Asian Journal of Chemistry; Vol. 27, No. 9 (2015), 3503-3506

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2015.19108

Comparison of Different Coagulants for Removal of Phenol from Aqueous Solution

SARASWATI RANA and S. SURESH*

Advanced Industrial Pollution Abatement & Analytical Laboratory, Department of Chemical Engineering, Maulana Azad National Institute of Technology, Bhopal-462 051, India

*Corresponding author: E-mail: sureshpecchem@gmail.com

Received: 17 February 2015; *Accepted*: 18 March 2015; *Published online*: 26 May 2015; AJC-17283

In today's World with the degradation of environment, waste management has become important for sustainable development. Attempts were made in this study to examine the performance of coagulation and flocculation process using different coagulants [$FeCl_3$, alum, $FeSO_4$, polyaluminium chloride (PAC), tamarind seed powder, chitosan, xanthum gum] and polyelectrolyte for removal of phenol from aqueous solution. Also, the optimum conditions for coagulation/flocculation process, such as coagulant dose, pH solution, contact time, settling time, initial concentration and temperature were investigated using jar-test experiment. The results revealed that the optimal operating pH were 2, 4,6,4,6,4,8 and 5.8 for tamarind seed powder, $FeCl_3$, $FeSO_4$, alum, polyaluminium chloride, chitosan, xanthum gum and without coagulant, respectively. A maximum percentage removal of phenol was found to be 75 by addition of 100 mg/L polyelectrolyte. The sludge produced, when tamarind seed powder was used solely, was higher compared to the use of combination of polyelectrolyte and tamarind seed powder. The combined use of coagulant and polyelectrolyte resulted in the production of sludge with reduction of 76.3 % of the amount produced.

Keywords: Phenol, Coagulants, $FeCl_3$, Chitosan, Polyaluminium chloride, Ferrous sulphate, Xanthum gum.

INTRODUCTION

Water pollution is the second most important environmental issue after air pollution it's any undesirable change in the state of water. Phenol is one of the most important aquatic pollutants, found in the effluents of industries such as petroleum refinery, pharmaceutical, petrochemical, textile, paper and pulp, dye and cosmetics *etc.*[1]. Phenolic compounds are toxic, irritants for the skin, eye and mucous membrane it causes nausea, vomiting, pulmonary edema, hepatic injury, kidney injury, paralysis, heart damage, paralysis and death[1]. It also increases land infertility. These compounds are considered as the primary pollutants in wastewater by US Environmental Protection Agency (EPA)[2] due to their high toxicity, high oxygen demand & low biodegradability. Concentration of phenols should not be exceed 1 mg/L for their discharge into surface water and 5 mg/L for discharge into public sewers, land for irrigation and on marine coastal areas[3]. There are so many techniques for phenol containing wastewater treatment like-coagulation, adsorption, ozonation, ultra filtration, electrochemical oxidation, photo-degradation and biological process *etc.*[1,4-8]. These techniques have their own advantages and disadvantages. Among all above techniques, coagulation is an effective and useful process in terms of low cost, simplicity of design, easy availability of adsorbent, good effluent quality, easy to handling[9-12]. Inorganic metal salts and polyelectrolytes of various structures are used for coagulation process to enhance the formation of larger floc in order to improve the rate of sedimentation due to charge neutralization of negatively charged colloids by cationic hydrolysis products and incorporation of impurities in an amorphous hydroxide precipitate so-called sweep flocculation[13]. The relative importance of these mechanisms depends on factors such as pH and coagulant dosage. In the present study, different coagulants have been used for the removal of phenol from aqueous solution *e.g.*, tamarind seed powder, $FeCl_3$, alum, polyaluminium chloride, chitosan, ferrous sulphate, xanthum gum and without coagulant. The effect of process parameters such as coagulant dose, pH, contact time, settling time, initial concentration and temperature were also studied for the phenol removal efficiency.

EXPERIMENTAL

Phenol, NaOH, H_2SO_4 and HCl were purchased from S.D. Fine Chemicals, Ltd., New Delhi, India, alum and $FeCl_3$ was purchased from Central Drug House (P) Ltd, New Delhi, India, polyaluminium chloride and xanthum gum were purchased from National Chemicals, Vadodara, Gujarat, India, Ferrous sulphate was purchased from Himedia Laboratories, Mumbai, India and chitosan was purchased from Sisco Research Laboratories, Mumbai, India. The mature seed of tamarind was collected from local market, Bhopal and washed with water to remove dust and then dried in an oven at 65 ± 2 °C. The dried seed were crushed and powdered and sieved through 200 μm nylon sieves and used as coagulant.

