Removal Of Heavy Metals From Aqueous Solution Using Sludge Based Activated Carbon – A Review

Dr. S. Kanchana

Department of Civil Engineering, RVS Technical Campus-Coimbatore, Coimbatore.
kash10304@gmail.com

Abstract: Industrial activities paves way for the production of an important byproduct called the sludge. The properties of Industrial sludge shows broad variations based on its origin and type of treatment undergone. Positively the sludge is found to be a material that is rich in carbon. This property of the sludge is being utilized for the production of activated carbon. Adsorption using activated carbon is a popular treatment method nowadays. But the expensive nature of commercial activated carbon demands its replacement by low cost carbon procured from waste materials. Sludge to carbon conversion processes can significantly reduce the sludge volume produced, eliminate the need for further treatment of sludge, reduce the cost of hauling and land filling the sludge, and reduce transportation costs. Many research works reported the adsorbing properties of different sludge based adsorbents in removing industrial pollutants. This paper critically reviews the usage of sludge based activated carbon in adsorbing the heavy metals from industrial wastewaters.

[Kanchana S. **Removal of Heavy metals from aqueous solution using sludge based activated Carbon – A Review.** *Life Sci J* 2017;14(4):99-103]. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online). http://www.lifesciencesite.com. 12. doi:10.7537/marslsj140417.12.

Keywords: Activated Carbon, Adsorption, Heavy Metals, Industrial Sludge.

1. Introduction

The degradation of the environment due to the polluting nature of the metal laden industrial wastewater is a real problem in several countries. The toxic heavy metals present in the industrial wastewater include arsenic, lead, mercury, cadmium, chromium, copper, nickel and zinc. These heavy metals are discharged primarily from metal working industries especially electroplating industries. Metal plating, mining operations, tanneries, chloralkali, radiator manufacturing, smelting, alloy industries and storage batteries industries discharge huge amounts of metal laden wastewaters [1]. The recalcitrance and persistence nature of the heavy metals necessitates treatment before its discharge into the water bodies [2]. Heavy metals pose harmful effects on land animals including human beings apart from being toxic to aquatic organisms. Once the metal enters the food chain, large concentrations of heavy metals may accumulate in the human body [3]. Heavy metals disrupt metabolic functions by accumulating and thereby disrupting the function in vital organs and glands such as the heart, brain, kidneys, bone, liver, etc and by displacing the vital nutritional minerals from their original place, thereby, hindering their biological function [4]. Metal toxicity is highly dependent on the absorbed dose, the route of exposure and duration of exposure, i.e. acute or chronic [5]. Different treatment technologies are practiced for the removal of heavy metals from industrial wastewater including adsorption on new adsorbents, ion exchange, membrane filtration, electrodialysis, reverse osmosis, ultrafiltration and photocatalysis [9]. The disadvantages of conventional methods include incomplete metal removal, high reagent and energy requirements, generation of toxic sludge or other waste products that require careful disposal [10]. Adsorption process is considered better than other methods because of convenience, easy operation, simplicity of design and capability of removing different types of pollutants [11]. The present review article deals with the usefulness of different sludge based absorbents in removing heavy metals from industrial wastewaters.

2. Heavy Metal Sources

Various industrial sectors produce and discharge wastewater containing several heavy metals into the ecosystem such as mining and smelting of metallic ferrous, surface finishing industry, energy and fuel production, fertilizer and pesticide industry and application of metallurgy, iron and steel electro plating, electrolysis, electro osmosis, leather working, photography, electrical appliance manufacturing, metal surface treating, aerospace and atomic energy installation [35]. Chromium (VI) is known to cause skin rashes, respiratory problems, weakened immune systems, kidney and liver damage, alteration of genetic material, lung cancer and death [6]. The contamination of copper can cause severe damage of kidney and liver and even death when consume in high concentrations [7]. Cadmium has been classified by U.S. Environmental Protection Agency as a probable human carcinogen. Its chronic exposure results in kidney dysfunction and high levels of exposure will result in death [8].

3. Carbon Adsorption

Adsorption using low-cost adsorbents is found to be more environmental friendly technique with wide number of natural materials or industrial wastes gathering in abundance from our environment [12]. Industrial wastes represent unused resources and also cause serious disposal problems [13]. One such useful material is the industrial sludge with rich carbon content.

3.1. Industrial Sludge

Activated carbon is that carbon produced from a carbonaceous source. It can be produced by carbonization, activation or chemical activation. Activated carbon is characterized extraordinary large specific surface area, well-developed porosity and tunable surface containing functional groups. Commercial activated carbons are commonly produced from naturally occurring carbonaceous materials such as coal, wood and peat. The carbon content of the industrial sludge can be effectively utilized for the production of activated carbon. Several organic wastes can be used as a precursor of activated carbon. The final properties of the obtained product depend not only on the characteristics of the used raw material but also on the activating agent used and the conditions of the activation process [14].

