BULLETIN OF ENVIRONMENTAL STUDIES

Removal of reactive dye yellow 145 by adsorption using white quartz

Saleha Anwar Kazi[1], Hafiza Hira Iqbal[1*], Naeem Shahid[2], Ghulam Mustafa Shah[2], Nadia Jamil[1]

1. College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan
2. Department of Environmental Sciences, COMSATS Institute of Information Technology, Vehari, Pakistan

Abstract

Batch process was performed to remove the reactive yellow 145 dye by using white quartz. Different operating parameters such as shaking speed, concentration of quartz, adsorbate concentration, pH values, contact time and temperature were evaluated to find maximum level of adsorption. The maximum adsorption efficiency was observed at pH 1. Increase in temperature and contact time showed positive effect on adsorption while optimum adsorption was recorded as 60 °C and 15 minutes, respectively. Moreover, concentration of the adsorbate was directly related to increase in adsorption process and the highest adsorption was achieved at 25 ppm. By contrast, increasing adsorbent level showed a gradual decrease in adsorption efficiency. In a nutshell, results obtained from this study elucidate that white quartz can be considered as an efficient adsorbent for the removal of reactive dye yellow 145.

Keywords: Quartz; Reactive Yellow dye 145; Wastewater Treatment; Water Pollution; Removal by Adsorption

Introduction

The lesser availability of fresh water necessitate the recycling of contaminated water using cheap and environmental friendly technologies (Barlow, 1999). Systematic reviews illustrated that after every twenty years, consumption of water is doubling and hence available water resources must be reclaimed before their application in different sectors such as, agriculture, industry, municipal, etc. (Mohammadi et al., 2004). The contamination of water bodies with dyes is a recent challenge as it impart color; causing low esthetics and fouling of freshwater resources (Namasivayam and Kavitha, 2002). The majority of dyes consist of complex organic molecules as they are used to impart color on fabric surfaces (Yagub et al., 2014). The application of dyes can be seen in many industries including plastic, rubber, cosmetics food processing, printing (Dawood et al., 2014; Wróbel et al., 2001), paper, leather tanning (Kabdaşli et al., 1999) and textile (Sokolowska-Gajda et al., 1996).

It is estimated that more than 100,000 types of dyes are produced annually with total amount exceeding 7×10^5 tons (McMullan et al., 2001). During the dyeing process, approximately 1–20% of dyes are lost and hence are released into the adjacent environment as textile effluent (Weber and Stickney, 1993). Besides, different toxic metabolites (derivatives of dyes) are also produce as a result of weathering either by hydrolysis, oxidation and/or other (bio) chemical reactions (Pagga and Brown, 1986; Saquib and Muneer, 2003). The recalcitrant nature of compounds makes them highly

undesirable in water bodies even at very low concentration (Park et al., 2007). In this regard, a number of techniques have been employed including flocculation and coagulation (Panswad and Wongchaisuwan, 1986), ozonation or oxidation (Malik and Saha, 2003), photocatalytic degradation (Sleiman et al., 2007), micellar enhanced ultrafiltration (Zaghbani et al., 2008), membrane separation (Ciardelli et al., 2001), electrochemical degradation (Fan et al., 2008), sonochemical degradation (Abbasi and Asl, 2008), Fenton-biological treatment scheme (Lodha and Chaudhari, 2007), solar photo-Fenton and biological processes (García-Montaño et al., 2008) and adsorption (Anbia and Moradi, 2009a,b).

Among these techniques, adsorption has gained tremendous popularity over conventional techniques due to less capital investment, ease of operation, flexibility of design, and insensitivity to toxic pollutants (Ali and Gupta, 2006). Earlier studies have reported the variety of adsorbents such ion-exchange resins, clay, activated carbon and zeolites (Forgacs et al., 2004; Messina and Schulz, 2006). The adsorption using activated carbon is known as an effective approach however but the natural minerals are cheap and easily available, e.g., quartz; however, very few studies have been conducted to test its efficiency.

