

Applicability of Used Tea Leaves for Heavy Metal Retention from Industrial Effluents

Md. Misbah Uddin, Khayrun Nahar Mitu*

Department of Civil & Environmental Engineering, Shahjalal University of Science & Technology, Sylhet

*Corresponding author: sustnitu@gmail.com

Received May 08, 2020; Revised June 10, 2020; Accepted June 17, 2020

Abstract Heavy metal pollution is one of the significant concerns in Bangladesh. Due to complex behavior, heavy metal requires specialized treatment; among them, adsorptive retention from aqueous solutions proved as a cost-effective technique. This study investigates the usefulness of used tea leaves for adsorptive retention of Cu^{2+} ions from synthetic wastewater. Series of batch experiments identify the factors affecting adsorption, such as the adsorbent dose, agitation time, and the initial metal ion concentration. Maximum 95.1% Cu^{2+} retained on used tea leaves within 120 minutes of agitation time. The equilibrium data show compatibility with Langmuir and Dubinin-Radushkevich isotherms. High retention capacity proves used tea leaves as one of the excellent alternative adsorption materials.

Keywords: adsorption, heavy metal, industrial effluents, isotherms, tea leaves

Cite This Article: Md. Misbah Uddin, and Khayrun Nahar Mitu, "Applicability of Used Tea Leaves for Heavy Metal Retention from Industrial Effluents." *Applied Ecology and Environmental Sciences*, vol. 8, no. 5 (2020): 187-191. doi: 10.12691/aees-8-5-1.

1. Introduction

Environmental damage by toxic heavy metal is a global problem, as these are non-biodegradable (e.g. [1-9]). Generally, metals that have a density of greater than 5 gm/cm^3 are known as heavy metals (e.g. [10,11]). Particularly notable hazardous heavy metals are arsenic, chromium, copper, mercury, lead, nickel [8]. The toxicity of heavy metal causes a significant health risk to the human as well as other terrestrial and aquatic communities (e.g. [11-20]).

Heavy metal contamination is also a challenging crisis for Bangladesh. Environmental stress in river bounded Bangladesh is growing fast with rapid industrialization (e.g. [21,22,23,24]). Lack of environmental consciousness among both polluters and enforcers, almost all factories do not use effluent treatment facilities and dispose of untreated wastes directly into nearby water bodies. As a consequence, the water qualities of the rivers are getting polluted gradually (e.g. [25,26,27,28]). From different investigations around some critical industrial zone, including some river, Buriganga, Korotoa showed a higher amount of metals contained in the soil and vegetables of that area and also in the water, sediments, and fishes. Among the studied heavy metal, the most dominant are As, Cr, Fe, Ni, Cu, Cd, Pb, Mn, and Zn (e.g. [6,20,22,24,29,30,31,32,33,34,35]). So considering the threats, there is a need to increase the popularity of a remediation process with a locally available adsorbent so that industry and other responsible sectors adopt it directly.

Inquiry for most cost-effective and efficient treatment mechanisms has been going on. Removing constraints of available technologies, researchers are interested in complete remediation of toxic heavy metal with readily available inexpensive adsorbents. Several authors studied. The adsorption of metal ions such as chromium, lead, arsenic, nickel, copper, cadmium, and zinc from effluents using different agricultural waste: like Rice husk, peanut hulls, tea- waste, fruit peels.