Methods: Coagulation/flocculation process was performed in the conventional jar apparatus (Metrex Flocculator model, India) using 1 L phenol containing aqueous solution. Different operating parameters of pH (2-12), coagulant loading of tamarind seed powder, $FeCl_3$, $FeSO_4$, alum, polyaluminium chloride, chitosan, xanthum gum (g/L) (1-8), reaction time (30-180 min), temperature (25-75 °C) and polyelectrolyte loading (mg/L) (5-100) were tested. Effect of initial concentration of phenol solution was also tested (mg/L) (50-1000). The selected coagulant dosage was added to 1000 mL of phenol containing solution and it was stirred for a period of 2 min at 200 rpm. It was followed by a further slow mixing of 15 min at 40 rpm after the selected coagulant dosage was added to the same solution. The pH of the solution was adjusted by using 0.1 N of NaOH and HCl solution. The flocs formed were allowed to settle for 30 min. After settling, supernatants were analysis through HPLC system. The procedure of HPLC analyser for final concentration determination was given by Suresh *et al.*[1]. Settling study was carried by using non-ionic polyelectrolyte with and without coagulant. All parameters were determined according to the APHA method.

RESULTS AND DISCUSSION

Fig. 1 represents the effect of pH for removal of phenol using tamarind seed powder, $FeCl_3$, $FeSO_4$, alum, polyaluminium chloride, chitosan, xanthum gum and without coagulant. It is observed from graph that removals of phenol were higher at pH 2, 4, 6, 4, 6, 4, 8 and 5.8 respectively. Maximum removal of phenol found to be 48.4, 45.4, 42.6, 40.2, 36.4, 31.6, 22.3 and 13.5 % respective coagulants. Similar observations were observed by Aguilar *et al.*[14] for slaughter house effluents in-terms of reduction of chemical oxygen demand using $FeSO_4$, polyaluminium chloride as coagulants and found that optimum pH was 7 and 6 respectively. This is due to sweep floc mechanism predominates when under optimal pH conditions, the metal salt added is sufficient to exceed the solubility level of the amorphous metal hydroxide, which then precipitates[15]. Pan *et al.*[16] reported the mechanism related with pH for treatment of turbid water using modified chitosan. At acidic pH, it becomes a more charged and therefore produces smaller and looser flocs. So efficiency is quite poor for removal of phenol by using chitosan as a coagulant.

Effect of coagulant doses on the removal of phenol from aqueous solution was shown in Fig. 2. It is observed from graph that removals of phenol were higher at mass loading (g/L) 4, 3, 3, 4, 4, 4, 4 and 5 for tamarind seed powder, $FeCl_3$, $FeSO_4$, alum, polyaluminium chloride, chitosan and xanthum gum. Maximum removal of phenol found to be 74.2, 45, 44.2, 37.4, 36.4, 29.4 and 18.2 % respective coagulants. So it is used as optimum dose for these coagulants in further study. At 3 g/L of $FeCl_3$ and $FeSO_4$ were found to be optimum dosage for maximum removal of phenol due to total solid in a diminishing fashion with increasing doses of above 3 g/L. However, above 3 g/L concentration of $FeCl_3$ and $FeSO_4$ confer positive charges on the particle surface (positive zeta potential), thus re-dispersing the particles[17]. Similarly, Madhavi *et al.*[18] observed that maximum reduction of turbidity values from tap water in the range of 200-250 mg/L dosage. In general, higher dose of coagulant may pose health hazard and also it may interferes with fish survival and growth.

