International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2019): 7.583

Adsorptive Removal of Some Pollutants from Industrial Effluent Using Eco-Friendly Biomaterial

Digvijay Singh Chauhan[1], Dr. Prabha Chauhan[2]

[1]Research Scholar, Department of Chemistry, SMS Govt. Model Science College, Gwalior, Madhya Pradesh, India
Contact No: 9039013812 E-mail- digvijay.shch[at]gmail.com
[2]Professor, Department of Chemistry, SMS Govt. Model Science College, Gwalior, Madhya Pradesh, India

Abstract: ***The effluent samples were collected from selected manufacturing units established nearby Gwalior, Madhya Pradesh, India. The study found that COD and heavy metals namely Fe, Cr, Pb and Zn were present in the sample and their concentration exceeds the permissible limit sometimes as prescribed by BIS. These pollutants cause serious health problems in human beings when they enter through food chain. Therefore, to minimize health problems, the effluent treatment using Neem leaf adsorbent was done. The percentage removal depends on the factors like pH, conc. of pollutants, amount and particle size of adsorbent, contact time etc. The maximum COD removal was observed up to 68.66%, whereas the maximum removal of Fe, Cr, Pb and Zn was observed up to 60%, 48.48%, 63.72% and 59.13% respectively. The findings before and after the adsorption treatment indicate that the pollution level minimized considerably when compared to the permissible limit of BIS.***

Keywords: Effluent, COD, Adsorbent, Human being

1.Introduction

It is common that the industrial effluent released directly from manufacturing units under investigation in water bodies through runnels and also in the open or agricultural land without any prior treatment. These untreated effluents contaminate soil by accumulating various toxic substances in it and ground water by percolating through soil bed. Once pollutants enter into soil, the concentration of toxic chemicals increases in the course of time, which further transfer in plants and human beings via food chain, especially heavy metals are the important contaminants that can be found in tissues, surface of fresh fruits, vegetables and also water creature like fishes[37]. Prolonged consumption of such contaminated food that has unsafe concentration of heavy metals, may lead to the disruption of numerous biochemical and biological processes in the human body. The accumulation of heavy metals give rise to toxic concentration in the body, while some metals like Cr, Cd act as carcinogenic and others like Pb, Hg are caused mental abnormalities in Children[35-37]. The high value of TDS and COD proliferate various abdominal problems in humans. Therefore, an intense need for researchers from all over the world has been observed and they developed a number of methods to minimize water pollution. The different methods such as sedimentation, coagulation, filtration, ion exchange, solvent extraction, electrolysis, chemical oxidation, adsorption etc. can be used for the removal of waste water pollutants. Although, these methods have their own shortcomings and limitations[1-2, 4-5]. Among the possible techniques for waste water treatment, 'adsorption' process is the most efficient and widely used method for the treatment and removal of inorganic and organic contaminants from industrial wastewater because of convenience, easy operation and simplicity of design and low cost[6]. In recent years, the search for low-cost and eco-friendly adsorbents that have pollutant binding capacities has intensified[32-33]. In the study, Neem leaves[19-21] used as adsorbent to minimize heavy metal contents along with the organic and inorganic load in industrial effluents. The selection of adsorbents based on its availability, cost, eco-friendly nature and efficiency in removal of water pollutants.[7]. The aim of this work is to study the removal of organic content and toxic heavy metal ions by Neem leaves from industrial waste water and to offer this biosorbent as local replacement for existing commercial adsorbent materials [22].

2.Method and material - Preparation of Neem leaves adsorbent

The mature fresh Neem leaves were collected from Neem trees and were washed repeatedly with water to remove dust and soluble impurities and were allowed to dry at room temperature in a shade. Then, the leaves were dried in an hot air oven at 60-70^{o}C for 30 h, when the leaves became crisp and brittle, the crisp leaves were ground in a mechanical grinder to obtain a fine powder. The Neem leaf powder was sieved and fractionated using a series of sieves. The 0.25 to 0.5 mm fraction was separated and taken as the adsorbent. This fraction was washed several times with double distilled water till the washings were free of color and turbidity. The washed powder was dried for several hours at room temperature and was preserved in glass bottles [25-26].