An investigation by Bailey et al., [36] reported highest adsorption capacities for lead, mercury, chromium, and cadmium respectively 1, 587 mg Pb/g lignin, 796 mg Pb/g chitosan, 1, 123 mg Hg/g chitosan, 1, 000 mg Hg/g CPEI cotton, 92 mg Cr^{3+} /g chitosan, 76 mg Cr^{3+} /g peat, 558 mg Cd/g chitosan, and 215 mg Cd/g seaweed. Daifullah et al. [37] examined adsorptive removal of Fe, Mn, Zn, Cu, Cd, and Pb using sorbents made from rice husk, and efficiency was 100%. Agarwal et al. [38] evaluated the effectiveness of Tamarindus indica seeds (TS), crushed coconut shell (CS), almond shell (AS), groundnut shell (GS), and wall nutshell (WS) as a low-cost adsorbent. According to the study, the adsorption capacity (q_e) of hexavalent chromium followed the order: TS>WS>AS> GS>CS. Amin et al. [39] proposed a treatment system utilizing rice husk for the retention of arsenic and achieved 96% efficiency. Gao et al. [40] investigated the removal of Cr^{4+} by rice straw; obtained sorption capacity was 3.15 mg Cr^{4+} /g rice straw. Rocha et al. [41] experimented removal of Cu, Zn, Cd, and Hg ions using rice straw. The order of retention was Cd>Cu>Zn>Hg. Prabhakaran et al., [42] conducted a study for the adsorption of Cr^{4+} using spent tea and coffee dust, and uptakes resulted in 44.9mg Cr^{4+} /g

tea dust and 39.0 mg Cr⁴⁺/g coffee dust. Anagement [43] showed that the efficiency of Coconut husks and Palm Kernel fiber for Cr⁴⁺ ion removal were 91.14% and 84.89%, respectively. Biiyikgiingor et al., [44] carried a study to determine the potentiality of nut, Turkish coffee, waste tea, exhausted coffee, and walnut shells as a sorbent of Al³⁺ the adsorption were, 99.5, 99, 98, 96 and 96% respectively. Çay et al. [45] studied the adsorption ability of tea waste for the removal of Cu²⁺ and Cd²⁺. The reported capacity of per gram of tea waste was as 8.64 ± 0.51 mg Cu²⁺ and 11.29 ± 0.48 mg Cd²⁺ for single and 6.65 ± 0.31 Cu²⁺ and 2.59 ± 0.28 mg Cd²⁺ for binary systems respectively. Malkoc and Nuhoglu [46] carried out batch adsorption studies of Ni²⁺ on waste tea resulted in 15.26 mg Ni²⁺ /g waste tea. Furthermore, Malkoc and Nuhoglu [47] also experimented with the efficiency of waste tea in a fixed-bed column adsorption test. With an increase of initial Ni²⁺ concentration from 50 to 200 mg/L, the adsorption capacity increased from 7.31 to 11.17 mg/g waste tea. An investigation by Murugesan et al. [48] revealed that tea fungal mats removed 100% of As³⁺ and Fe²⁺ and 77% of As⁵⁺. Amarasinghe and Williams [11] showed maximum metal retention of 48 mg Cu²⁺/g tea waste and 65 mg Pb²⁺/g tea waste.

This study mainly focuses on the efficiency of a locally available adsorbent for the retention of heavy metal from industrial effluents, and its applicability in Bangladesh. The reason behind the selection of used tea leaves as the adsorbent was mainly because of their low cost and availability. In Bangladesh, copper has received attention because of its increasing pollution rate and impact. So this investigation aimed to remove the excess concentrations of the Cu²⁺ ion from aqueous solution in a cost-effective manner without much effort and time. The work also expects a solution for the management of used tea leaves by ensuring their value-added application.

2. Materials and Method

2.1. Adsorbent

Used tea leaves (chosen as the adsorbent) were collected from a food court (local name 'tong') located in SUST campus Sylhet, Bangladesh. Additional color, dirt, and other contents were removed. After rinsing with distilled water, leaves were oven-dried at 60°C for 24 hours. The leaves were crushed in a grinding mill to increase surface area. For preservation, leaves were kept in an airtight container at room temperature. Then the preserved leaves were ready to use as an adsorbent. Characterizations like moisture content, volatile matter, ash content, and particle size of used tea leaves were determined.

2.2. Adsorbate

For Cu²⁺ standard solution, 3.93 g of CuSO₄.5H₂O was added in the 100 mL of distilled water in a container then raise the volume to 1,000 mL. The initial concentration of the standard solution of Cu²⁺ was 1,000 mg/L. Working solutions prepared by adding water to a concentrated solution.