The present study employs quartz as an adsorbent for the removal of dye RY145. Quartz is natural mineral and has exemplary properties of reservoir rock. The mineral possess porous texture, me-

chanical stability and high surface area and therefore can be considered as attractive adsorbent for removal of dyes. In previous studies, different type of siliceous material are used including zeolites, glass and perlite for the removal of dyes. Due to their low cost, ease of availability and abundance, the use of these adsorbents is increasing every day (Rafatullah et al., 2010). In Pakistan, a number of industries are operating which employs highly reactive dyes for the subsequent staining procedures. Due to inefficiencies of dying process, 10-15% of dye is released in effluents (Asgher et al., 2006). The dye reactive yellow 145 is one of them which is ever exploited in tremendous amount for the dyeing of cotton. This dye represents azo group as it comprises both monochlorotriazine (MCT) and sulphatoethylsulphone (SES) groups which are resistant to conventional biological treatments. Therefore, the aim of this study to find optimum pH, concentration of dye, time, shaking speed, temperature and amount of adsorbent towards better removal of RY145 while using quartz.

Materials and Methods

Adsorbate and Reagents

The reactive yellow 145 ($C_{18}H_{14}C_{12}N_8Na_2O_9S_2$) was used as adsorbate material; which is also called as reactive yellow 3RS, and have wavelength of 419 with the molecular weight of 1026.20 (Aguedach et al., 2005). Standard solutions (0, 5, 10, 15, 20, 25, 30, 35, and 40) were prepared from stock solution (100 ppm) by simple dilution method using distilled water. The hydro chloric acid (HCl) and sodium hydroxide (NaOH) solutions were used for the adjustment of pH. The dye and reagents were obtained from A.M Scientific System Ltd., Lahore. White quartz was used as adsorbent and was collected from natural origin in Sawat. After removing dirt, the material was crushed and passed through a sieve of 100 mesh size as described earlier (Arias et al., 2006).

Batch Method

In batch method, particle size of used adsorbent was 0.149 mm. To get the optimum dye removal, effect of different factors such as shaking speed, amount of adsorbent, contact time, temperature, pH and concentration of adsorbate on adsorption was studied. A wide range of rotations per minutes (i.e., 0 to 250 rpm) used for the determination of optimal shaking speed; whereas, 1 to 3 grams of white quartz was used to assess the effect of adsorbent dosage on adsorption process. Likewise, different ranges of other factors i.e. contact time (0-60 min), temperature (18-80 °C), adsorbent dosage (5-40ppm) and pH (1-13) were used to check their effect on removal efficiency. To maintain the pH level, 0.1 molar hydrochloric

moval efficiency. To maintain the pH level, 0.1 molar hydrochloric acid (HCL) and sodium hydro oxide (NaOH) were used.

Statistical Analysis

All of the statistical analyses were performed using SPSS (v 22.0). The descriptive analyses, i.e. mean, standard deviation (SD), median and ranges were analyzed to summarize the dataset. Independent samples t-test was used for the comparisons between treatments.

Results and Discussion

Effect of different parameters on adsorption

Effect of Shaking Speed: The effect of variation in stirring speed on adsorption process was studied over the range of 0 to 250 rpm. Other experimental conditions such as concentration of yellow dye 145, adsorbent dosage, contact time, and pH were kept constant. The highest adsorption 86.6% was obtained at 50 rpm whereas the lowest was 51.6 at 250 rpm (Table 1). It was observed that adsorption yield increases with increase in stirring speed up to the optimal level; however, further rise in speed declined the adsorption efficiency.

