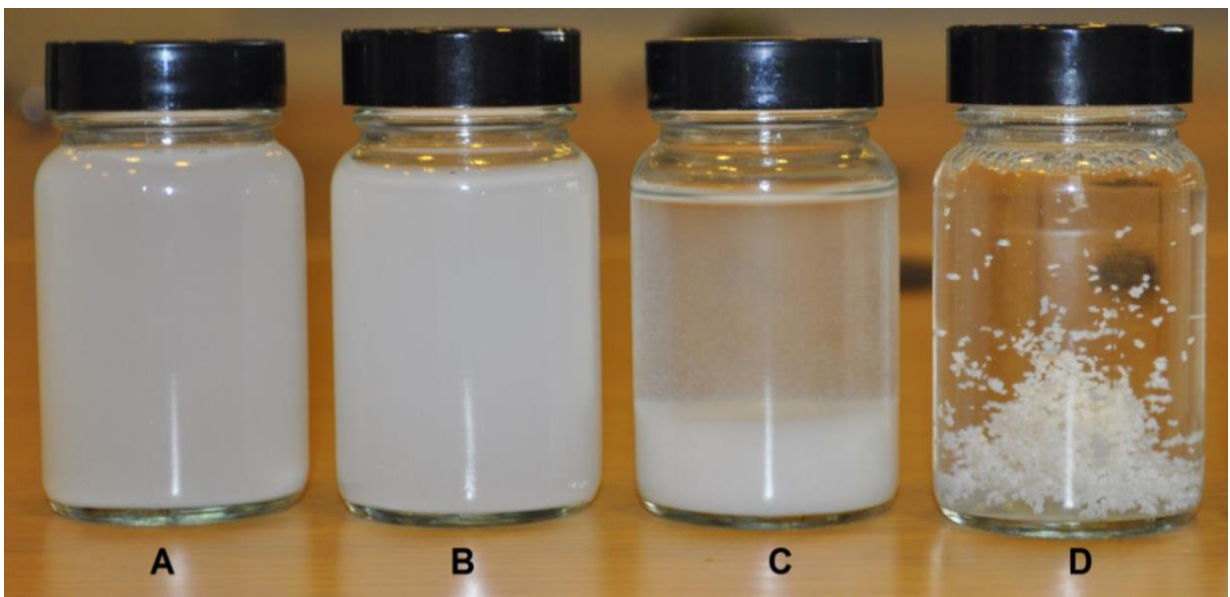


285 **Fig. 6.** Turbidity removal with varying pH values for coagulation and flocculation.
286

287
288 In contrast to the trends of COD and SS removals shown in Figs. 5-6, the pH value of
289 flocculation has a much smaller influence on the removal of turbidity. In addition, within the
290 ranges of the investigated pH values (4 to 8 for coagulation and 6 to 10 for flocculation), the
291 percentage of turbidity removal remained above 80% although it peaked to 98% at the pH value
292 of 6 for coagulation and 8 for flocculation.

293

294 The second series test results showed that the maximum removal efficiencies of 91% for COD,
295 90% for SS and 98% for turbidity could be achieved with the pH value of 6 for coagulation and 8
296 for flocculation. Under these conditions, the required target values for COD, SS and Turbidity
297 were all successfully achieved. Therefore, it can be concluded that the pH value of 6 for
298 coagulation and pH value of 8 for flocculation are the optimal pH values for targeted parameters.
299 Examples of jar tests, which yielded good results, are shown in Fig. 7.



300
301 **Fig. 7.** Effluent samples during treatment: (A) acid addition, (B) coagulant addition, (C) lime addition,
302 and (D) flocculant addition.

303
304 These jar tests were then followed by a successful pilot scale trial at the polymer plant with 1000
305 litres of effluent in an Intermediate Bulk Container (IBC) using the same optimal pH and dosage
306 values. 1000 litres of the effluent was transferred into an open top Intermediate bulk container
307 (IBC) with an air driven agitator fitted on it and spinning at 30 rpm. The total solids in this
308 effluent were 1.1% (dry basis). The pH of the effluent was adjusted to 6 by adding 77%
309 sulphuric acid. 7.5 litres of coagulant (26% aluminium sulphate) solution was added into IBC.

310 The pH was re-adjusted to 8 by manually adding 12% lime solution. Then 7.5 litres of flocculant
311 (0.16% Magnafloc) was added and the agitator speed was slowed down to 15 rpm. The agitator
312 was stopped 5 minutes after adding flocculant and the flocs were allowed to settle. After 10
313 minutes of sedimentation, the sludge was settled at bottom taking about 15% volume of IBC.
314 Supernatant water was collected for analysis and the results showed its pH 7.9, Suspended Solids
315 280 mg/L, COD 350 mg/L, Turbidity 20 NTU. These values were quite similar with those of jar
316 tests.

317
318 The results of the present study are also better than those of few studies on the treatment of
319 polymer effluent [29] found in the literature. Ayara et al. [29] investigated the feasibility of the
320 anaerobic treatment of an industrial polymer synthesis plant effluent having the initial COD
321 value of about 2000 mg/L. Their process was able to reduce the COD value by 75%, which is
322 much smaller 91% achieved with the present work.

323 **4 Conclusions**

324 The chemical coagulation-flocculation process for the treatment of effluent from a polymer
325 industrial plant showed a great potential to reduce the COD, SS, colour and turbidity. The
326 process effectively removed COD, SS and turbidity up to 98%, 91% and 99% respectively.
327 However, the jar tests found that the treatment process was highly sensitive to the pH values and
328 the coagulant and flocculant doses used for the effluent treatment. The targeted values of the
329 main parameters (COD<6000 mg/L, SS<1000 mg/L and turbidity < 20 NTU) were achieved by
330 the coagulant and flocculant doses of 7.5mL/L(1.5 mL per 200 mL of effluent) each at the pH
331 value of 6 and 8 respectively. Thus 7.5 mL/L doses of coagulant and flocculant at pH values of 6
332 and 8 were found to be optimal conditions for the effluent treatment. Under the optimal

333 conditions, the final values of COD, SS and turbidity were 1750 mg/L, 354 mg/L and 18 NTU
334 respectively, meeting their respective standard values. The jar test results were also confirmed by
335 a successful pilot scale trial at the polymer plant with 1000 L effluent in an Intermediate Bulk
336 Container (IBC) using the same optimal values. So far, there are only a few studies having
337 investigated the treatment of polymer effluent and therefore more investigations are required.
338 The chemical coagulation and flocculation process has been shown to be a feasible solution for
339 the treatment of effluent from polymer industry.

340

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