2.3. Adsorption

A series of experiments (Table 1) were carried out for adsorption of heavy metal on used tea leaves. In a beaker, a known weight of used tea leaves was added with 100 ml of synthetic wastewater (solution of known metal ion concentration, namely Cu²⁺); then, the mixture agitated in a magnetic stirrer. The required amount of sample was taken from the beaker at known predetermined time intervals. Then the sample were filtered and the concentration of concerned heavy metal remaining in suspension were measured by UV spectrophotometer. All tests conducted at room temperature.

Table 1. Full Factorial Design of Batch Tests for Cu²⁺ Ion

Initial concentration (mg/L)	10, 15, 20, 25
Adsorbent dose (g/100ml)	0.25, 0.50, 1.0
Agitation time (minute)	30, 60, 90, 120
PH	5.4

2.4. Analysis

Samples were analyzed using a UV spectrophotometer, then retention efficiency of metal ions was determined. The following equation was used for calculation.

$$R_e = \frac{C_i - C_f}{C_i} \times 100\% \quad (1)$$

Where Re refers to retention efficiency, C_i and C_f represent the initial and final metal ion concentration (mg/L).

The quantity of heavy metal adsorbed on used tea leaves was calculated using the following well-known equation.

$$q_m = \frac{C_i - C_f}{w} \times v \quad (2)$$

Where q_m refers to adsorption capacity (mg/g). w represents the weight of adsorbent (g). v represents the volume of synthetic wastewater (L).

2.5. Adsorption Isotherm

Isotherm model defines the nature of adsorption [49]. So to get an understanding of the design and analysis of the adsorption process, it requires a relevant isotherm model that fits the equilibrium data. The present study used Langmuir and Dubinin-Radushkevich isotherms model to analyze the adsorption mechanism.

3. Result and Discussion

The physical properties of tea leaves used in the present study indicate that adsorbent prepared and handled appropriately. The moisture content of tea leaves was 1.67%. It demonstrates that this adsorbent with low moisture content expected to swell more, thus accelerate pore size expansion for adsorbate uptake. The amount of volatile matter was 94.8%; this is due to the presence of a higher percentage of the volatile organic compound in

most of the agro products. Higher content of volatile matter reported as a favorable property that is responsible for the development of microporous structures. Ash is a measure of inorganic impurities in the carbons. The tea leaves showed 1.8% ash content, which indicates good quality of adsorbent. The pH of used tea leaves was also favorable as higher or lower pH affects the adsorption process and even influence the pH of the treated water. The particle size of used tea leaves determined by the sieve analysis method (Figure 1). The average particle size was in the range of 0.15 mm to 0.3 mm.

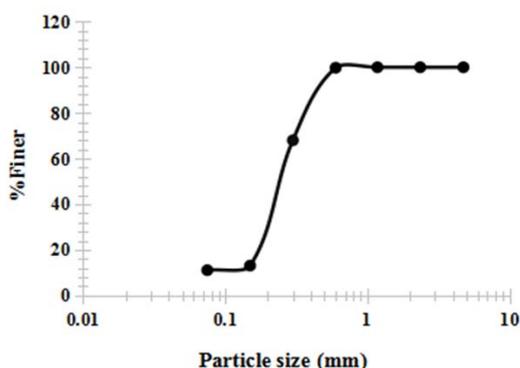


Figure 1. Particle size distribution curve (Tea Leaves)

Batch tests were carried out with 100 ml solution of desired Cu^{2+} concentration (10, 15, 20, 25 mg/L) at pH 5.4 with different adsorbent doses (0.25, 0.5, 1.0 g) for different agitation time (30, 60, 90, 120 min). In Table 2, four events show results for four different initial concentrations 10, 15, 20, and 25 mg/L, respectively. In all tests sets the amount of Cu^{2+} adsorbed per unit weight of tea leaves at equilibrium state (q_m) decreases with an increase in the number of tea leaves. Because at a higher dose, the system reaches equilibrium at a lower concentration.