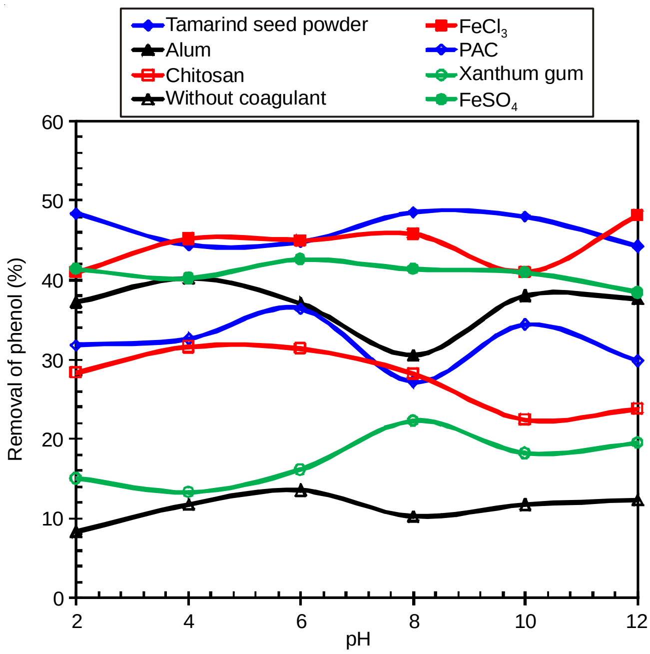

Fig. 1. Effect of pH on the removal of phenol from aqueous solution

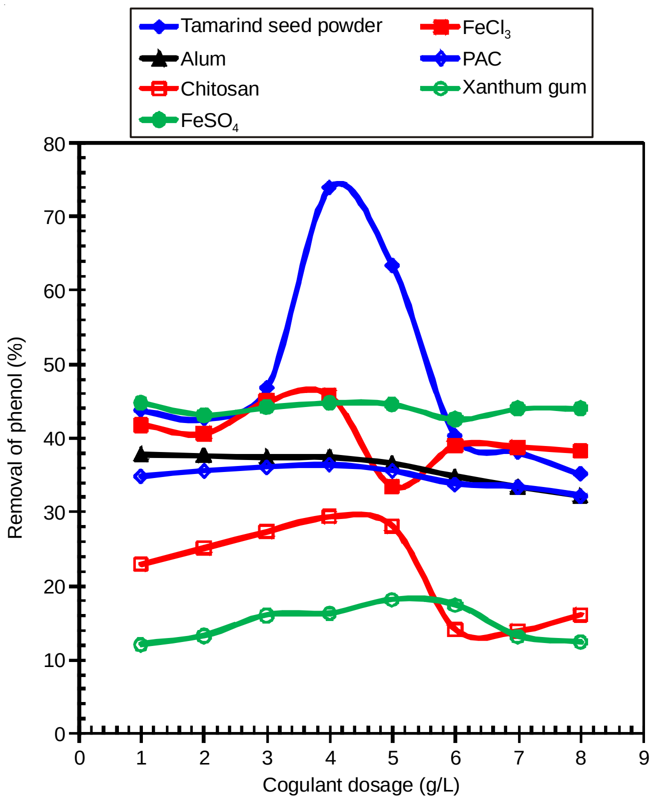

Fig. 2. Effect of coagulant doses on the removal of phenol from aqueous solution

Fig. 3 shows the effect of reaction time on the removal of phenol using different coagulants. The sample was stirred for a period of 2 min at 200 rpm followed by a further slow mixing of 15 min at 40 rpm after the optimum coagulant dosage was added to the same solution. It is observed that reaction time is increase with increase phenol efficiency also and reached at maximum in 90 min. However, after 90 min, the performance was slowly reduced and constantly maintained upto 180 min. The maximum removal of phenol by different coagulants such as 65.3, 45, 41.6, 35.8, 34.6, 28.6, 15.3 and 9.3 % for tamarind seed powder, $FeCl_3$, $FeSO_4$, alum, polyaluminium chloride, chitosan, xanthum gum and without coagulant, respectively. Similar study was carried out by using chitosan as a coagulant for removal of chemical oxygen demand (COD) and colour from textile wastewater[19]. They found that removals was highest (69.6 %) at increasing flocculation time upto 120 min and thereafter decreased or constant.