Effect of adsorbent dose: The effect of variation in the adsorbent dose on the adsorption of yellow 145 was studied by using optimum shaking speed 50 rpm while reaming experimental conditions remained constant. Adsorbent dose used in the range of 1 to 4 g per 50 mL. It was observed that the adsorption efficiency decreases with increasing adsorbent dose (Table 2). The minimum adsorption was 57.5% at 4 g whereas the maximum adsorption (81.6 %) was recorded at 1 g. Results elucidates the adsorption is indirectly related to adsorbent dosage. For further experimental setup, 1 g per 50 ml of yellow dye 145 with 50 rpm was used. The negative relation between adsorption efficiency and adsorbent dose might be attributed to particle interactive behavior such as aggregation, that would lead to decrease in total surface area of adsorbent and hence the adsorption is decreased. In addition, it might be due to splitting effect of flux between adsorbent and adsorbate which cause decrease in amount of adsorption of dye on unit weight of quartz (adsorbent) (Vadivelan and Kumar, 2005). Same results have been described in previous studies (Bulut and Aydın, 2006; Chiou et al., 2004; Çiçek et al., 2007). By contrast, Gül and Özcan-Yıldırım (2009) reported a positive relation between adsorption efficiency and adsorbent.

Effect of time: Contact time is an important factor that influence the adsorption process wastewater treatment (Mall et al., 2006). To

Table 1: Effect of adsorption at different shaking speeds

	Shaking Speed (rpm)	C_i (ppm)	C_f (ppm)	Adsorption (%)
1	0	30	6	80
2	50	30	4	86.6
3	100	30	10	66.6
4	150	30	10.5	65
5	200	30	10.25	65.8
6	250	30	14.5	51.6

C_i: Initial Concentration; C_f: Final Concentration

Table 2: Effect of adsorption at different concentrations of adsorbent

	Adsorbent (g)	C_i (ppm)	C_f (ppm)	Adsorption (%)
1	1.0	30	5.5	81.6
2	1.5	30	6.5	78.3
3	2.0	30	7.25	75.8
4	2.5	30	8.5	71.6
5	3.0	30	9.75	67.5
6	3.5	30	12.5	58.3
7	4.0	30	12.75	57.5

C_i: Initial Concentration; C_f: Final Concentration

evaluate the effect of contact time on adsorption efficiency, adsorption press was carried out for different time intervals ranging from 0 to 60 minutes while keeping the experimental conditions same for all treatments as described earlier. A rapid increase in adsorption efficiency was observed with increasing contact time but after attaining the optimal time, adsorption efficiency started decreasing with further increase in contact time. The lowest adsorption rate (78.3 %) was recorded at 0 minutes whereas the highest (90%) was at 15 minutes (Table 3). For further investigations 15 minutes contact time was used. In start the increase in contact time between adsorbent and solution containing adsorbate increases the adsorption efficiency. It is suggested that the longer time period is required for bond of adsorbate with adsorbent to achieve optimum level (Mall et al., 2006). As the equilibrium state attained, the adsorption cannot be enhanced by increasing the contact time. It could be explained by the fact that in start more surface area is available and adsorbate ions attached to active sites and reached the saturation level (Çiçek et al., 2007). After saturation, deposition starts and this results decrease in adsorption.

Effect of Temperature: The efficiency of adsorption was studied at various temperatures ranging from 18 to 80°C while remaining experimental set conditions kept constant for all the treatments on each temperature. The highest adsorption (98.3%) was recorded at 60 °C whereas the lowest at room temperature (i.e., 18°C) (Table 4). It is suggested that the increase in temperature may enhance the diffusivity of dye ions that could be resulted in rise of adsorption rate (Benguella and Benaissa, 2002). Diffusion is considered as endothermic reaction (Juang et al., 1997) and suggested as a potential factor to increase adsorption efficiency. Çiçek et al. (2007) also reported an increase in adsorption efficiency with increasing temperature that confirms the results of current study.