Table 2. Adsorption of Cu^{2+} At pH. 5.4 And Different Adsorbent Dose.

Time (min)	Initial Concentration (mg/L)											
	10			15			20			25		
	Adsorbent Dose (g/100ml)											
	0.25	0.50	1.0	0.25	0.50	1.0	0.25	0.50	1.0	0.25	0.50	1.0
	q_m (mg/g)			q_m (mg/g)			q_m (mg/g)			q_m (mg/g)		
30	3.71	1.81	0.92	4.80	2.69	1.34	6.24	3.48	1.79	8.27	4.21	2.19
60	3.72	1.82	0.93	4.83	2.71	1.35	6.46	3.52	1.79	8.3	4.21	2.23
90	3.73	1.84	0.95	4.88	2.72	1.37	6.47	3.53	1.83	8.37	4.22	2.24
120	3.73	1.84	0.95	4.88	2.72	1.37	6.48	3.54	1.84	8.37	4.22	2.25

Influential parameters such as initial concentration agitation time and adsorbent dose were checked to determine optimum condition for adsorption. Adsorption tests as a function of agitation time for Cu^{2+} showed that equilibrium established at 90 minutes of agitation time for all initial concentrations with all adsorbent doses. At first

30 minutes of agitation, retention was found at a higher rate in each test set which indicates more available vacant sites at the beginning of the time than a successive time. After a 90-minutes retention rate was found almost the same for all concerned initial Cu^{2+} concentrations, so 90 minutes of agitation time was the optimum agitation time for Cu^{2+} Adsorptive tests (Figure 2). One trend was noted that as the initial concentration increased, the adsorption decreased. Due to a higher concentration, many unadsorbed ions were left for the same adsorbent dose compared with a lower concentration. At a lower concentration higher number of available vacant pores causes higher interaction between adsorbent and adsorbate (Figure 2).

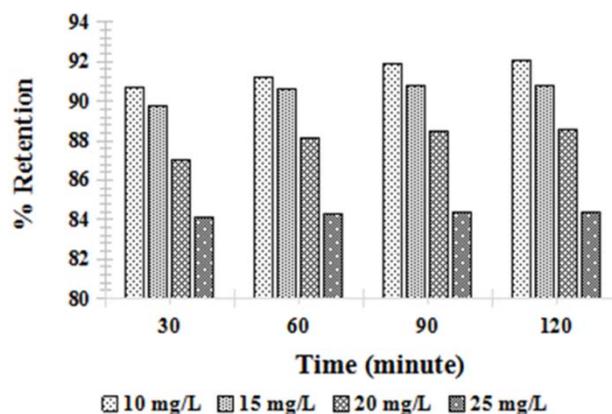


Figure 2. Effect of agitation time and initial concentrations on adsorption of Cu^{2+} onto used tea leaves: 1.0 g of adsorbent mixed with 100 ml of solution at pH 5.4 and room temperature

The amount of adsorbent is also a vital factor in adsorption. The adsorbent dose study showed that an increased amount of adsorbent increases the percentage retention of Cu^{2+} on leaves. It credited to the number of the increased surface area resulting from the increased amount of tea leaves. Maximum 95.1% retention efficiency obtained at 1g tea leaves /100ml for 10 mg/L initial concentration (Figure 3).

