

## **COLOR REMOVAL FROM WATER BY COAGULATION/CAUSTIC SODA AND LIME**

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### **ABSTRACT**

Due to aesthetic aspects, use of colored water even approved hygienically, is not acceptable worldwide. Consumers prefer to use colorless water. Color in water is usually associated with aromatic compounds produced from decay of natural herbal substances. Undesirable taste and odor and disinfection by products are of the reasons of color existence in water. The present study was performed using jar apparatus, lime and NaOH as softener agent and for increasing the pH of the process. Alum and ferric chloride coagulants were used to increase the size of flocs in various pH and color removal from water. It was tried to simulate the conditions of water treatment plants. Coagulant and lime doses, initial color and pH were studied. After the process, the residual color, as well as pH and electrical conductivity of water were measured. The results showed a significant increase in color removal with increasing pH. The highest percentage of color removal was 75% using 40mg/L of alum and ferric. The best efficiency of color removal was 86.68% and 94% by 12(g/L) lime for methylene blue and eriochrome black T, respectively. However, during the procedure, the electrical conductivity of water increased.

**Key words:** Color removal; Enhanced softening; Coagulation

### **INTRODUCTION**

The presence of color in water affects consumer assurance toward the quality of drinking water. People atheistically do not accept colored water (Bryant *et al.*, 1996; EPA, 1999). If the consumers are free in choice of the desired water, they commonly prefer colorless water. Water with high amount of color is not suitable for cloth washing, dyeing, paper industry, beverages production, dairies and other food products, textile industry, as well as plastic production. Therefore, color contained in water play negative

effects on people assurance (Degremont, 2002; Kim *et al.*, 2003; Christie, 2007; Mohammadian Fazli *et al.*, 2010).

Color in water is of two types of true color and apparent color. True color is the result of soluble chemical substances that cannot be separated by filtration. Apparent color is the result of suspended and colloid matters that can be isolated by filtration (AWWA, 1999; Chermisinoff, 2002; Degremont, 2002; AWWA, 2005; Spellman, 2008). The WHO guidelines give a guide level of 15 TCU for color, above which the color would be noticeable in a glass of water by most people. The USEPA advisory limit is the same.

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The current UK regulations set a maximum value for color of 20 mg/L as Pt-Co (Twort, 2000). Color sources in water may include natural metal ions (iron and manganese), humic and fulvic acids, lignin, tannin, algae, peaty matters, planktons, ferric and sulfuric bacteria and trade waste matters (AWWA, 1999; Kawamura, 2000; Chermisinoff, 2002; AWWA, 2005; Spellman, 2008). A great number of water treatment plants use raw water emanated from rivers, lakes and dam reservoirs. These sources contain suspended matters with low density such as algae and organic compounds that cause high rate of color in water (HDR, 2001). In the case of presence of heavy metals in water, humic substances in water react with them, causing color in water (Kawamura, 2000; Crittenden *et al.*, 2005). The effect of color in corrosion of iron, cast iron and acetyl is varied; because the nature of organic matters causing colored water is basically different from one source to another. These substances reduce iron oxidation and calcium carbonate settling (AWWA, 1999). The produced colors in water have commonly hydrophobic characteristic (Nalco, 1988).

Dissolved organic carbon (DOC) such as humic and fulvic substances may cause color in water as and have impacts on anionic exchange resin. Settlement of these matters on resins causes resins darkness, decrease of exchange capacity and increase of resins reconstruction frequency (AWWA, 1999). There exist numerous methods for color removal, including coagulation and flocculation, filtration, adsorption using granulated and powder activated carbon, chemical oxidation, biological process and nanofiltration (AWWA, 2005; Crittenden *et al.*, 2005; Nabi Bidhenhi *et al.*, 2007; Naimabadi *et al.*, 2009). Color removal from waters with low turbidity requires considering specific unit in water treatment plant (Nalco, 1988). Color removal by chemical oxidation, especially when chlorine is used as oxidative agent, produces problematic products (AWWA, 1999; Kawamura, 2000; Rezaee *et al.*, 2008). Application of advanced oxidation process using TiO<sub>2</sub> nanoparticles in removal of color from water and wastewater has shown good results (Mahvi *et al.*, 2009).

