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ORIGINAL ARTICLE

Effect of pH on Separation of Solid Content from Paint Contained Wastewater by a Coagulant-flocculant Compound

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KEYWORDS

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ABSTRACT: Chemical wastewater treatment is one of the attracting and common methods for wastewater treatment among the currently employed chemical unit processes. The use of coagulant-flocculant compound is one of the efficient methods for separating of paint and recovery of water. In this research, it was introduced and the effect of pH on removal of solid content from solution was studied experimentally. For this purpose, sludge and suspended solid content of the solution were determined in a jar test by measurement of UV absorption of treated solution and solid separation percentage. The results showed that in pH range 9.5-10.5, maximum efficiency of solid content removal was up to 95%. Consequently, maximum paint removal was obtained in this range of pH. The separation of solid content of the solution was due to formation of aluminum hydroxide. As shown by the results, the reduction of potassium hydroxide as pH adjuster caused decrease of pH and consequently decreases of aluminum hydroxide and solid content removal.

INTRODUCTION

In chemical industries, organic compounds are the most pollutants of effluent in water. The basis of water treatment process is separating solid-liquid phase. This process accomplish with chemical materials and special equipments. The high purity water can be achieved by this type of process and it can reuse in various industries. Flocculants and coagulants are used in suspending and coagulating process for separating of solid phase which exists as a suspension in a liquid. For ion separation, size and surface charge are two significant factors which play a vital role in coagulation-flocculation processes [1]. Coagulation is a process which neutralizes all negative charges of water and accordingly contaminations absorb each other. The use of polymeric Aluminum compound as a flocculant agent is more common these days. Poly Aluminum Chloride

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(PAC) and Poly Aluminum Phosphate are two clear-cut examples of mentioned compound.

Note that PAC application is more popular than other compounds. These kinds of coagulants efficiently act in a low temperature and wide range of pH. Polymeric coagulants usually have high charge density and chain length. They can surround the color by their metallic elements like Aluminum, Iron and Silicon. Through this process, the color is neutralized and removed [2, 3].

Aluminum sulphate is an example of flocculants that could bond with Sodium Hydrogen Carbonate or Potassium Hydroxide and they are formed insoluble metallic Hydroxides such as Aluminum Hydroxide and Iron Hydroxide. Generally, Hydroxides which are water-insoluble have such a low solubility and cause of polymeric and viscous form of water [4].

The coagulation of colloidal ions were examined in solutions which contain Humic acid/Aluminum sulphate solution at pH in range 4-10 and Aluminum sulphate (3-1000 µM Al). They studied the effects of colloidal ions with analyzing colloid surface change and UV absorbance of solution. The obtained results showed the appropriate performance range of coagulation (pH solution and quantity of Al) and the mechanism of coagulation [5].

In an *invitro* study, the effects of three organic coagulants were presented on decrease of discharge effluent turbidity in an industrial unitare. These coagulants consist of Aluminum sulphate, Ferric chloride II and Poly Aluminum chloride which optimum dosage and pH of each ones are determined. In the case of applying 20 mg/L of PAC at pH=6, optimum efficiency of decreasing wastewater turbidity are reached, although the maximum turbidity decrease up to 90% could be achieved by applying 50 mg/L of PAC at pH=6 [6].

The effects of pH, Aluminum and Iron concentration were studied on color removal from effluentsare. They presented the effects of those factors on amount of sedimentation in different Aluminum Hydroxide Compounds which form in accordance with correspondent reactions [7].

In an *in vitro* investigation, a novel formulation of Poly Aluminum chloride and Potassium hydroxide along with other materials as pH adjuster and coagulant aid was introduced which increases the amounts of solid content removal to 96% [8].

The Polymeric chloride – Poly-epichlorohydrin-dimethylamine (PFC-ECH-DAM) composite flocculants with different OH/Fe ratios, Fe to organic ECH-DAM mass ratios and cross-linker types were comparatively investigated in terms of formed floc aggregation process and floc characteristics for the treatment of synthetic dyeing wastewater. The results demonstrated that the synergic effect of PFC with ECH-DAM promoted the formation of larger flocs with higher growth rate and wider distribution of floc sizes. During the coagulation of reactive red (K-2BP) dyeing wastewater, strengthened floc properties can be obtained at higher flocculant dosage ranges (>80 mg/L) and solution pH of about 7.5 [9].