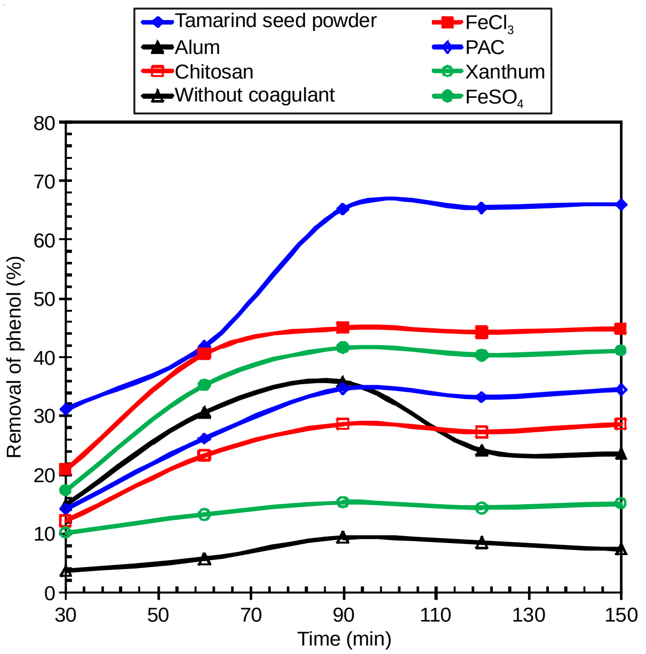

Fig. 3. Effect of reaction time on the removal of phenol from aqueous solution

The optimum coagulant dosage was added to different concentration of phenol containing solution (50-1000 mg/L) and shown in Fig. 4. It is observed that initial concentration of phenol increases, removal efficiency also increased upto 250 mg/L, however, after initial concentration of 250 mg/L, removal efficiency become constant. Maximum removal efficiency of phenol were found to be 69.2, 47.6, 41.5, 30.2, 32.7, 35.3, 15.7 and 6.2 % by tamarind seed powder, $FeCl_3$, $FeSO_4$, alum, polyaluminium chloride, chitosan, xanthum gum and without coagulants, respectively.

The effect of temperature on the phenol removal using coagulants was investigated and shown in Fig. 5. Temperature was varied from 25 to 75 °C in the mixed pollutant-coagulant system. Maximum removal efficiency was achieved at 35 °C and after this temperature increases, value of removal efficiency remain constant. It is concluded that maximum removal efficiency was attained at 68.2 % for tamarind seed powder and compared to other coagulants used. Patel and Vashi[19]

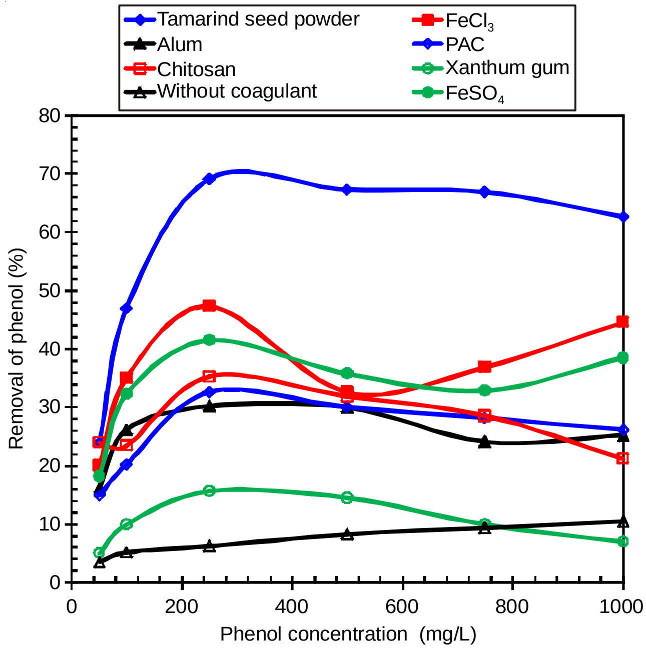

Fig. 4. Effect of initial concentration on the removal of phenol from aqueous solution

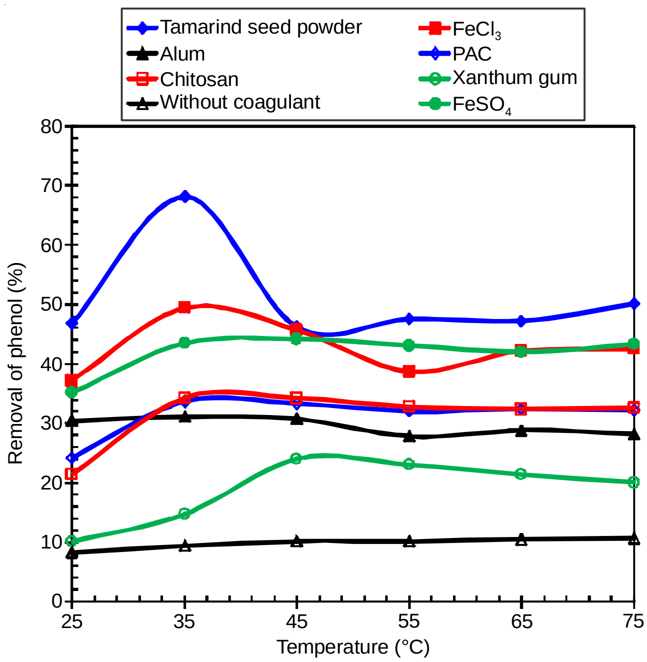

Fig. 5. Effect of temperature on the removal of phenol from aqueous solution

reported that percentage removal of chemical oxygen demand and colour was increased with increasing temperature by using $FeCl_3$, $FeSO_4$ and alum as coagulant. At higher temperature, higher removal was achieved due to better floc settlement when the temperature increases[20].