Traditionally, hardness removal is applied for

removing hardness producing ions. Enhanced softening process is the result of changing conventional softening process in a way that for magnesium settling, pH increases to higher levels (Kirmeyer *et al.*, 2000; Lowler, 2004). According to the definition of EPA, enhanced softening is a process in which greater amounts of softeners are added to the water in order to obtain pH > 10.5 and consequently achieve more desirable removal for DBPs precursors during softening procedure. Considering the total organic carbon (TOC), the process of enhanced softening has an efficiency rate of 25-30% for TOC (EPA, 1999).

Enhanced softening is efficient in control of pollutants such as iron, manganese, aluminum, sulfide, chloride and sodium (EPA, 1999). TOC, UV<sub>254</sub>, DOXFP<sub>n</sub> (dissolved organic halides formation potential), alkalinity, calcium hardness and pH are also affected by that (Spatial, 1998; EPA, 1999). USEPA has considered enhanced softening under the heading of disinfection by-products and disinfection (D/DBPs), as an executive criterion of softening units for removal of greater amounts of TOC in water treatment plant, essentially. By application of enhanced softening processes in combination with enhanced coagulation, the system will contain fewer precursors to react with chlorine. Hence, there is no reason for chlorine exchange with other disinfectants (Pontius, 2003). After enhanced softening procedure, alkalinity and DIC (dissolved inorganic carbon) levels should be reduced and disregarding this action will lead to instable pH in distributional system. Therefore, following enhanced softening procedure, adjustment of alkalinity and DIC may be needed (Kirmeyer *et al.*, 2000).

In this research, in order to determine the role of enhanced softening in color removal from water, its applicability in various conditions was studied.

## MATERIALS AND METHODS

### *Instrumentation*

Color and pH were measured using HANNA Instrument C200 model and ATIORION model 310, respectively.

### Chemicals

The color was added to water samples using potassium chloroplatinate and cobaltous chloride; methylene blue (MB) and eriochrome black T (EBT). Alum and ferric chloride were used as coagulant and lime and NaOH as softener agents. The chemicals used were supplied from Merck Co., of analytical grade.

### Tests procedure

This study was performed using jar apparatus. It was tried to simulate the conditions of water treatment plant in the laboratory. Color was added to water samples using potassium chloroplatinate and cobaltous chloride; methylene blue (MB) and eriochrome black T (EBT). For providing turbidity, screened clay was solved in water and allowed to be settled for 24 h. The water in top was added to the samples to produce turbidity. The sample water was taken from the drinking water of Kerman located in southeastern Iran. Except to color and turbidity that were added to the tested water, other features were similar to those of Kerman drinking water. At the first stage, water and coagulant were mixed at 110 rpm for

90 s. Then, NaOH (as softener and in order to increase pH) was added and slowly agitated for 5 min at 30 rpm to provide the conditions of slow mixing required for reactions to take place. At this time, the pH of the processed water was measured and it was agitated for another 30 min at 30 rpm to provide the conditions required for reactions of softening that take place slowly. Finally, the contents of the container were allowed to be settled for 30 min. The sample of settled water was passed from Whatman paper filter and was placed in a dark place; color analysis was performed (Coro and Laha, 2000). At the second stage, lime was used as softener agent at 0.1 to 12 g/L dose and initial color 70, 100 and 150 Pt-Co. All testing methods were based on "standard methods for examination of water and wastewater" (APHA, 2005).

### RESULTS

Table 1 presents the results of color removal by different doses of alum and ferric chloride at various pH conditions. Figs.1, 2 and Table 2 show the results of the effects of different doses of lime on color removal.