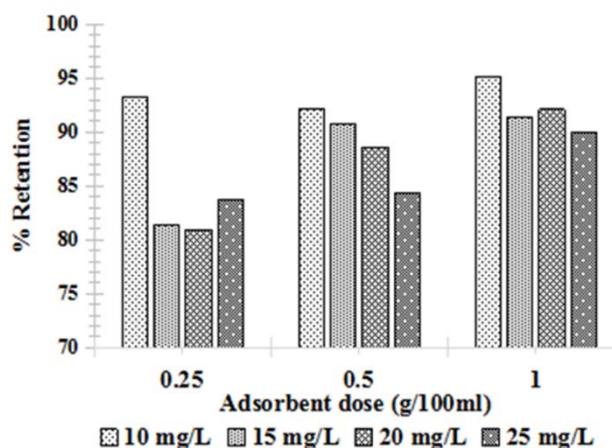


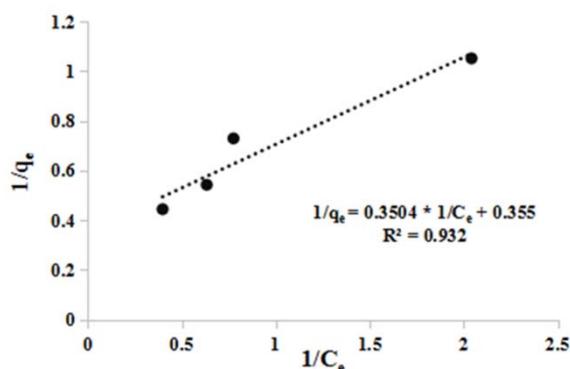
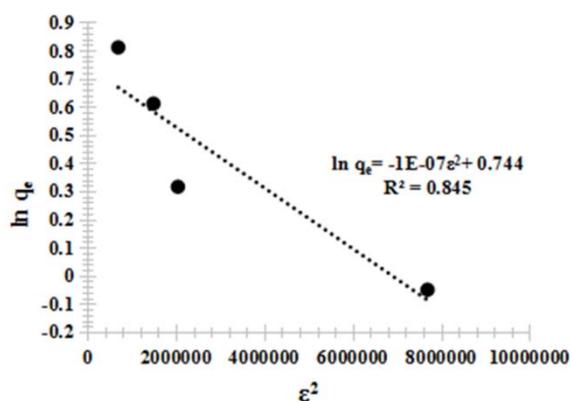
Figure 3. Effect of adsorbent dose on adsorption of Cu^{2+} onto used tea leaves: at 120 min of agitation time, 100 ml of solution at pH 5.4 and room temperature

Maintaining optimum parameters in all experimental sets remaining concentration of a copper ion in solution was within the permissible limit by The Environment Conservation Rules, 1997' Bangladesh [50]. (Table 3).

Table 3. Permissible Limits and Health Effects of Various Toxic Heavy Metal

Metal	Standards for Waste from Industrial Units (mg/L)			
	Bangladesh Standard			WHO
	Inland surface water	Public Sewers	Irrigated Land	Inland surface water
Copper (as Cu ²⁺)	0.5	3.0	3.0	0.05-1.5

This Study examined several isotherm models to define the nature of the interaction between adsorbate and adsorbent. Among them, equilibrium data of Cu²⁺ adsorption tests were fitted better to Langmuir isotherm and Dubinin-Radushkevich model (Figure 4 and Figure 5). Langmuir isotherm achieved the best fit with equilibrium adsorption data of Cu²⁺ which has the highest determination coefficient value, R² (Table 4). R_L value (Table 5), is an essential parameter of the Langmuir isotherm indicates adsorption for all initial concentrations of Cu²⁺ was favorable. From the Dubinin-Radushkevich isotherm parameters calculated apparent free energy for Cu²⁺ was 2, 236 kJ/mol. Higher energy indicates it, may be a chemical ion exchange process involved in the adsorption mechanism.