Five novel coagulants, DC-491, Fennofix K97, BWD-01, MD-03 and MD-04 were chosen to treat reactive brilliant red X-3B simulated wastewater by jar tests. The results showed that the decolorization efficiencies were all higher than 75% at initial pH 8.2 and temperature 20 after 20 minutes of reaction. Then, two typical coagulants, BWD-01 and MD-04 which had better performance were chosen to study the effect of dye removal of X-3B at different operating parameters, including coagulant dosage, pH, and sedimentation time and reaction temperature of simulated wastewater. Decolorization efficiency of MD-04 for X-3B solution was higher than 80% in pH range from 3 to 9, while for

BWD-01, efficiency increased from 37.3% to 82.3% in this pH range [10].

Several options of decolorization of textile wastewater by chemical means have been reviewed. Based on this review, some novel pre-hydrolyzed coagulants such as Polyaluminium chloride (PACl), Polyaluminium ferric chloride (PAFCl), Polyferrous sulphate (PFS) and Polyferric chloride (PFCl) have been found to be more effective and suggested for decolorization of the textile wastewater. Moreover, use of natural coagulants for textile wastewater treatment has also been emphasized and encouraged as the viable alternative because of their eco-friendly nature [11].

The coagulation–flocculation treatment using $FeSO_4 \cdot 7H_2O$ as a coagulant was evaluated for the removal of organic compounds and color from synthetic effluents simulating the cotton, acrylic and polyester dyeing wastewaters. The obtained results showed that the optimal operating conditions were different for each effluent, and the process (coagulation–flocculation) as a whole was efficient in terms of color removal (~91% for cotton, ~94% for acrylic effluents; polyester effluent is practically colorless) [12].

The coagulation–flocculation process was studied to find out the performance of different coagulants and flocculants like alum, ferric chloride, Aluminium chloride, ferrous sulphate, poly Aluminium chloride (PAC), cationic and anionic Polyacrylamide polymers in individual form as well as in different combinations. The effects of dosing rate, settling time and pH were examined for reduction of COD, TSS and color. Coagulants used in combinations were found to be more effective in reducing COD, TSS and color instead of using individual form. The initial pH of the effluent for coagulation process was found to have remarkable effect on COD, TSS and color removal. The most effective results were found using cationic and anionic Polyacrylamide combination with ferric chloride and Aluminium chloride and reduction of 76% COD, 95% TSS and 95% color were observed at pH < 3 [13].

In this investigation, the effects of pH solution were experimentally examined on performance of color removal by coagulation–flocculationprocess. For this purpose, a new coagulant-flocculant compound was applied in the form of solid powder [14].

MATERIALS AND METHODS

Materials

*The Sample***:** For preparing the sample, a kind of alkyd paint (vehicle color paint-Hadi's brand) was dissolved in water such a way that the concentration of color in water equals 5gr/L. This concentration of color was chosen according to presented information by PPG (Italy) and BASF (Germany) companies about concentration of colors in effluent of automotive factories [15, 16].

Flocculant-Coagulant Materials

The new flocculant-coagulant compoundis were used to investigate the role of pH. This powdery substance contained the following composition that each of them played a role in the flocculation-coagulation process. The role of each component in flocculant-coagulant composition shows in Table 1.

Table 1. Composition of flocculant-coagulant powder [8]

Component	Weight percentage	Role
PAC	37	Coagulant
KOH	8	pH adjuster
$NaAlO_2$	40	Coagulant
Na_2SiO_3	4	Coagulant
Na_2CO_3	4	pH adjuster
PVA	6	Coagulant aid
PAA	1	Flocculant

Experimental

A mixer model RW20-n fabricated by IKA company was used for mixing coagulant-flocculant powder of sample. Its characteristics are listed in Table 2.

