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Efficiency Evaluation of Tea Waste for Adsorption of Hexavalent Chromium from Industrial Effluent

Khushboo Bhavsar[1] and Payal Patel[2]

[1, 2] Department of Environmental science, Institute of Science and Technology for Advanced Studies and Research, Sardar Patel University, Vallabh Vidyanagar, Anand, Gujarat, India

Abstract: ***Water used in industries creates a wastewater that has a potential hazard for our environment because of introducing various contaminants such as heavy metals into soil and water resources. There are atleast 20 metals which cannot be degraded or destroyed. In this study, removal of Chromium (VI) from the industrial effluent has been investigated by using activated waste tea (AWT) as a useful natural adsorbent. The study was performed using batch experiments with chemical industry effluent having Cr(VI) in higher concentration. The adsorption experiments were carried out under different conditions of solution pH and AWT dose. The results indicated that the AWT has good removal efficiency. About 88% and 98% Cr removal was achieved by using 0.5 gm and 2 gm adsorbent for wastewater initial concentration of 250 mg/l. The adsorption process reached equilibrium within 40 minutes of the contact time with maximum adsorption at neutral pH. The equilibrium data were fitted to Langmuir and Freundlich isotherms. The adsorption behaviour followed both Langmuir and Freundlich isotherm model. Higher sorption capacity of this sorbent indicates that the waste tea can be used for the treatment of effluent containing Cr(VI).***

Keywords: Adsorption; Cr (VI); Low-cost adsorbents; Tea waste; Langmuir; Freundlich; Isotherm

1. Introduction

The discharge of heavy metals into aquatic ecosystems has become a matter of concern over the last few decades. The pollutants of serious concern include lead, chromium, mercury, uranium, selenium, zinc, arsenic, cadmium, gold, silver, copper, nickel, etc (Ahalya N et al, 2005). Anthropogenic sources such as industrial point sources, combustion by-products, automobile emissions, present and former mining activities, foundries and smelters, and diffuse sources such as piping, constituents of products etc, contribute to anomalously high concentrations of metals in the environment relative to the normal background levels (Dhanakumar S et al, 2007). The release of large quantities of heavy metals into the natural environment e.g. irrigation of agricultural fields by using sewage has resulted in a number of environmental problems and due to their non-biodegradability and persistence, can accumulate in the environment elements such as food chain, and thus may pose a significant danger to human health (Mahvi A. H et al, 2005). As a result we are harming our planet and organism die at very alarming rate[4]. Therefore, it is necessary to treat metal contaminated wastewater prior to its discharge to environment. Several processing techniques are available to reduce the concentrations of heavy metals in wastewater, including precipitation, flotation, ion exchange, solvent extraction, adsorption, cementation onto iron, membrane processing and electrolytic methods (Lokendra and Mukesh, 2013).

Pollution by Cr (VI) is one of the major concerns as the metal is used in electroplating, leather tanning, metal finishing, and chromate preparation (Gopalakrishnan S. et al, 2013). Conventional methods for removing Cr (VI) ions from industrial wastewater are expensive. Recently, numerous approaches have been studied for the development of the cheaper and more effective technologies for the removal of the heavy metals esp. Cr(VI) from the wastewater. Also, the idea of utilizing biomass from agricultural and livestock waste as a raw material for the production of activated carbon is the topic of interest for most of the researchers specially from agricultural base. Many agriculture residues such as coconut husk, turmeric waste, ferronia shell waste Jatropha curcus seed shell waters, delonix shell waste, ipomea carnia stem, rice husk, jack fruit peel, bamboo, cow dung have been prove suitable for the production of activated carbon.

It is always preferred to aim at working on low-cost adsorption processes. This study aims at efficiency evaluation of Activated Waste Tea (AWT) as an adsorbent material for removal of Cr (VI) from industrial effluent.