Figure: Fresh Matured Neem Leaf and its Powder

Characterization of Neem (Azadirachta indica) leaves adsorbent

The fresh Neem leaf has a moisture content of 59.4%, carbohydrates 22.9%, protein 7.1%, fibre 6.2%, minerals 3.4%, fats 1% and many other chemicals. It also has certain important chemical ingredients such as azadirachtin, salannin, meliantriol, nimbin and nimbidin. These belong to a general class of natural products called "triterpenes", or more specifically limonoids. These chemical compounds were found to have a great metal binding tendency towards Pb, Zn, Cr and Ni [23-24].

Scanning Electron Microscopy (SEM) is an important tool to study the surface topography of a solid material. Scanning electron microscopic image of the neem leaf powder showed that the surface of adsorbent appears as a fibrous material with irregular macropores and some expanded cavities which may allow for the diffusion of the atoms or molecules through the macropores of the adsorbent [29].

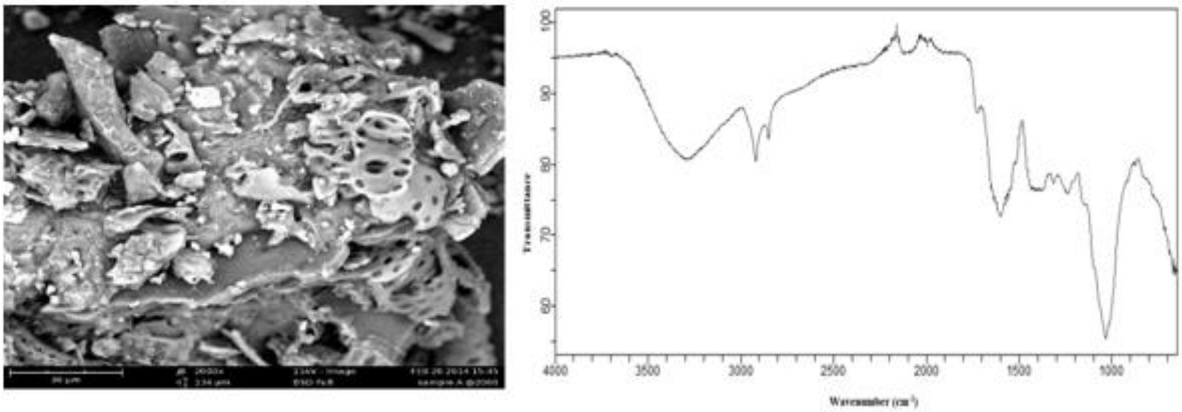


Figure: SEM and FTIR image of Neem Leaf Powder

IR spectroscopy is one of the major tools used for obtaining information on functional groups on a solid surface. The principle of IR spectroscopy is based on molecules vibrating with specific frequencies associated with internal vibrations of groups of atoms. These frequencies occur in the IR region of the electromagnetic spectrum, i.e. ~ 200 to ~ 4000 cm^{-1}. When a sample is placed in a beam of IR radiation, the sample absorbs all radiations corresponding to those of molecular vibrational frequencies, and transmits all other frequencies. Identification of functional groups is possible because differences in the chemical structure give rise to characteristic vibrations and yield unique IR spectra.. The IR spectra show the presence of C–H bending (985.56 – 1472.55 cm^{-1}), C–H Stretching (2845.77 – 2909.42 cm^{-1}), $O–CH_3$ (1475.42 cm^{-1}), C=C, Ketone (1575.73 – 1748.35 cm^{-1}), Carboxylic (1319.22 – 1717.49 cm^{-1}), Amides (1575.73 cm^{-1}), aromatic (754.12 – 762.79 cm^{-1}), C-O-C stretching (1164.92 cm^{-1}), sulphur compounds (1097.42 – 1339.47 cm^{-1}), alcohols and phenols (1271 – 3627.85 cm^{-1}). Also, –OH (3597–3600cm^{-1}), $–NH_2$ (3399cm^{-1}), ≡CH (3297cm^{-1}), >C=N– (1656cm^{-1}), ≡C–C≡, ≡C–N< and ≡C–O– (1160cm^{-1}), >C=O (1633, 1656, 1672, 1688, 1714cm^{-1}), >C=C< (1656cm^{-1}), and >C=S (1105cm^{-1}) functional groups on the surface of neem leaf powder [28, -29]. The FTIR spectrum of the Neem Leaf Powder has also been shown to contain a number of fatty acids like oleic acid, stearic acid, palmitic acid, linoleic acid, etc. The presence of polar groups on the surface has been shown to be responsible for considerable cation exchange capacity of a solid.