Table 1: Effect of different amounts of coagulant

Parameters	Alum (mg/L)			FeCl <sub>3</sub> (mg/L)		
	20	40	60	20	40	60
Initial color (Pt-Co)	60	60	60	60	60	60
pH for softening process	11.08	11.15	11.06	11.12	11.16	11.08
Residual color (Pt-Co)	20	15	17	20	15	17
Electrical conductivity (μS/cm)	2008	2061	2050	2038	2046	2040
Removal (%)	66.67	75	71.67	66.67	75	71.67
Initial color (Pt-Co)	70	70	70	70	70	70
pH for softening process	10.01	10.77	10.93	10.01	10.69	10.87
Residual color (Pt-Co)	29	25	20	29	26	20
Electrical conductivity (μS/cm)	1820	2046	2195	1846	2075	2095
Removal (%)	58.57	64.28	71.43	58.75	62.85	71.43
Initial color (Pt-Co)	80	80	80	80	80	80
pH for softening process	10.63	10.35	10.01	10.52	10.48	9.65
Residual color (Pt-Co)	29.72	30.66	29.72	29.72	30.66	33.14
Electrical conductivity (μS/cm)	2061	1935	1846	1958	1973	1853
Removal (%)	62.85	61.42	62.85	62.85	61.42	58.57

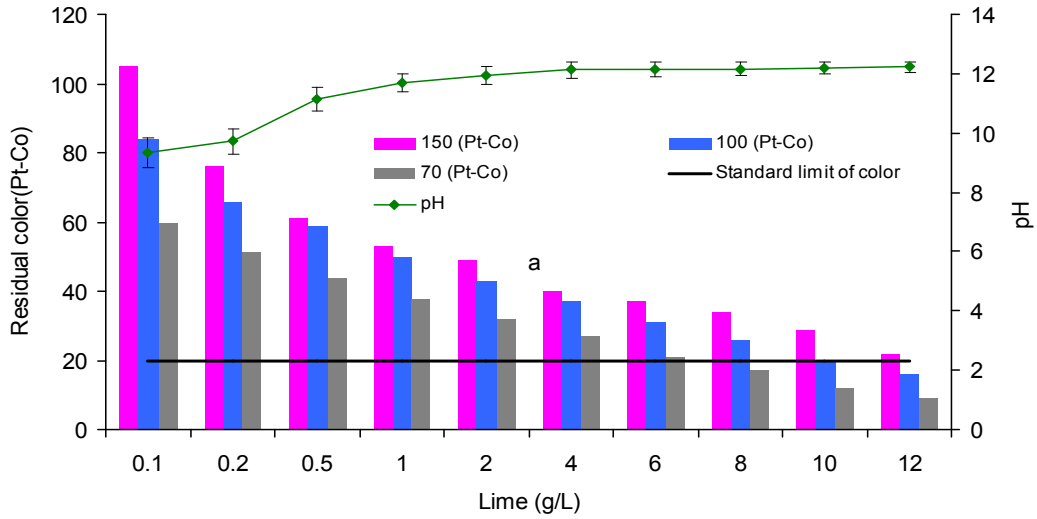


Fig 1: Residual color of EBT at various doses of lime

Table 2: Color removal efficiency by various doses of lime

Dose (g/L)	Removal of MB (%)			Removal of EBT (%)		
	150 (Pt-Co)	100 (Pt-Co)	70 (Pt-Co)	150 (Pt-Co)	100 (Pt-Co)	70 (Pt-Co)
0.1	20	39.33	57.33	30	44	60
0.2	26.67	42.67	62	49.33	56	66
0.5	29.33	46	66.67	59.33	60.67	70.67
1	36	50	70.67	64.67	66.67	74.67
2	40	58.67	73.33	67.33	71.33	78.67
4	44.67	62	78	73.33	75.33	82
6	50.67	66.67	80	75.33	79.33	86
8	59.33	70.67	82	77.33	82.67	88.67
10	62.67	73.33	84	80.07	86.67	92
12	67.33	78	86.67	85.33	89.33	94