2. Experimental Methods

All the reagents used for the experimental studies were of analytical grade. In order to assess the performance of the adsorbent, the influent wastewater was collected from one of the chemical industries in Vitthal Udhyognagar with the concentration of Chromium (250 mg/l).

2.1 Adsorbent preparation

Waste tea was collected from teashops and hotels in and around the city. It was decolorized using distilled water and dried at 105^{o}C for 24 hrs. The dried material was ground and sieved by 10 mesh sieve to get the particle size of 125-250µm. The powder was then dried at 105°C for 6 hours and stored in plastic bags at room temperature. Finally, the AWT powder was used for adsorption studies.

2.2 Experimental Procedure

The adsorption capacity of AWT as an adsorbent was determined by batch mode adsorption studies. Sorption technique were performed to obtain rate and equilibrium data. The batch technique was selected because of its simplicity. The effect of different controlling parameters like pH, Contact time and adsorbent dosage of activated tea waste was studied. For the determination of rate of Cr (VI) adsorption by AWT from 100 ml of the wastewater (250mg/l). They were conducted with varying pH (2-9), Contact time (5-50 min) and adsorbent dose(0.5-2gm) at room temperature(30 ± 2^oC). The adsorbent and adsorbate were separated by centrifuging at 10,000 rpm for 20 minutes. Cr (VI) was estimated spectrophotometrically at 540nm using 1, 5-diphenyl carbazide method (APHA, 1985).

The experimental data were analyzed using Langmuir and Freundlich isotherm and different constants were generated. The adsorption parameters and correlation coefficient were calculated to determine the best model that characterizes the adsorption mechanism.

3. Results and Discussion

The physical characteristics of the adsorbents are shown in Table 1. The data obtained during the adsorption studies made to evaluate the effect of pH, contact time and adsorbent dosage on the removal of Cr (VI) from the wastewater have been analyzed and discussed under the following heads.

3.1 Effect of pH on Cr (VI) removal

The influence of solution pH on the extent of adsorption of Cr (IV) is shown in figure 1.The removal of metal ion from the solution by adsorption is highly dependent on pH of the solution. The results indicated that acidic pH (2-6) favoured lower adsorption with a gradual increase to 89% removal of Cr (IV) at pH 7. Additionally, the percent removal decreased with the increase in pH as 8,9 and 10.

3.2 Effect of contact time on Cr (VI) removal

The effect of contact time on the system is presented in figure 2.The amount of Cr (VI) adsorbed increases with the contact time and attained equilibrium at 40 mins. The adsorption rate was rapid during first 10 min of agitation. Subsequently, with the increase in contact time it became slower near the equilibrium due to the accumulation of Cr (VI) on the ATW surface. At equilibrium, the rate of Cr (VI) uptake remains asymptotic with time.

3.3 Effect of adsorbent dosage on Cr (VI) removal

The experimental results for the effect of dosage on adsorption are as shown in figure 3. Results revealed that with increasing adsorbent concentration, the percent removal of Cr (VI) also increased upto a certain level and beyond that more or less remained constant.

3.4 Adsorption isotherm

The experimental adsorption data were analysed using the Langmuir and Freundlich models to determine the best model that characterise the adsorption mechanism.

3.4.1 Langmuir Isotherm

Linear form of Langmuir model is expressed by Eq. (1)

$$\frac{C_e}{q_e} = \frac{C_e}{Q} + \frac{1}{Qb}$$

Where, **Ce** is equilibrium concentration of Cr (mg/L), **qe** is amount of Cr adsorbed at equilibrium (mg/g), Q_0 and b are Langmuir constants related to adsorption capacity and rate of adsorption capacity, respectively. The linear plot of Ce/qe versus Ce is shown in **Fig. 5**. The maximum monolayer adsorption capacity of AWT was found to be 20.41.mg/g. The shape of the langmuir isotherm was investigated by the dimensionless constant separation term (R_L) to determine high affinity adsorption. R_L was calculated as per Eq (2).

$$R_L = \frac{1}{1 + bC_0}$$

$\mathbf{R_L}$ indicates the type of isotherm to be irreversible ($R_L = 0$), favourable ($0< R_L <1$), linear ($R_L = 1$)(or) unfavourable ($R_L > 1$). In the present investigation, the R_L value (i.e 0.075) was less than one for Cr concentration range studied, which shows the adsorption process was favourable.