Effluent Collection

The effluent samples were taken from some selected industrial points of manufacturing plants around the city in pre-cleaned bottles. The selection of industrial points based on the physico chemical analysis of such units for a period of three years and most polluted samples were considered to adsorptive removal of major pollutants.

Bioadsorptive removal of COD, Fe, Pb, Cr and Zn with Neem Leaf Powder

According to Environmental Protection Agency, USA, the metals As, Pb, Hg, Cd and Cr (VI) are included in the toxic substances. Hence, in this part of work, Fe, Pb, Cr, Zn and COD were chosen for study with respect to removal from the industrial effluent samples by a natural adsorbent. The first step of the study consisted of the assessment of industrial effluent in reference of COD, Fe, Pb, Cr and Zn, whereas, during the second step, adsorption was applied to reduce COD, Fe, Pb, Cr and Zn from released waste water which is taken as a sample. The one part of effluent was treated with Neem leaf Powder as adsorbent, termed as treated effluent and another remaining part was termed as untreated effluent. The treated and untreated effluent samples were analyzed for COD, Fe, Pb, Cr, and Zn.

The adsorption measurements were conducted by mixing specified amount of adsorbent (3 g) in 500 mL Borosil Conical flasks containing 250 cm^3 of effluent sample. The initial pH of the effluent samples were adjusted to the desired values by adding few drops of 0.1M HCl or 0.1M NaOH aqueous solution. The samples were agitated using a magnetic stirrer for a predetermined time (180 minute) to attain equilibrium at constant agitation speed of 300 rpm and room temperature; after which the samples were taken out and allowed to settle and then, the sample was filtered through Whatmann filter paper and filtrate was analyzed by standard testing procedures for COD and metals [17].

The percentage adsorption and substrate's equilibrium adsorption capacity (mg/g) were evaluated using following equations[17]

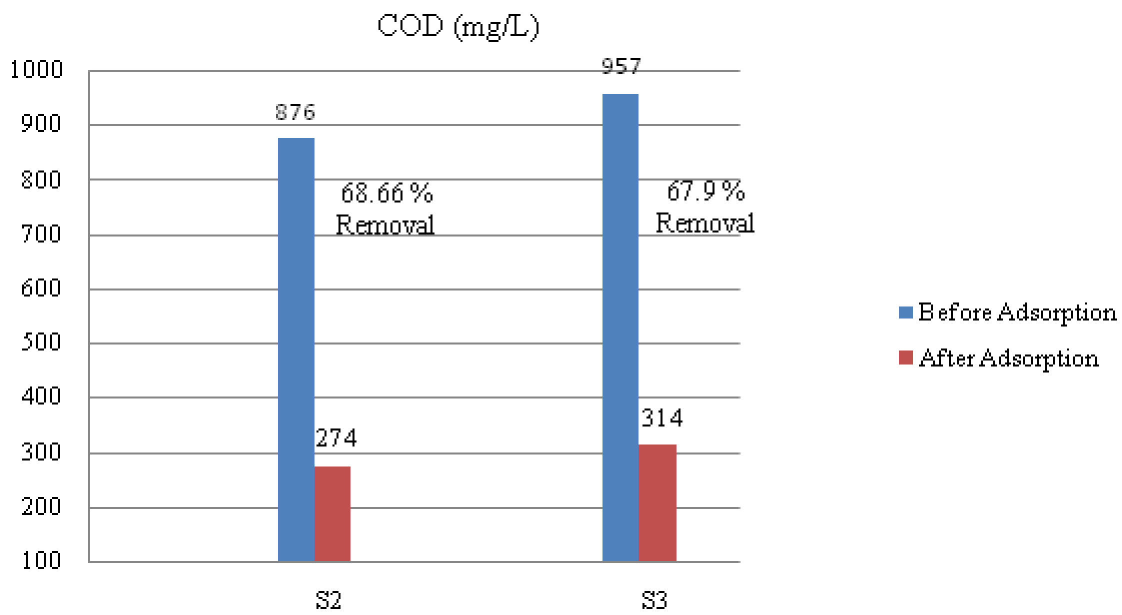
$$\text{Adsorption or Removal } (\%) = \frac{\text{Initial Conc.} - \text{Final Conc.}}{\text{Initial Conc.}} \times 100$$