Effect of pH: The effect of pH on yellow 145 was studied by varying the pH from 1 to 13 with interval of odd numbers. The level of pH was maintained by using 0.1 molar HCl and NaOH solutions. Moreover, other experimental conditions for treatments at all pH levels were kept same as described earlier. Results showed that the quartz is a good adsorbent for yellow 145 in acidic conditions as reported in previous study (Aguedach et al., 2005). Initially, the adsorption efficiency decreases with gradual increase in pH level up to pH 5 (Table 5). Again, from neutral pH 7, the adsorption efficiency starts increasing along with increase in pH . By contrast, Gül and Özcan-Yıldırım (2009) reported highest adsorption efficiency at neutral pH. The optimal pH level for adsorption efficiency depends on the type of dye and adsorbent. The change in

Table 3: Effect of adsorption at different contact time

	Contact time (min)	C_i (ppm)	C_f (ppm)	Adsorption (%)
1	0	30	6.5	78.3
2	15	30	3.0	90
3	30	30	3.5	88.3
4	45	30	5.0	83.3
5	60	30	5.5	81.6

C_i: Initial Concentration; C_f: Final Concentration

Table 4: Effect of adsorption at different temperature

	Temperature °C	C_i (ppm)	C_f (ppm)	Adsorption (%)
1	20	30	1.75	94.1
2	40	30	1.25	95.8
3	60	30	0.5	98.3
4	80	30	1.0	96.6
5	18 (Room)	30	2.5	91.6

C_i: Initial Concentration; C_f: Final Concentration

Table 5: Effect of adsorption at different pH

	pH	C_i (ppm)	C_f (ppm)	Adsorption (%)
1	1	30	0.5	98.3
2	3	30	1.25	95.8
3	5	30	4.5	85.0
4	7	30	3.0	90.0
5	9	30	3.5	88.3
6	11	30	5.5	89.6
7	13	30	1.5	95.0

C_i: Initial Concentration; C_f: Final Concentration

Table 6: Effect of adsorption at different amount of adsorbate

	C_i (ppm)	C_f (ppm)	Adsorption (%)
1	5	4.10	18.0
2	10	7.60	24.0
3	15	11.1	26.0
4	20	14.7	26.5
5	25	18.3	26.8
6	30	22.3	25.5
7	35	26.2	25.0
8	40	30.4	24.0

C_i: Initial Concentration; C_f: Final Concentration

pH level affects the adsorption process by dissociation of functional groups from adsorbents surface. Effect of pH on adsorption process also related to chemistry of solution and functional groups present on adsorbent.

Effect of Adsorbate Concentration: Initial concentration of adsorbate provides driving force which is useful to overcome the resistance in transferring the molecules present between aqueous and solid phase (Akkaya and Özer, 2005). Therefore, the effect of initial concentration of adsorbate on the adsorption process was investigated by using different concentration ranging from 5 to 40 ppm with interval of 5 ppm while keeping the other experimental conditions constant for all adsorbate concentrations. Initially the adsorption efficiency was increased with increasing concentration of dye but after gaining optimum level it was gradually decreased. Highest adsorption (26.8%) was recorded at 25 ppm whereas the lowest (18%) at 5ppm of adsorbate concentration (Table 6). In previous studies it has been explained that the adsorption rate increases with increasing initial concentration of adsorbate due to more availability of binding sites. When all binding sites of adsorbent are occupied, adsorbate ions have less chance to attach on adsorbent (Sekhar et al., 2003).

Conclusions

The present study shows that the the white quartz, which is naturally occurring and cheap geological material, was found to be a very good adsorbent for the adsorption of Yellow 145. The amount of adsorption was increased with increasing shaking speed, contact time and temperature. After achieving optimum level there was no further increase in rate of adsorption. Likewise, 60 °C of temperature was found to give best adsorption, whereas; the best shaking speed, adsorbent dosage and contact time were 50 rpm, 1 gram and 15 minutes, respectively. The adsorption capacity of dyes was found to be highest at pH level 1; however; the adsorbate concentration was 25 ppm that showed the highest removal efficiency.

Compliance with Ethical Standards

Conflict of Interests

The authors declare that they have no conflict of interests.

References

Abbasi, M., Asl, N.R., 2008. Sonochemical degradation of Basic Blue 41 dye assisted by nanoTiO$_2$ and H$_2$O$_2$. Journal of hazardous materials 153, 942-947.

Aguedach, A., Brosillon, S., Morvan, J., Lhadi, E.K., 2005. Photocatalytic degradation of azo-dyes reactive black 5 and reactive yellow 145 in water over a newly deposited titanium dioxide. Applied Catalysis B: Environmental 57, 55-62.