**Figure 4.** Adsorption isotherms of Cu²⁺ on used tea leaves fitted to Langmuir isotherms**Figure 5.** Adsorption isotherms of Cu²⁺ on used tea leaves fitted to Dubinin-Radushkevich isotherm**Table 4. Isotherm Parameters for Cu²⁺ Adsorption at Temperature 27°C**

Langmuir isotherm			Dubinin-Radushkevich isotherm		
Q ₀ (mg/g)	K _L (L/mg)	R ²	Q _m (mg/g)	K (mol ² /kJ ²)	R ²
2.82	1.01	0.932	2.10	10 ⁻⁷	0.845

Table 5. R_L Value Indicates the Adsorption Nature of Cu²⁺ Ions

The initial concentration of Cu (mg/L)	R _L	Adsorption nature
10	0.09	Favorable
15	0.06	Favorable
20	0.05	Favorable
25	0.04	Favorable

4. Conclusion

The proposed treatment system proved that used tea leaves can be utilized as an excellent alternative adsorbent for heavy metal retention. Throughout this paper, the retention of Cu²⁺ particularly from industrial wastewater, was highlighted. Adsorbent dose, agitation time, and initial concentration of metal ion are the main operating conditions that influence the degree of retention. Isotherm studies also validate the present adsorption process. Excellent retention of Cu²⁺ ions achieved without any pre-treatment of used tea leaves. Used tea leaves subjected to adsorption resulted in maximum 95.1% retention of Cu²⁺ ion within 120 minutes of agitation time at pH 5.4. And the adsorbent dose of 1g was proved sufficient.

However, this process can perform at a low cost, so the treatment system is appropriate for the industrial sector to apply. It may also be suitable as a homemade approach because of its simplicity in operation & handling.

Acknowledgements

The research supported by lab facilities by the Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology.

References

- [1] Gaur N, Flora G, Yadav M, Tiwari A. A review with recent advancements on bioremediation-based abolition of heavy metals. *Environ. Sci. Process. Impacts*. 2014; 16: 180-193.
- [2] Malik R N, Zeb N. Assessment of environmental contamination using feathers of *Bubulcus ibis* L., as a biomonitor of heavy metal pollution, Pakistan. *Ecotoxicology*. 2009; 18: 522-536.
- [3] Chabukdhara M, Nema A K. Assessment of heavy metal contamination in Hindon River sediments: A chemometric and geochemical approach. *Chemosphere*. 2012; 87: 945-953.
- [4] An H K, Park B Y, Kim D S. Crab shell for the removal of heavy metals from aqueous solution. *Water Res*. 2001; 35: 3551-3556.
- [5] Bhagure G R, Mirgane S R. Heavy metal concentrations in groundwater and soils of Thane Region of Maharashtra, India. *Environ. Monit. Assess*. 2011; 173: 643-652.
- [6] Ahmad J U, Goni M A. Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. *Environ. Monit. Assess*. 2010; 166: 347-357.
- [7] Ijagbemi C O, Baek M H, Kim D S. Montmorillonite surface properties and sorption characteristics for heavy metal removal from aqueous solutions. *J. Hazard. Mater*. 2009; 166: 538-546.
- [8] Kołodyńska D, Hubicka H. Polyacrylate anion exchangers in sorption of heavy metal ions with non-biodegradable complexing agents. *Chem. Eng. J*. 2009; 150: 308-315.
- [9] Inyang M et al. Removal of heavy metals from aqueous solution by biochars derived from anaerobically digested biomass. *Bioresour. Technol*. 2012; 110: 50-56.
- [10] Tchounwou P B, Yedjou C G, Patlolla A K, Sutton D J. Heavy metal toxicity and the environment. *EXS*. 2012; 101: 133-164.