3. Result and Discussion

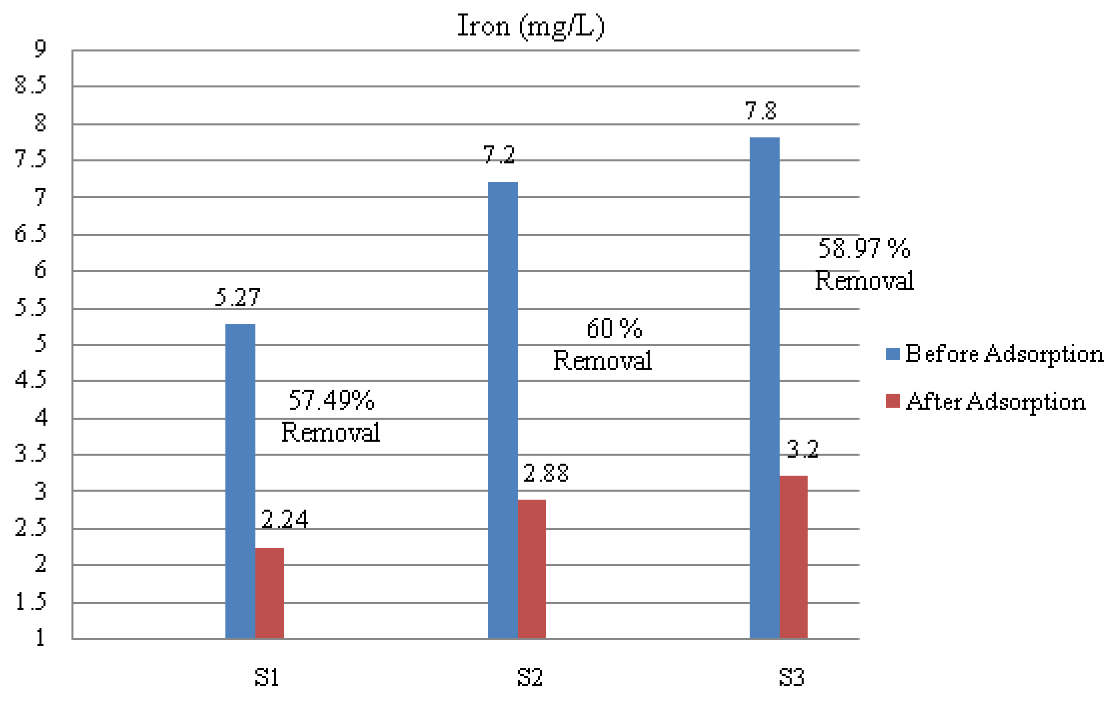
The results obtained from analysis of untreated effluent samples and treated effluent samples were represented in the following table.