Akkaya, G., Özer, A., 2005. Biosorption of Acid Red 274 (AR 274) on Dicranella varia: Determination of equilibrium and kinetic model parameters. Process Biochemistry 40, 3559-3568.

Ali, I., Gupta, V., 2006. Advances in water treatment by adsorption technology. Nature Protocols 1, 2661-2667.

Anbia, M., Mohammadi, K., 2009a. An effective method for removal of dichromate ion and furfural from aqueous solutions using a nanoporous adsorbent. Asian Journal of Chemistry 21, 3347.

Anbia, M., Moradi, S.E., 2009b. Adsorption of naphthalene-derived compounds from water by chemically oxidized nanoporous carbon. Chemical Engineering Journal 148, 452-458.

Arias, M., Da Silva-Carballal, J., Garcia-Rio, L., Mejuto, J., Nunez, A., 2006. Retention of phosphorus by iron and aluminum-oxides-coated quartz particles. Journal of Colloid and Interface Science 295, 65-70.

Asgher, M., Shah, S., Ali, M., Legge, R., 2006. Decolorization of some reactive textile dyes by white rot fungi isolated in Pakistan. World Journal of Microbiology and Biotechnology 22, 89-93.

Barlow, M., 1999. World Rivers Review. International Rivers Network, Berkeley, 6-7.

Benguella, B., Benaissa, H., 2002. Cadmium removal from aqueous solutions by chitin: kinetic and equilibrium studies. Water Research 36, 2463-2474.

Bulut, Y., Aydın, H., 2006. A kinetics and thermodynamics study of methylene blue adsorption on wheat shells. Desalination 194, 259-267.

Chiou, M.-S., Ho, P.-Y., Li, H.-Y., 2004. Adsorption of anionic dyes in acid solutions using chemically cross-linked chitosan beads. Dyes and Pigments 60, 69-84.

Ciardelli, G., Corsi, L., Marcucci, M., 2001. Membrane separation for wastewater reuse in the textile industry. Resources, Conservation and Recycling 31, 189-197.

Çiçek, F., Özer, D., Özer, A., Özer, A., 2007. Low cost removal of reactive dyes using wheat bran. Journal of Hazardous Materials 146, 408-416.

Dawood, S., Sen, T.K., Phan, C., 2014. Synthesis and characterisation of novel-activated carbon from waste biomass pine cone and its application in the removal of congo red dye from aqueous solution by adsorption. Water, Air, & Soil Pollution 225, 1-16.

Fan, L., Zhou, Y., Yang, W., Chen, G., Yang, F., 2008. Electrochemical degradation of aqueous solution of Amaranth azo dye on ACF under potentiostatic model. Dyes and Pigments 76, 440-446.

Forgacs, E., Cserhati, T., Oros, G., 2004. Removal of synthetic dyes from wastewaters: a review. Environment international 30, 953-971.

García-Montaño, J., Pérez-Estrada, L., Oller, I., Maldonado, M.I., Torrades, F., Peral, J., 2008. Pilot plant scale reactive dyes degradation by solar photo-Fenton and biological processes. Journal of Photochemistry and Photobiology A: Chemistry 195, 205-214.

Gül, Ş., Özcan-Yıldırım, Ö., 2009. Degradation of reactive red 194 and reactive yellow 145 azo dyes by O_3 and H_2O_2/UV-C processes. Chemical Engineering Journal 155, 684-690.

Juang, R., Wu, F., Tseng, R., 1997. The ability of activated clay for the adsorption of dyes from aqueous solutions. Environmental Technology 18, 525-531.

Kabdaşli, I., Tünay, O., Orhon, D., 1999. Wastewater control and management in a leather tanning district. Water science and technology 40, 261-267.

Lodha, B., Chaudhari, S., 2007. Optimization of Fenton-biological treatment scheme for the treatment of aqueous dye solutions. Journal of Hazardous Materials 148, 459-466.