- [11] Amarasinghe B M W P K, Williams R A. Tea waste as a low cost adsorbent for the removal of Cu and Pb from wastewater. *Chem. Eng. J.* 2007; 132: 299-309.
- [12] Järup L. Hazards of heavy metal contamination. *Br. Med. Bull.* 2003; 68: 167-182.
- [13] Kumar Sharma R, Agrawal M, Marshall F. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicol. Environ. Saf.* 2007; 66: 258-266.
- [14] Alam M G M, Snow E T, Tanaka A. Arsenic and heavy metal contamination of rice, pulses and vegetables grown in Samta village, Bangladesh. *Arsen. Expo. Heal. Eff. V.* 2003; 308: 103-114.
- [15] Wu P, Zhou Y. Simultaneous removal of coexistent heavy metals from simulated urban stormwater using four sorbents: A porous iron sorbent and its mixtures with zeolite and crystal gravel. *J. Hazard. Mater.* 2009; 168: 674-680.
- [16] Caeiro S et al. Assessing heavy metal contamination in Sado Estuary sediment: An index analysis approach. *Ecol. Indic.* 2005; 5: 151-169.
- [17] Yongming H, Peixuan D, Junji C, E S Posmentier. Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China. *Sci. Total Environ.* 2006; 355: 176-186.
- [18] Reza R, Singh G. Heavy metal contamination and its indexing approach for river water. *Int. J. Environ. Sci. Technol.* 2010; 7: 785-792.
- [19] Xiangdong L, Chi-sun P, Pui Sum L. Heavy metal contamination of urban soils and street dusts in Hong Kong. *Appl. Geochemistry.* 2001; 16:1361-1368.
- [20] Saha N, Zaman M R. Evaluation of possible health risks of heavy metals by consumption of foodstuffs available in the central market of Rajshahi City, Bangladesh. *Environ. Monit. Assess.* 2013; 185: 3867-3878.
- [21] Ahmed F, Bibi M H, Monsur M H, Ishiga H. Present environment and historic changes from the record of lake sediments, Dhaka City, Bangladesh. *Environ. Geol.* 2005; 48:25-36.
- [22] Ahmed F, Ishiga H. Trace metal concentrations in street dusts of Dhaka city, Bangladesh. *Atmos. Environ.* 2006; 40: 3835-3844.
- [23] Shahbaz M, Salah Uddin G, Ur Rehman I, Imran K. Industrialization, electricity consumption and CO 2 emissions in Bangladesh. *Renew. Sustain. Energy Rev.* 2014; 31: 575-586.
- [24] Bhuiyan M A H, Parvez L, Islam M A, Dampare S B, Suzuki S. Heavy metal pollution of coal mine-affected agricultural soils in the northern part of Bangladesh. *J. Hazard. Mater.* 2010; 173: 384-392.
- [25] Alam J B et al. Deterioration of water quality of Surma river. *Environ. Monit. Assess.* 2007; 134: 233-242.
- [26] Kam S K, Harada H. Surface water pollution in three urban territories of Nepal, India, and Bangladesh. *Environ. Manage.* 2001; 28: 483-496.
- [27] Kamal M M, Malmgren-Hansen A, Badruzzaman A B M. Assessment of pollution of the River Buriganga, Bangladesh, using a water quality model. *Water Sci. Technol.* 1999; 40: 129-136.
- [28] Polizzotto M L, Kocar B D, Benner S G, Sampson M, Fendorf S. Near-surface wetland sediments as a source of arsenic release to ground water in Asia. *Nature.* 2008; 454: 505-508.
- [29] Bhuiyan M A H et al. Investigation of the possible sources of heavy metal contamination in lagoon and canal water in the tannery industrial area in Dhaka, Bangladesh. *Environ. Monit. Assess.* 2011; 175: 633-649.
- [30] Islam M S, Ahmed M K, Raknuzzaman M, Habibullah -Al- Mamun M, Islam M K. Heavy metal pollution in surface water and sediment: A preliminary assessment of an urban river in a developing country. *Ecol. Indic.* 2015; 48: 282-291.