3.5.2 Freundlich isotherm.

Linear form of Freundlich model is expressed by Eq. (3)

$$\log q_e = \log K_F + \frac{1}{n} \log C_e$$

Where, $\mathbf{K_F}$ is measure of adsorption capacity (mg/g) and **n** is adsorption intensity. 1/n values indicate the type of isotherm to be irreversible (1/n = 0), favourable (0<1/n<1), unfavourable (1/n > 1). The linear plot of log qe versus log Ce was shown in **Fig 4**. The values of 1/n and K_F are 0.9697 and 0.0584 respectively. In the current study, the 1/n value shows that the adsorption process was favourable.

According to the present adsorption study, the correlation co-efficient for the Langmuir and Freundlich isotherms calculated from the graphs are summarized in table 2. The values were observed to be equal. Thus, it can be finally stated that Langmuir and Freundlich adsorption equations found to be better fitted.

4. Conclusion

The cooked tea waste, which is discarded as waste material from teashops and restaurant, proved to be an effective adsorbent for the removal of Cr (VI) from the wastewater. The percentage removal of chromium increased with increase in the adsorbent dosage and time. The percentage removal of chromium increased with the pH values and after attaining a equilibrium, it gradually decreased with increased pH values. The adsorption followed both Langmuir and Freundlich Adsorption Isotherm models. The studies revealed that AWT can be employed as an adsorbent for the treatment of chromium effluent.

5. Scope of Work

- Further studies are needed to explore the removal mechanism and interpret the fate of removed chromium ion if it be fixed by the porous structure of adsorbent depending on its nature.

- Also, the retention mechanisms of the adsorbent and possibility of exploration in the recovery cum reuse of adsorbed substance can be studied compared to the commercially available activated carbon.
- Additionally, observations can be made to assess the potential of low-cost adsorbents under multi component pollutants. This would make a significance impact on the potential commercial application of low cost adsorbents to industrial system. Therefore, more research should be conducted in this direction.
- It is further suggested that the research should not limit to only lab scale batch studies, but pilot plant studies should also be conducted utilizing low-cost adsorbents to check their feasibility on a commercial scale.