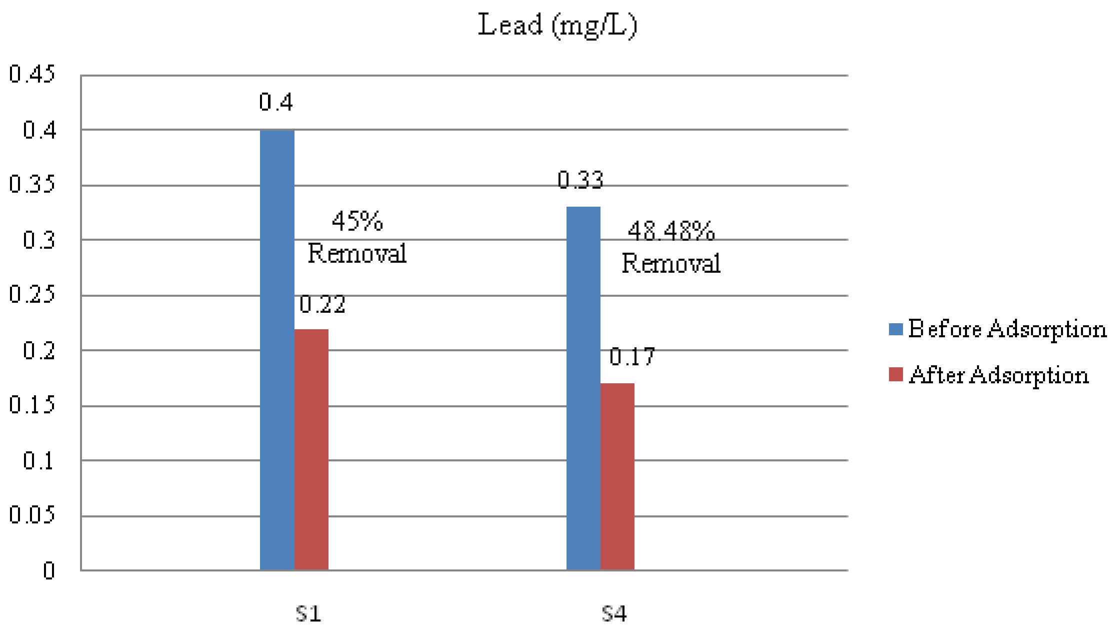
Parameter	Sample	Adsorption	
		Before	After
COD (mg/L)	S_2	876	274
	S_3	957	314
Fe (mg/L)	S_1	5.27	2.24
	S_2	7.2	2.88
	S_3	7.8	3.2
Pb (mg/L)	S_1	0.40	0.22
	S_4	0.33	0.17
Cr (mg/L)	S_3	5.1	1.85
Zn (mg/L)	S_3	11.5	5.2

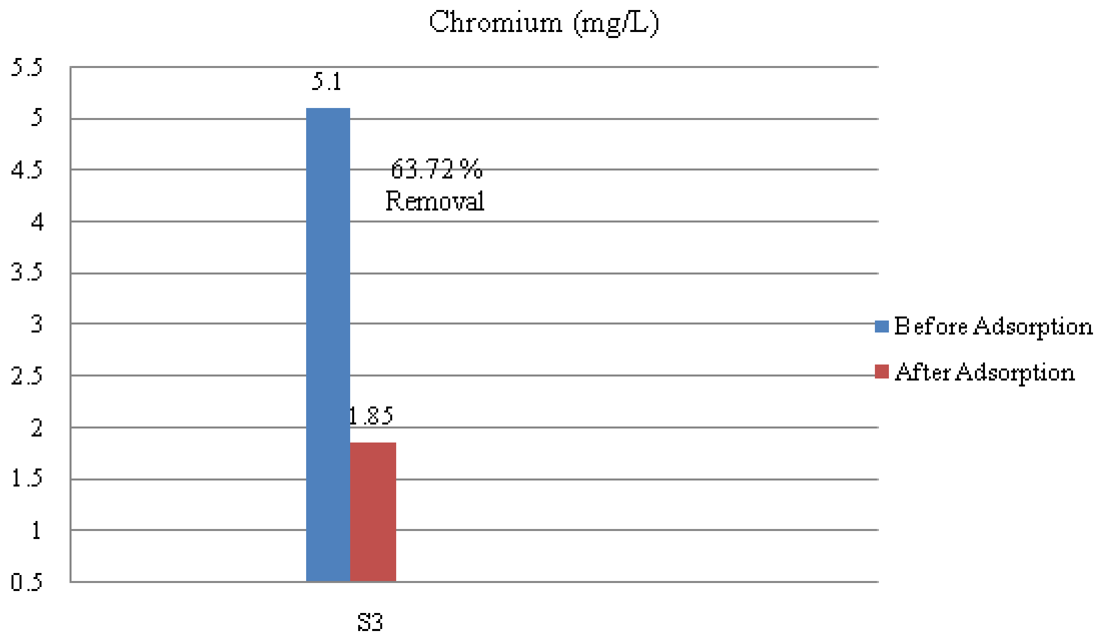
For all collected samples adsorbent dose was 12 g/L and samples were run for 180 min. The result shows that about 68.66% and 67.19 % removal of COD were obtained for S_2 and S_3 respectively. The obtained results show that maximum COD removal occurred for S_2, were achieved at pH 8-10 because of better adsorption observed at higher pH attributed to the co-precipitation of the organic matters[34]. The heavy metals content also showed remarkable reduction after adsorption, Iron in S_1 decreased from 5.27 mg/L to 2.24 mg/L, similarly in S_2 and S_3 reduced up to 60 % and 58.97 % respectively. Lead metal decreased from 0.40 mg/L to 0.22 mg/L in S_1 while in S_4 from 0.33 mg/L to 0.17 mg/L. The initial concentration of Cr and Zn decreased up to 1.85 mg/L and 5.2 mg/L respectively. The obtained readings of all selected parameters after adsorption showed appreciable decrease in their values. The results of the treated and untreated effluent samples and percentage removal of pollutants also represented graphically.