Table 2. Specifications of the mixer

Impeller Type	No. of Impeller	Impeller Dia.(mm)	Shaft Length(mm)	Shaft Dia.(mm)	Max. Speed(rpm)
Propeller	4	50	350	8	2000

UV Spectrophotometer model Ikon was supplied by Biotek-Kontron company which has one Tungsten lamp (for visible light) and one Deuterium lamp (for UV ray) was applied to determine the UV absorption. pH meter model RL-150 made by Russel company(England) was used to determine the quantity of solution pH.

Experimental procedure

A jar test was performed as one liter of the sample was poured into the mixer and mixed with 400 rpm speed. One gram of coagulant-flocculant powder was added during the mixing and mixing was continued within 1.5 minutes upon coagulating phenomena was completed. Then, mixing was implemented with 200 rpm speed within 15 minutes in order to flocculate the paint. For floating flocculated paint on the water, the solution was released within 2 hours. The paint which was turned into sludge was removed by filter Paper. pH of solution was changed by changing the quantity of Potassium Hydroxide. The operation was carried out in ambient temperature. The condition of the performed test shows in Table 3.

Table 3. The condition of the performed test

Coagulation Time(sec)	Coagulation Speed(rpm)	Focculation Time(sec)	Flocculation Speed(rpm)	Settling Time(hr)	Solution pH
90	400	900	200	2	8.5-10

Method of estimation of solid content removal

Presented method by PPG (Italy) and BASF (Germany) was applied to calculate the amount of solid content removal (paint plus coagulant-flocculant compound) which are suspended as a sludge in the solution such a way that sludge was separated from solution by paper filter[14, 15]. Then, the sludge was put on a watch glass and placed in oven with 105^{o}C within 2 hours until water was taken. If (a) shows the amount of remained solid after separation of water from the sludge and (b) shows the amount of coagulation-flocculation compound which was used, then color separation percentage was obtained by following equation. It should be noted that total amount of solid in the solution is flocculant-coagulant powder plus dissolved paint.

(I) a = Weight of solid content in the dry sludge (removed paintand coagulant-flocculant powder)

(II) b = Weight of remained (suspended) solid in the solution after coagulation-flocculation treatment

(III) c = Initial total weight of solid in the solution = $a + b$

(IV) Separation percentage of solid content $= (\frac{a}{c}) \times 100$

(V) Suspended solid content percentage

$$= (\frac{b}{c}) \times 100$$

RESULTS AND DISCUSSION

The variation of removed solid versus pH of solution is demonstrated in Figure (1). As it can be seen, due to increase of pH and alkalinity of solution, the amount of removed solid has been increased. Also, the most amount of solid has been separated when pH varied in range of 9.5-10.5. According to equation **IV** and considering that ***c*** is constant, increase of ***a*** (parameter of equation **I**) decreased band solution has the minimum amount of suspended solid when pH was in this range, as shown in Figure (2). Solid removal percentages in different pH are presented in Figure (3) which shows that maximum separation was achieved when pH varied in range of 9.5-10.5. Also, the results showed that in this range of pH, the minimum amount of solid spills existed in the remained solution and consequently, the minimum UV absorption of solution was obtained (Figure 4). For describing the phenomena, it should be mentioned that, the main coagulant agents in coagulant-flocculant composition contains *Al* ions, that surround color powder and neutralize them as it is illustrated in Figures (5) and (6). Furthermore, the alkaline pH of the solution, between 9.5-10.5, caused to release enough amount of OHions in solution which increased the intensity of reaction in order to produce aluminum hydroxide and consequently, to increase coagulation of paint ions and separating them. If pH of solution was decreased lower than the mentioned range (by decreasing potassium hydroxide which controls pH value), the intensity of reaction for production of aluminum hydroxide would decrease and, as a result, the required coagulating of solution for paint removal did not occur and this phenomena led to reduce the rate of paint removal. If pH solution increased more than 10.5, the extra amount of OH ions would remain in solution which caused the following reaction improved on the contrary way and reduced the quantity of Al ions thus lower amount of paint ions was coagulated in solution.