References

[1] Abu Qdaisa, H., Moussab, H., 2004. Removal of heavy metals from wastewater by membrane processes: a comparative study. Desalination. 164, 105–110.
[2] Acar F.N. and Malkoc E., 2004. The removal of chromium (VI) from aqueous solutions by Fagus orientalis L, Bioresource Technology, 94, 13–15.
[3] Ahalya N., R.D. Kanamadi and T.V.Ramachandra, 2005. Biosorption of chromium (VI) from aqueous solutions by the husk of Bengal gram (Cicer arientinum), Electron J Biotechno, 8(3), 258-264.
[4] Amana. T., Kazi. A.A., Sabri. M.U., Banoa. Q., 2008. Potato peels as solid waste for the removal of heavy metal copper (II) from waste water/industrial effluent. Colloids Surf. B: Biointerfaces 63, 116–121.
[5] Aziz, H.A., Adlan, M.N., Ariffin, K.S., 2008. Heavy metals (Cd, Pb, Zn, Ni, Cu and Cr(III)) removal from water in Malaysia: post treatment by high quality limestone. Bioresour. Technol. 99, 1578–1583.
[6] Babel, S., Kurniawan, T.A., 2003. Low-cost adsorbents for heavy metals uptake from contaminated water: a review. J. Hazard. Mater. B97, 219–243.
[7] Das D. D., Mahapatra R., Pradhan J., Das S. N., and Thakur R. S., 2000, Removal of Cr(VI) from Aqueous Solution Using Activated Cow Dung Carbon, Journal of Colloid and Interface Science 232, 235–240.
[8] Dhanakumar S., Solaraj G., Mohanraj R. and Pattabhi S. 2007. Removal of Cr(VI) from aqueous solution by adsorption using cooked tea waste. Indian J. Sci. Technol, Vol.1 (2), 1-6.
[9] Garg V.K., Gupta R., Kumar R., Gupta R.K, 2004, Adsorption of chromium from aqueous solution on treated sawdust, Bioresource Technology 92, 79–81.
[10] Gopalakrishnan S, Kannadasan T., Velmurugan S., Muthu S. and Vinoth Kumar P. 2013, Biosorption of chromium (VI) from industrial effluent using neem leaf adsorbent., Adsorbent, Research Journal of Chemical S. 3(4), 48-53.
[11] Haq B. I. U, Nursafura E. B. and Zakia K., 2013, Adsorption Studies of Cr (VI) and Fe (II) Aqua Solutions Using Rubber Tree Leaves as an Adsorbent, Int. Res. J. Environment Sci., 2(12), 52-56.
[12] Lokendra Singh T and Mukesh P, 2013, Adsorption of heavy metal (Cu2+, Ni2+ and Zn2+) from synthetic waste water by tea waste adsorbent, Int J of Chem and Phy Sc, 2(6), 6-19 .
[13] Mahvi A. H., N. Dariush, V. Forugh and N. Shahrokh, 2005, Teawaste as an adsorbent for heavy metal removal from industrial wastewaters, American J. Applied Sci., 2(1), 372-375.
[14] Miretzkya P., Cirellib F. A., 2010, Cr(VI) and Cr(III) removal from aqueous solution by raw and modified lignocellulosic materials: A review, Journal of Hazardous Materials, 180, 1–19.
[15] Nameni M., Alavi Moghadam M. R., Arami M., 2008, Adsorption of hexavalent chromium from aqueous solutions by wheat bran. Int. J. Environ. Sci. Tech., 5 (2), 161-168.
[16] Owlad M., Aroua M. K, Daud W. A. W. and Baroutian S., 2009. Rempoval of Hexavalent Chromium-contaminated water and wastewater: A review, Water Air Soil Pollut, 200: 59-77.
[17] Park S. J. and Jung W. Y., 2001. Removal of Chromium by activated carbon fibres plated with copper metal. Carbon Science, 2(1), 15-21.
[18] Prasad A. G. D. and Abdullah M. A., 2010, Biosorption of Cr(VI) from synthetic wastewater using the fruit shell of gulmohar (Delonix regia): Application to Electroplating wastetwater. Bioresources, 5(2), 838-853.
[19] Venkateswarlu P., Ratnam M. V., Rao D. S. and Rao M. V., 2007 Removal of chromium from an aqueous solution using Azadirachta indica (neem) leaf powder as an adsorbent, Int. J. of Phy. Sci., 2 (8), 188-195.
[20] Wankhade A. A. and Ganvir V.N., 2013, Preparation of Low Cost Activated Carbon from Tea Waste using Sulphuric Acid as Activating Agent, Int. Res. J. Environment Sci., 2(4), 53-55.

Authors Profile

Ms. Khushboo Bhavsar is a Lecturer at Department of Environmental Science and Technology, Institute of Science and Technology for advanced studies and research, Sardar Patel University, Vallabh Vidyanagar, Gujarat. Her research interest is in the area of Waste water Technologies. Also, she is a Principle Investigator for a project from Department of Science and Technology, New Delhi.

Ms. Payal Patel is a M.Sc. Student at Department of Environmental Science and Technology, Institute of Science and Technology for advanced studies and research, Sardar Patel University, Vallabh Vidyanagar, Gujarat.