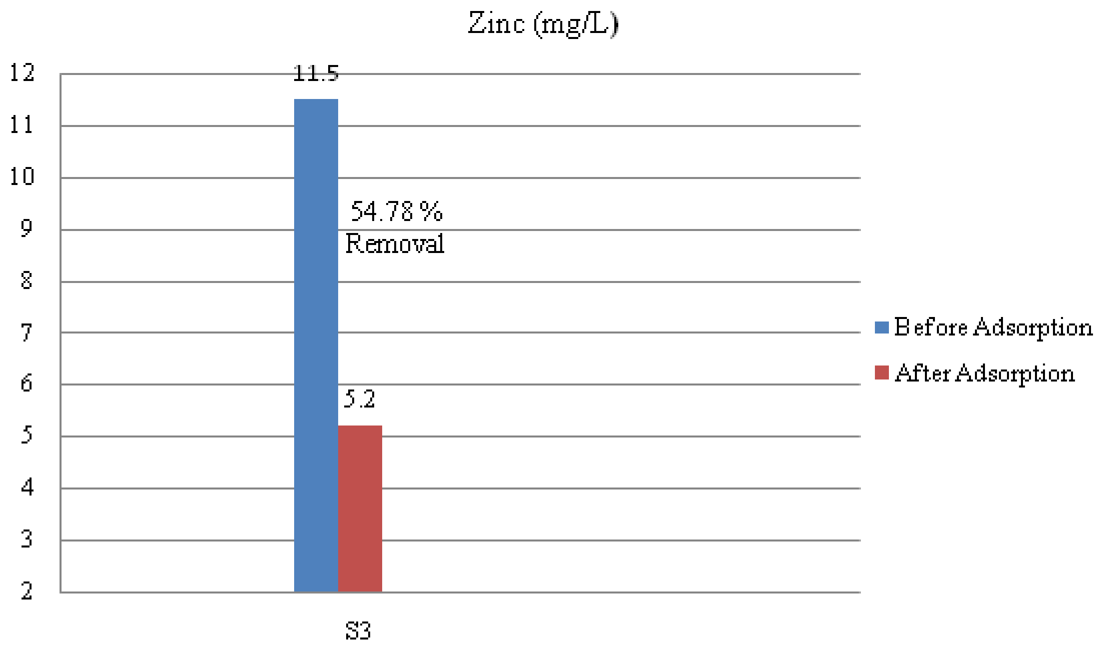


Paper ID: SR201117214946 DOI: 10.21275/SR201117214946


Iron (mg/L)
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
5.27
57.49%
Removal
2.24
7.2
60 %
Removal
2.88
7.8
58.97 %
Removal
3.2
S1
S2
S3
Before Adsorption
After Adsorption


Lead (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.4
45%
Removal
0.22
0.33
48.48%
Removal
0.17
S1
S4
Before Adsorption
After Adsorption





