International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 12, December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

WATER TREATMENT RESIDUAL REUSE FOR COLOUR REMOVAL: SUSTAINABILITY THROUGH WASTE REUSE

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ABSTRACT

The reuse of largely available water treatment residuals (WTR) as economical substitute for colour removal from synthetic dye wastewater was investigated. WTR was used in raw wet form as a coagulant. The results showed a maximum colour removal of 61% at initial pH value 3.0 and WTR dose of 600 mg/L. The study shows that WTR dose and initial and final solution pH affects colour removal using WTR. The study thus shows the potential of WTR for primary treatment of dye wastewater.

Keywords*: *Reactive Dye Removal, Colour Removal, Water Treatment Residuals, Coagualtion, Dye Removal

I INTRODUCTION

The rising demand for textile products, management of immense quantity of textile and dyeing wastewater generated from textile industries has become a prime concern as it contains a variety of pollutants and toxic compounds such as dyes [1]. At present, the synthetic origin of dyes to produce strong fastness has raised various detrimental consequences on the environment and human health. Primarily, very low concentration of dyes in water makes water highly coloured and unpleasant [2, 3], and further, the discharge of coloured wastewater affects metabolites in aquatic ecosystems and reduces sunlight penetration to cause inhibitory effects on photosynthesis [4]. Colour removal can be obtained through several treatment processes that based on physiochemical and biological processes. The reports suggest that the compounds produced when textile wastewater undergoes anaerobic degradation for colour removal are toxic, carcinogenic, and mutagenic [5]. Thus, typically coagulation, sedimentation, adsorption, and ion-floatation approaches are exploited for colour removal [5].

Reuse and recycling of waste material are essential for achieving the sustainable development goal. In view of sustainable development, several research efforts have been made inquisitively to recover and reuse waterworks sludge in beneficial ways at low cost. Waterworks sludge is a by-product yielded through the clari-flocculation process due to the addition of coagulant (aluminium or ferrous salts) in water treatment plants and is generally known as water treatment residuals (WTR). In India, alum is mostly used coagulant. The addition of alum leads to formation of precipitates as aluminium hydroxide as amorphous form together with which suspended impurities are removed in settling unit [6]. However, the lack of sustainable approaches towards utilizing of WTR in beneficial and economical way, WTR are still disposed of in water bodies in developing countries while another option used for disposal could be landfill [7]. Moreover, millions of tons of WTR are generated annually around the world, scarcity of landfill sites and stringent environmental legislation makes WTR disposal more problematic and costlier. Thus, reuse of WTR for potential applications towards sustainability goal has received much attention in recent years.

Water treatment residuals can be used through recovering the coagulant or direct reuse. Direct reuse with or without alteration is also possible. Coagulant recovery from WTR includes processes namely acidification, basification, ion exchange, and membrane separation [8] which are found effective, if they are economical. Moreover, WTR management approaches include reuse in construction materials [9, 10], wastewater treatment [11–14] and for soil improvement [9, 12]. WTR have been used in two different forms in wastewater treatment. WTR can be used in its raw (wet) form as a coagulant or as the sorbent in its dried form. The effective reuse of WTR as a coagulant has been reported for colour removal from acid dye [15], and disperse dye [8], and for post treatment of up-flow anaerobic sludge blanket reactor (UASBR)-treated wastewater [16]. The WTR have been widely used as the sorbent for removal of anionic/cationic compounds such as phosphorus [16–18], and heavy metals [19]. WTR have been used for colour removal by Gadekar and Ahammed [8], Moghaddam et al. [14, 15] in its wet-form. No studies have been reported on WTR use for treatment of reactive textile dye wastewater.

The present study focused on water treatment residuals reuse for colour removal from reactive dye wastewater. Initially water treatment residuals were characterised. The raw wet-form of WTR used as a coagulant for colour removal from a synthetic reactive dye wastewater. The effects of two parameters namely WTR dose and initial pH were studied.

II MATERIALS AND METHODS

2.1 Synthetic dye solution

Synthetic dye solution was prepared by dissolving Corafix G Yellow 150% MER which is widely used in the textile industries obtained from ColourTex, Surat, India. A stock dye solution of 1,000 mg/L was prepared in distilled water and it was diluted to the required concentrations with tap water (pH 8.1, total dissolved solids 190 mg/L, total hardness 160 mg/L as $CaCO_3$, alkalinity 76 mg/L as $CaCO_3$, chlorides 16 mg/L).