The settling study is one of the important that is given great consideration in any water treatment plant that involves coagulation-flocculation operations. Polyelectrolyte acts good coagulant aids in the waster and wastewater treatment[21,22] and also many of polyelectrolytes are advantageous over chemical coagulants because they are safer to handle and are easily biodegraded[21]. Percentage removal of phenol as function of polyelectrolyte dose shown in Fig. 6. Mass of polyelectrolyte

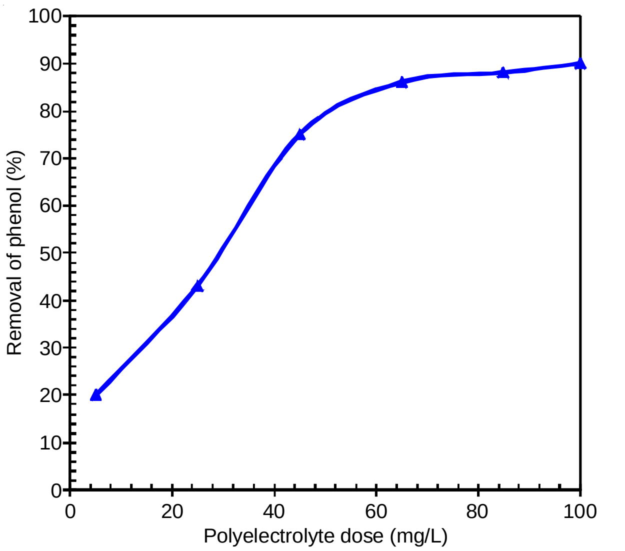

Fig. 6. Effect of polyelectrolyte doses on the removal of phenol from aqueous solution

varied in the range of 5-100 mg/L. Maximum removal efficiency was attained at 100 mg/L of 90 %. However, several studies have been done for combination of polyelectrolyte and chemical coagulants[23-25].

Addition of tamarind seed powder to polyelectrolyte for understanding settling behaviour was shown in Fig. 7. From Fig. 7, it can be seen that coagulation process was very fast in the polyelectrolyte + tamarind seed powder system as compared to coagulant system alone. The addition of polyelectrolyte had a significant effect on the settling time when tamarind seed powder was used as coagulants. In our study, around 50 min was enough to settle the phenol pollutant (14.5 to 6.9 cm) for polyelectrolyte + tamarind seed powder system, while tamarind seed powder alone, it was taken the time around 400 min to settle the same concentration of phenol pollutant (14.3 to 7.5 cm). This may be due to the bridging flocculation mechanism of the high molecular weight flocculant by which this flocculant may coil the flocs formed by the coagulants to become more compact, high strength and larger flocs[26,27].

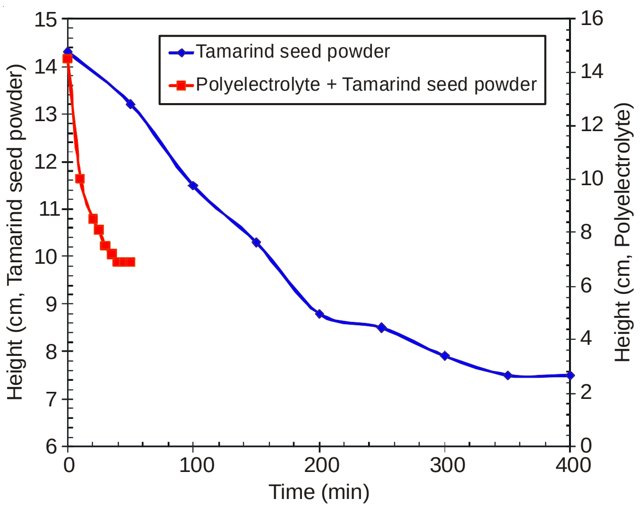

Fig. 7. Effect of addition of different doses of polyelectrolyte and without polyelectrolyte on the removal of phenol from aqueous solution

Conclusion

Coagulation/flocculation process was conducted for the removal of phenol from aqueous solution. Coagulant dose, pH of solution, time, temperature, initial concentration of phenol and polyelectrolyte and addition of polyelectrolyte as coagulant aid were investigated and found to be important parameters for maximum removal of phenol from aqueous solution. Phenol removal by the different coagulants (tamarind seed powder, $FeCl_3$, $FeSO_4$, alum, polyaluminium chloride, chitosan, xanthum gum) in the order of following sequence, tamarind seed powder > $FeCl_3$ > $FeSO_4$ > alum > polyaluminium chloride > chitosan > xanthum gum > without coagulant. tamarind seed powder was found to maximum reduction in phenol concentration while compared to other coagulants which used in this study.

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