4.Conclusion

In this part of work, an attempt has been made for studying the removal of COD, Fe, Pb, Cr and Zn from industrial effluent using Neem Leaf Powder adsorbent. The result of present work showed that Neem Leaf Powder can be used as an effective low cost bioadsorbent for removal of COD, Fe, Pb, Cr and Zn from industrial effluents. The maximum COD removal was observed up to 68.66 %, whereas the maximum removal percentage of Fe, Pb, Cr and Zn occurred up to 60 %, 48.48%, 63.72 % and 54.78% respectively. The findings before and after the adsorption treatment indicate that the level of water pollution minimized considerably when compared to the permissible limit of BIS [31]. The adsorption process is influenced by pH of the sample, initial concentration of the metal ions, the amount of adsorbent, particle size, and contact time of adsorbent[10]. Therefore, efficiency of adsorption can be further enhanced by adjusting pH of solution, adsorption time, particle size and quantity of an adsorbent.

This present work will not be significant only to the manufacturing industries to minimize cost of COD and heavy metals removal, but also to minimize the impact to the environment for the betterment of mankind. It has also demonstrated that mature Neem leaves, a useless plant waste which are shed regularly each winter, can be converted into an excellent and beneficial adsorbent for organic as well as inorganic pollutants.

References

[1] Weber W J Jr, Physiochemical processes for water quality control (Wiley-Interscience, New York), 1972.
[2] Pontius FW, Water quality and treatment, 4th edition (McGraw hill Inc, New York), 1990.
[3] Goto S, Goto M & Uchiyama S, J Chem Eng Jpn, 17 (1984) 204.
[4] Kace J S & Linford H B, J Water Pollution Control Fed.47 (1975)1971.
[5] Snider E H & Porter J J, J Water Pollution Control Fed.46 (1974)886.
[6] Faust S D 7 Aly O M, Adsorption process for water treatment (butterworths publishers, stoneham) 1987.
[7] Pollard SJT, Fowler GD, Sollars CJ & Perry R, Sci Total Environ, 116 (1952) 31.
[8] Barakat.M.A (2011) 'New trends in removing heavy metals from industrial wastewater' Arabian Journal Chemistry, Vol. 4, pp. 361-377.
[9] Jiaping.P.C (2012) 'Decontamination of Heavy Metals: Processes, Mechanisms, and Applications' CRC Press, Print ISBN: 978-1-4398-1667-7
[10] Azouaou.N, Sadaoui.Z, Djaafri.A and Mokaddem .H (2010) 'Adsorption of cadmium from aqueous solution onto untreated coffee grounds: Equilibrium, kinetics and thermodynamics' Journal of Hazardous Materials, Vol.184, pp.126-134.
[11] Babu .B .V and Gupta .S (2008) 'Adsorption of Cr (VI) using activated neem leaves: kinetic studies.' Adsorption, Vol.14, pp. 85-92.
[12] Hao .C, Guoliang .D, Jie.Z, Aiguo.Z, Junyong.W and Hua.Y (2010) 'Removal of copper (II) ions by a biosorbent- *Cinnamomum camphora'* Journal of Hazardous Materials, Vol.177, pp. 228-236.
[13] Mohammad .M .M .R, Parisa.R, Atefeh.A and Ali.R.K (2011) 'Kinetics and equilibrium studies on biosorption of cadmium, lead, and nickel ions from aqueous solutions by intact and chemically modified brown algae' Journal of Hazardous Materials, Vol. 185, pp. 401-407.
[14] Maria.M, Nuria.M, Soraya.H and Nuria.F (2006) 'Removal of lead (II) and cadmium (II) from aqueous solutions using grape stalk waste' Journal of Hazardous Materials, Vol. 133, pp.203-211.
[15] EI-Said.A.G, Badaway.N.A and Garamon (2010) 'Adsorption of Cadmium (II) and Mercury (II) onto Natural Adsorbent Rice Husk ash (RHA) from Aqueous Solutions: Study in Single and Binary System' Journal of American Science, Vol.12, pp.-400-409.