2.2 Water Treatment Residuals

The WTR was collected from the coagulation/flocculation unit of a water treatment plant in Bhandup, Mumbai, India, where poly-aluminium chloride (PACl) is used as a coagulant. The collected sludge was stored at room temperature (27–30°C) in its original form and was used in its raw state. Elemental analyses of the dried PACl-based WTR were carried out by ICP (Element XR, Thermo Fisher Scientific, Germany).

2.3 Experimental Procedure

A six-beaker jar-test apparatus (DBK Instruments, Mumbai) was used for coagulation/flocculation simulation study. Each beaker contained 250 mL of the synthetic dye solution. WTR in its raw form was added as the coagulant. The WTR dosages were calculated based on dry weight. The coagulation/flocculation procedure consisted of 2-min rapid mixing at 150 rpm, followed by 30-min slow mixing at 25 rpm, and 20-min settling. Two important parameters affecting coagulation process, namely, initial pH, and WTR dosage were varied in different experiments in specified ranges. The ranges for these parameters were selected based on the values based on the preliminary tests. Initial pH of the samples was adjusted to a desired value by adding 0.1 N H_2SO_4 or NaOH using a pH meter (Hanna 209). The ranges of the three parameters used in the study are shown in Table 1. Centrifugation (at 5,000 rpm for 3 min) of the sample was performed before analysis. Colour was measured using a UV–visible spectrophotometer (Varian Cary 50) at a wavelength corresponding to the maximum absorbance of 420 nm for the dye used. Percentage of dye removal was calculated by the following equation (equation 1):

$$Colour\ removal\ (\%) = \frac{Co - Ce}{Co} \times 100 \quad (1)$$

where, C_o and C_e are colour concentration measured as absorbance at maximum absorbing wavelength of raw and treated wastewater, respectively.

Table 1 Ranges of different parameters used in study

Sr. No.	Parameter	Range
1.	Initial pH	3 - 7
2.	WTR Dose (mg/L)	100 - 600

III RESULTS AND DISCUSSIONS

3.1 Characterization of WTR

Important chemical composition of WTR is shown in Table 2. Composition of WTR mainly depends on the source water quality and the coagulant used in water treatment plant. Aluminium and iron concentration were found to be 64.60 and 93.01 mg/g, respectively while other cations such as calcium, magnesium and potassium were also detected in ample amounts. The studies presented typical aluminium content of 27.09 – 171.77 mg/g dry WTR [8, 20]. WTR has slightly alkaline pH of 7.4 with solid content of 5.4%. Most of the investigation reported were based on alum-based WTR, however, present study was carried out using PACl based WTR. The aluminium in together with iron content contributes towards effective coagulation and flocculation while reuse of WTR as coagulant [8]. The iron content was majorly depends on the elemental composition in raw water.

Table 2 Characteristics of water treatment residuals used

Sr. No.	Parameter	Value	Unit
1.	pH	7.4	-
2.	Solid content	5.4	(%)
3.	Al	64.60	(mg/g of dry sludge)
4.	Fe	93.01	(mg/g of dry sludge)
5.	Ca	27.27	(mg/g of dry sludge)
6.	Mg	17.34	(mg/g of dry sludge)
7.	K	20.06	(mg/g of dry sludge)

3.2 Effects of water treatment residuals

Fig. 1 shows the effect of WTR dose on color removal at different initial dye concentrations. It can be seen that the color removal increased with the increase in WTR dose and the highest color removal was obtained at a dose of 600 mg/L. The maximum color removal of 61% was obtained for initial dye concentrations 25 mg/L. However, increasing WTR dose beyond 300 mg/L presented only marginal increase (up to 4%) in colour removal. Similar trends of increase in colour removal with the increase in coagulant dose were obtained using WTR as a coagulant on disperse dye (88%) [8] at WTR dose of 3000 mg/L, and acid dyes(94%) [14, 15] at a dose of 4.55 g/L with PACl-based WTR. Further, literature reports on disperse dyes employing alum as coagulant reported colour removal in the range of 80–90% at doses of 40–200 mg/L [21, 22], whereas with ferric salt as coagulant gave 75% colour removal at a dose of 60 mg/L [22]. The low concentration of dye and the high concentration of aluminium and iron in WTR have shown increased colour removal at lower WTR dose. Thus, at lower dye concentration low WTR dose can achieve significant colour removal.