CONCLUSION

In this study, effects of pH on removal of solid content from painted wastewater were examined with a novel coagulant-flocculant composition. Experimental results showed that, as pH solution was closer to 10.5 and solution was more alkaline, amount of OH ions increased and coagulation of paint ions were improved. The increase of coagulation of paint ions caused increase of solid separation in sludge form and therefore, amount of suspended solid were reduced in the solution. Moreover, decrease of solution alkalinity (by decreasing of amount of potassium hydroxide formation) led to form the lower amount of Al $(OH)_3$ and consequently, coagulation and solid removal were decreased.

$$Al(OH)_3 \rightleftarrows Al^{3+} + 3OH^-$$

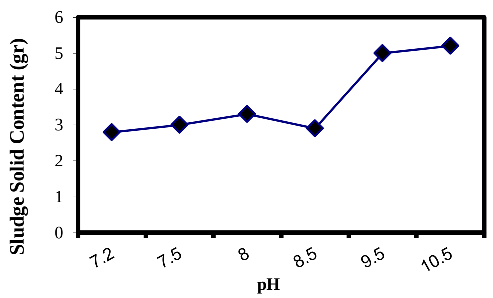

Figure1. Variation of separated solid as sludge in different pH

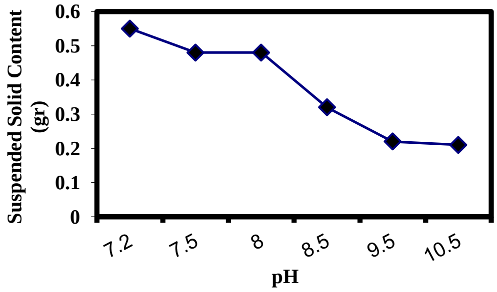

Figure 2. Variation of remaining suspended solid in solution in differentpH

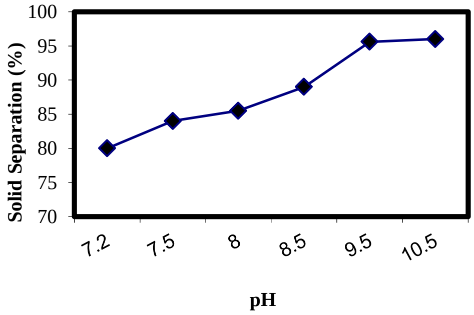

Figure 3. Variation of color solid separation percentage in different pH

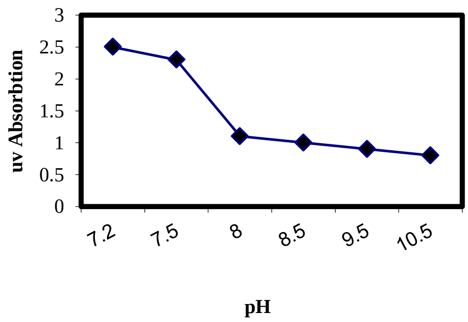

Figure 4. The absorption of solution after solid separation in different pH

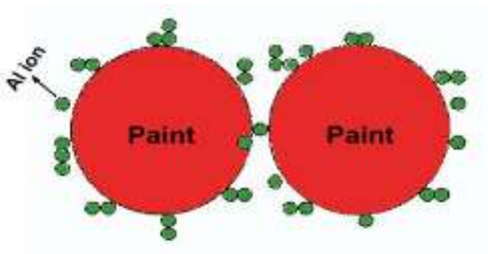

Figure 5: Illustration of surrounding paint ions by *Al* ions

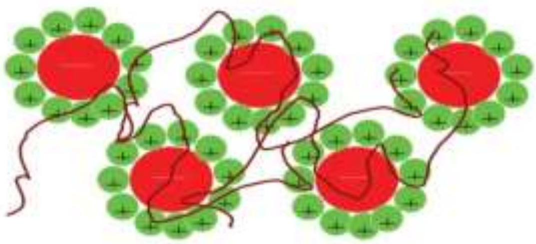

Figure 6. Coagulating-Flocculation phenomena on paint particles (ions)bypresence of the coagulant-flocculant powder in paint contained waste water

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