[16] Saifuddin .M .N and Kumaran .P (2005) 'Removal of heavy metal from industrial wastewater using chitosan coated oil palmshell charcoal' Electronic Journal of biotechnology, Vol.1, pp. 43-53.
[17] Suyamboo, B.K. and Perumal R.S. (2012) Equilibrium, Thermodynamic and Kinetic Studies on Adsorption of a Basic Dye by Citrullus lanatus Rind. Iranica Journal of Energy & Environment, **3**, 23-34
[18] R. W. Matthews, *Water Res*. 25 (1991) 1169.
[19] Ibrahim, M. B. and W. L. O. Jimoh (2008). Adsorption studies for the Removal of Cr (VI) ion from aqueous Solution. *Bayero Journal of Pure and Applied Sciences*. 1 (1):99 – 103.
[20] Ibrahim, M. B. and W. L. O. Jimoh (2012) Thermodynamics and Adsorption Isotherms for the Biosorption of Cr (VI), Ni (II) and Cd (II) onto Maize Cob. *ChemSearch Journal*, 3 (1): 7 – 12.
[21] Muhammad B. Ibrahim, Maje A. Haruna and Atika M. Ibrahim (2012). Optimization of Crystal Violet Dye Removal from Aqueous Solution using Agro Wastes. *ChemSearch Journal*, 3 (1): 28 – 33.
[22] Http://en.wikipedia.org/wiki/Neem.
[23] Ang X. W., Sethu V. S., Andresen, J. M. and Sivakumar, M. 2012. Copper (II) ion removal from aqueous solutions using biosorption technology: thermodynamic and SEM–EDX studies. Clean Technologies and Environmental Policy. 15: 401-407.
[24] Neem Foundation. 1997. (Available at) http://www.neemfoundation.org, 1997.
[25] Sharma, A. and Bhattacharyya, K. G. (2005) *Azadirachta indica (*Neem) leaf powder as a biosorbent for removal of Cd (II) from aqueous medium *Journal of Hazardous Materials* B125 102–112.
[26] Gopalakrishnan, K., Manivannan, V. and Jeyadoss, T. (2010). Comparative study of Zn (II), Cu (II) and Cr (VI) from textile dye effluent using sawdust and neem leaves powder. *E-Journal of Chemistry*, 7, *S1*, S504-S510.
[27] Sud, D., Mahajan, G. And Kau, M. 2008.Agricultural waste material as potential adsorbent for sequestering heavy metal ions from aqueous solutions. A review. Bioresource Technology. 99 (14) : 6017-6027.
[28] Febriana, N., Lesmana, S.O., Soetaredjo, F.E., Sunarso, J. and Ismadji, S. 2010, Neem leaf utilization for copper ions removal from aqueous solution. Journal of the Taiwan Institute of Chemical Engineers, 41 (1): 111-114.
[29] Bhattacharyya, K. G. and Sharma, A. 2004. Adsorption of Pb (II) from aqueous solution by Azadirachta indica (Neem) leaf powder. Journal of Hazardous Materials B113. 97–109.
[30] Yazici, H., Kilic, M. and Solak, M. 2008. Biosorption of copper (II) by Marrubium globosum subsp. Globosum leaves powder: Effect of chemical pre-treatment. Journal of Hazard Mater. 151: 669 – 675.
[31] BIS (2009). Indian standards drinking water specification, Bureau of Indian Standard, Indian Standard 10500.
[32] Ali, I., Mohd. Asim, Tabrez A. Khan. Low cost adsorbents for the removal of organic pollutants from wastewater. Journal of Environmental Management 2012;113, 170-183.
[33] Crini G. Recent developments in polysaccharide-based materials used as adsorbents in wastewater treatment, .Prog. Polym Sci. 2005, 30, 38–70
[34] Sabur. M.A., Rahman. M.M. &Safiullah. S, (2013). ' Treatment of Tannery Effluent by Locally Available Commercial Grade Lime', journal of Scientific Research (JSR), 5 (1), 143-150
[35] Executive summary of technical report; March 2003. Heavy metal contamination of vegetables in Delhi.
[36] www. Ncbi.nlm.nih.gov/pmc/article/pmc3113373/#ref17.
[37] Sharma RK, Agrawal M, Marshall FM (2009). Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. Food chem toxicology;47;page 58-91