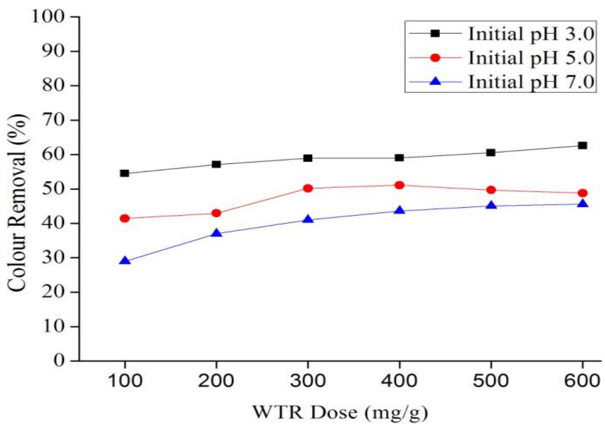

Figure 1 Effect of WTR dose on colour removal

3.3 Effect of pH

The pH of the solution is the major contributing parameter that affects the coagulation efficiency. Fig. 2A depicts the effect of pH on colour removal. It is observed that colour removal decrease with the increase in pH. The maximum colour removals 61% was obtained at pH 3 for WTR dose of 600 mg/L, which was decreased to 45% at pH value 7.0. It was also observed that the colour removal shown slight variation at lower pH values (3 and 4) depicts that colour removal was more dependent on the pH of solution. Similar results have been reported in the literature for colour removal of acid red dyes using PACl- and ferric chloride-based WTR as coagulants, and maximum removals of 94.2–96.5% were obtained at pH values 3.42–3.50, respectively, using PACl [15] and ferric chloride [14]-based WTR. While disperse dye shown 88% colour removal at pH value 3.0.

In order to further explore the influence of WTR dose on pH of system, initial pH and final pH post WTR addition were plotted for different WTR doses and is presented in Fig. 2B. It is clear that the addition of WTR increased the solution pH. However, the increase was prominent at lower initial pH values of 3.0–4.0. At initial pH values more than 5 there were little increase in the final pH. This suggests that the final solution pH was influenced by the WTR dose.

Shi et al. [23] reported behaviour of different aluminium species on colour removal which are pH dependent, and coagulation efficiencies of poly-aluminium chloride and alum tended to increase with decrease in pH and approached complete removal when pH was sufficiently lower. It was reported that due to formation of $Al(OH)_3$ precipitate the solution pH drops to 4.0. This suggests that the coagulation process is pH dependent [22]. Several reports on utilizing aluminium salts for colour removal described maximum yield at lower pH range of 4–5.5.0, and 5.0–6.0 for poly-aluminium chloride and alum, respectively [21–23]. The surface charge of the coagulants related to zeta potential measurement is pH dependent, and can affect removal efficiency to some extent [24]. This also suggests that the initial and final pH of solution balances the net charges on the WTR and dye which facilitate the performance of coagulants.

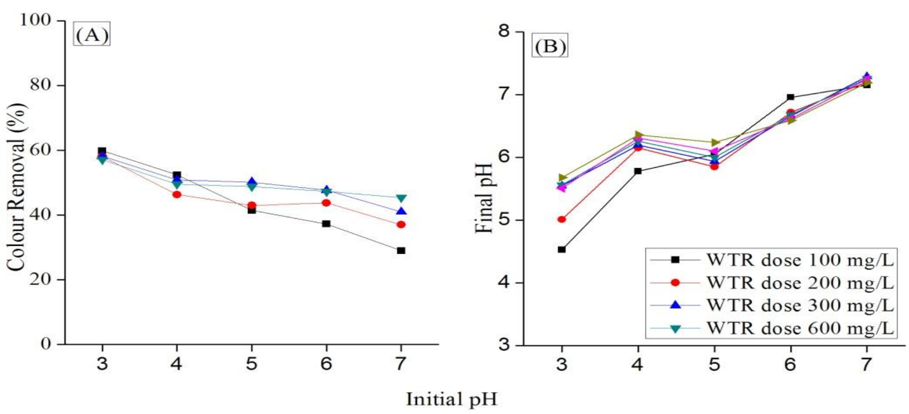

Figure 2 Effect of initial pH on (A) colour removal (B) Final pH

IV CONCLUSION

The potential of of WTR as a coagulant for the colour removal of a synthetic reactive dye (Corafix G Yellow 150% MER) solution was assessed in laboratory studies. The results of this study suggested that up to 61% color removal could be obtained with WTR dosage of 600 mg/L and at initial pH 3. Color removal was greatly affected by the pH of the system, with lower pH presenting higher colour removal.

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