Malik, P., Saha, S., 2003. Oxidation of direct dyes with hydrogen peroxide using ferrous ion as catalyst. Separation and Purification Technology 31, 241-250.

Mall, I.D., Srivastava, V.C., Agarwal, N.K., 2006. Removal of Orange-G and Methyl Violet dyes by adsorption onto bagasse fly ash—kinetic study and equilibrium isotherm analyses. Dyes and pigments 69, 210-223.

McMullan, G., Meehan, C., Conneely, A., Kirby, N., Robinson, T., Nigam, P., Banat, I., Marchant, R., Smyth, W., 2001. Microbial decolourisation and degradation of textile dyes. Applied Microbiology and Biotechnology 56, 81-87.

Messina, P.V., Schulz, P.C., 2006. Adsorption of reactive dyes on titania–silica mesoporous materials. Journal of Colloid and Interface Science 299, 305-320.

Mohammadi, T., Razmi, A., Sadrzadeh, M., 2004. Effect of operating parameters on Pb_2^+ separation from wastewater using electrodialysis. Desalination 167, 379-385.

Namasivayam, C., Kavitha, D., 2002. Removal of Congo Red from water by adsorption onto activated carbon prepared from coir pith, an agricultural solid waste. Dyes and Pigments 54, 47-58.

Pagga, U., Brown, D., 1986. The degradation of dyestuffs: Part II Behaviour of dyestuffs in aerobic biodegradation tests. Chemosphere 15, 479-491.

Panswad, T., Wongchaisuwan, S., 1986. Mechanisms of dye wastewater colour removal by magnesium carbonate-hydrated basic. Water Science and Technology 18, 139-144.

Park, C., Lee, M., Lee, B., Kim, S.-W., Chase, H.A., Lee, J., Kim, S., 2007. Biodegradation and biosorption for decolorization of synthetic dyes by Funalia trogii. Biochemical Engineering Journal 36, 59-65.

Rafatullah, M., Sulaiman, O., Hashim, R., Ahmad, A., 2010. Adsorption of methylene blue on low-cost adsorbents: a review. Journal of hazardous materials 177, 70-80.

Saquib, M., Muneer, M., 2003. TiO_2-mediated photocatalytic degradation of a triphenylmethane dye (gentian violet), in aqueous suspensions. Dyes and pigments 56, 37-49.

Sekhar, K.C., Kamala, C., Chary, N., Anjaneyulu, Y., 2003. Removal of heavy metals using a plant biomass with reference to environmental control. International Journal of Mineral Processing 68, 37-45.

Sleiman, M., Vildozo, D., Ferronato, C., Chovelon, J.-M., 2007. Photocatalytic degradation of azo dye Metanil Yellow: optimization and kinetic modeling using a chemometric approach. Applied Catalysis B: Environmental 77, 1-11.

Sokolowska-Gajda, J., Freeman, H.S., Reife, A., 1996. Synthetic dyes based on environmental considerations. Part 2: Iron complexes formazan dyes. Dyes and Pigments 30, 1-20.

Vadivelan, V., Kumar, K.V., 2005. Equilibrium, kinetics, mechanism, and process design for the sorption of methylene blue onto rice husk. Journal of Colloid and Interface Science 286, 90-100.

Weber, E.J., Stickney, V.C., 1993. Hydrolysis kinetics of reactive blue 19-vinyl sulfone. Water Research 27, 63-67.

Wróbel, D., Boguta, A., Ion, R.M., 2001. Mixtures of synthetic organic dyes in a photoelectrochemical cell. Journal of Photochemistry and Photobiology A: Chemistry 138, 7-22.

Yagub, M.T., Sen, T.K., Afroze, S., Ang, H.M., 2014. Dye and its removal from aqueous solution by adsorption: a review. Advances in Colloid and Interface Science 209, 172-184.

Zaghbani, N., Hafiane, A., Dhahbi, M., 2008. Removal of Safranin T from wastewater using micellar enhanced ultrafiltration. Desalination 222, 348-356.