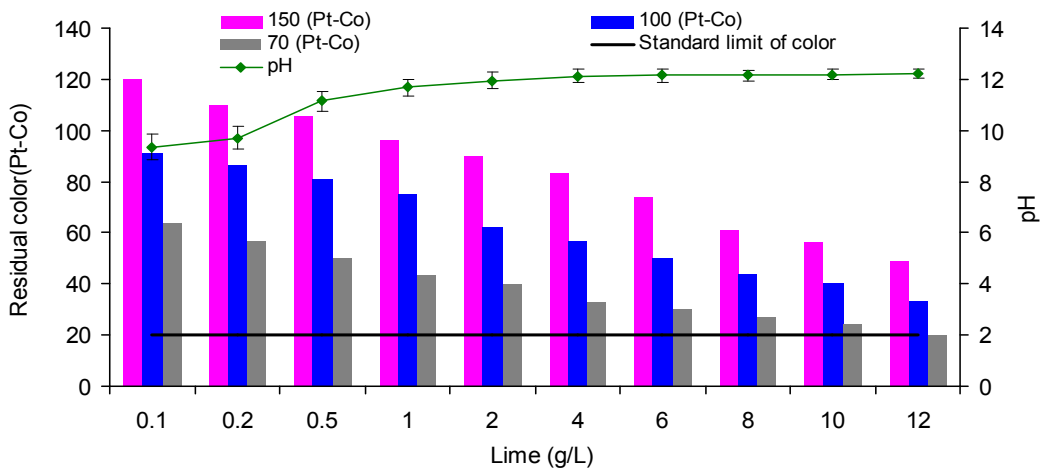


Fig 2: Residual color of MB at various doses of lime

## DISCUSSION

Table 1 summarizes the results of different stages of experiments. As it is seen, in the first stage, the highest percentage of color removal is achieved using 40mg/L of alum and ferric chloride and higher pH for softening. The results of this stage showed that with increasing of pH, electrical conductivity of the final solution increased as well. According to the results of the second stage, the highest removal percentage was related to the highest dose of coagulant and highest pH of softening. Moreover, with increasing of coagulant dose and pH, electrical conductivity increased. Results of the third stage illustrated that the lowest dose of the applied coagulant provided the highest pH and removal efficiency. The lowest removal percentage was obtained for the highest dose of applied coagulant and the lowest pH and removal efficiency. As it is shown in Table 1, by applying each of the coagulants, increasing of pH led to higher removal efficiency rate.

Qasim (1992) tested the effects of iron (coagulant) on water sources with high turbidity during hardness removal and observed that with increasing the dose of iron, the removal of TOC increases (McGuire *et al.*, 2003). Coro and Laha used this method in 2000 for removal of color from underground water in Florida and observed that by increasing pH to above 11 (enhanced softening), the color of filtered water reduced to less than 15 units (Coro and Laha, 2000).

Results of the present study are in line with color removal from landfill leachate by coagulation and flocculation processes (Aziz *et al.*, 2007). But Wang *et al* reported that treatment of leachate using coagulation/photo-oxidation process showed better result at lower pH value (Wang *et al.*, 2002).

However, this study is in contraire with the results of Coro and Laha in regard to decreasing the amount of color to less than 15 units. In the mentioned study, the researchers reached to less than 15 units color by adding high doses of coagulants of ferric chloride, organic polymers and activated silica to the water. It seems that the involved mechanism in color removal in this condition has been coagulation and fluctuation rather than enhanced softening. Moreover, this study aimed to provide a practical cost-effective

solution in removing color. However, in the mentioned study using those unconventional doses of coagulants for achieving less than 15 unit colors, the cost-effectiveness of the study is under question.

As shown in Figs. 1, 2, lime dose and pH played significant roles in color removal, so that with increasing of lime, the color removal efficiency increased. The results show that with increasing of color, the color removal efficiency reduced. The highest color removal efficiency takes place in 12(g/L) of lime.

This procedure can be used instead of the conventional processes of color removal in water treatment plants. Due to using low cost substances for increasing pH (lime), this method can economically compete with other methods of color removal. Therefore, in color removal from waters with high amount of color, this process seems to be efficient. Using conventional doses of coagulant, any change in the type of coagulant has no significant effect on the efficiency of color removal. One of the disadvantages of this process is increasing the electrical conductivity of water, but since the minerals producing electrical conductivity are not capable of being settled (hardness-creating minerals) they had no problem in regard to settling in water transport systems.

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