- [31] Rahman M S, Saha N, Molla A H. Potential ecological risk assessment of heavy metal contamination in sediment and water body around Dhaka export processing zone, Bangladesh. *Environ. Earth Sci.* 2014; 71: 2293-2308.
- [32] Ali M M, Ali M L, Islam M S, Rahman M Z. Preliminary assessment of heavy metals in water and sediment of Karnaphuli River, Bangladesh. *Environ. Nanotechnology, Monit. Manag.* 2016; 5: 27-35.
- [33] Rahman M S, Molla A H, Saha N, Rahman A. Study on heavy metals levels and its risk assessment in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh. *Food Chem.* 2012; 134: 1847-1854.
- [34] Shaheen N, Irfan N M, Khan I N, Islam S, Islam M S, Ahmed M K. Presence of heavy metals in fruits and vegetables: Health risk implications in Bangladesh. *Chemosphere.* 2016; 152: 431-438.
- [35] Ahmed M K et al. Human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh. *Environ. Sci. Pollut. Res.* 2015; 22: 15880-15890.
- [36] Bailey S E, Olin T J, Mark Bricka R, Dean Adrian D. A Review of Potentially Low-Cost Sorbents for Heavy Metals. *Wat. Res.* 1999; 33: 2469-2479.
- [37] Daifullah A A M, Girgis B S, Gad H M H. Utilization of agro-residues (rice husk) in small waste water treatment plans. *Mater. Lett.* 2003; 57: 1723-1731.
- [38] Agarwal G S, Bhuptawat H K, Chaudhari S. Biosorption of aqueous chromium(VI) by Tamarindus indica seeds. *Bioresour. Technol.* 2006; 97:949-956.
- [39] Amin N et al. Removal of arsenic in aqueous solutions by adsorption onto waste rice husk. *Ind. Eng. Chem. Res.* 2006; 45: 8105-8110.
- [40] Gao H, Liu Y, Zeng G, Xu W, Li T, Xia W. Characterization of Cr(VI) removal from aqueous solutions by a surplus agricultural Waste-Rice straw. *J. Hazard. Mater.* 2008; 150: 446-452.
- [41] Rocha C G, Zaia D A M, Alfaya R V da S, Alfaya A A da S. Use of rice straw as biosorbent for removal of Cu(II), Zn(II), Cd(II) and Hg(II) ions in industrial effluents. *J. Hazard. Mater.* 2009; 166: 383-388.
- [42] Prabhakaran S K, Vijayaraghavan K, Balasubramanian R. Removal of Cr(VI) ions by spent tea and coffee dusts: Reduction to Cr(III) and biosorption. *Ind. Eng. Chem. Res.* 2009; 48: 2113-2117.
- [43] Anagement M. Adsorption Studies of Heavy Metals by Low-Cost Adsorbents. *J. Appl. Sci. Environ. Manag.* 2014; 18: 443-448.
- [44] Biiyikgiingor H, Orhan Y, Büyükgüngör H, Biiyikgiingor H. "The Removal of Heavy Metals by Using Agricultural Wastes. *Water Sci. Technol.* 2018; 28: 247-255.
- [45] Çay S, Uyanik A, Özaşık A. Single and binary component adsorption of copper(II) and cadmium(II) from aqueous solutions using tea-industry waste. *Sep. Purif. Technol.* 2004; 38: 273-280.
- [46] Malkoc E, Nuhoglu Y. Investigations of nickel(II) removal from aqueous solutions using tea factory waste. *J. Hazard. Mater.* 2005; 127: 120-128.
- [47] Malkoc E, Nuhoglu Y. Removal of Ni(II) ions from aqueous solutions using waste of tea factory: Adsorption on a fixed-bed column. *J. Hazard. Mater.* 2006; 135: 328-336, 2006.
- [48] Murugesan G S, Sathishkumar M, Swaminathan K. Arsenic removal from groundwater by pretreated waste tea fungal biomass. *Bioresour. Technol.* 2006; 97: 483-487, 2006.
- [49] Rangabhashiyam S, Anu N, Giri Nandagopal M S, Selvaraju N. Relevance of isotherm models in biosorption of pollutants by agricultural byproducts. *J. Environ. Chem. Eng.* 2014; 2: 398-414.
- [50] E.C.R. 1997. Schedule - 10. Standards for Waste from Industrial Units or Projects Waste. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, Bangladesh Gazette, 213.