4. Activated Carbon from Industrial Sludge

Several literatures report the successful utilization of industrial sludge in making activated carbon for removal of several contaminants from industrial wastewaters. Activated carbon derived from primary sewage sludge was used for adsorption of phenol from the synthetic wastewater [17]. Activated carbon derived from textile industry sludge was synthesized as an initiative of low cost adsorbent for removing dyes [18]. Activated carbon (AC) was also prepared using corn stalk and sewage sludge by chemical activation method [19]. The paper mill ETP sludge was found to contain unused wood based material generated during digestion process. The wood based material after drying was processed to develop micro porous structure [20]. The developed carbon removed colour from the same paper and pulp industry wastewater. The paper mill sludge char on chemical activation by potassium hydroxide was found to adsorb metals [21]. The characterization of the activated char revealed its iodine and methylene blue number; and specific surface area. The process of development of micro and mesoporous structure was also done using the method of zinc chloride activation [22]. The preparation of activation carbon was made possible using the waste activated sludge from water purification plant [23]. The carbon adsorbed contaminants like metals, phenols, xylidines, amines, Methylene blue and molasses [24]. A potential adsorbent for removing acid and basic dyes was developed from sewage sludge by pyrolysis under N_2 or CO_2 atmospheres [25]. Composite materials were also used for metal adsorption from solution. Composite materials exhibited metal adsorption capacity in par with commercial activated carbon [26]. Sulphuric acid was found to be a good chemical activation agent that produced activated carbon with high porous structure and large specific surface area [27,32]. The activated carbon (AC) prepared from wastewater treatment sludge by KOH activation was used to purify crude glycerol [28]. sludge based activated carbon was also developed by activated using Fenton's reagents (H_2O_2/Fe^{2+}) [29]. Methylene Blue (MB) and Reactive Red 24 (RR 24) dyes are removed from aqueous solution using sludge based activated carbon prepared from paper mill sludge by the method of carbonization at low temperature [30]. Nitrate present in ground water was removed using activated carbon developed from rice husk and paper industry sludge [31]. The activated carbon synthesized from paper mill sludge at low cost was found to remove phenol from aqueous solution. The adsorbent characteristics before and after adsorption process were examined using BET, FTIR, and SEM analyses [33]. Textile sludge based activated carbon was found effective in oil removal as well [34].

5. Removal of Heavy Metals using Sludge Based Activated Carbon

Food processing industry sludge was used to prepare activated carbon by direct chemical activation with $ZnCl_2$ that removed heavy metals Cu (II), Pb (II) and Cd (II) from aqueous solution [15]. Sugar mill sludge was used to prepare activated carbon for removal of heavy metals namely nickel, lead and cadmium from industrial wastewater [16]. The activated carbons (ACs) prepared by chemical activation of brewing industry sewage sludge with 5M zinc chloride or concentrated phosphoric acid had high adsorption capacity of Pb(II) and Cr(VI) ions [23]. The possibility of removing nickel and cadmium from aqueous solutions by Sewage sludge ash was studied [36]. The adsorbent derived from sewage sludge through chemical pyrolysis has been used for the adsorption of Cd^{2+} and Ni^{2+} from aqueous solution. The capacity of adsorption calculated from the Langmuir isotherm was 16 and 9 mg/g for Cd^{2+} and Ni^{2+}, respectively at the initial pH of 5.8 at 25 °C [37]. The removal of binary mixed metal ions [Hg(II), Pb(II), Cu(II) and Cr(III)] from water was investigated. Two different sewage sludge-based adsorbents were produced and used for this purpose: PS, obtained by pyrolysis of sewage sludge, and AS, by $ZnCl_2$chemical activation of sewage sludge followed by pyrolysis [38]. Smith et al., has reviewed the published research in this field of production, the characteristics and the potential applications of sewage sludge-based adsorbents (SBAs) [39]. The use of cheap carbon-based adsorbents from sewage sludge pyrolysis to remove Na^+, K^+, Ca^{2+} and Mg^{2+} from saline water was studied [40]. Two materials produced from sewage sludge one by pyrolysis of dried sewage sludge and the other by chemical activation of dried sewage sludge with $ZnCl_2$ followed by pyrolysis (AS) to adsorb metals Hg(II), Pb(II), Cu(II) and Cr(III) [41]. Sewage sludge and bagasse were used as raw materials to produce cheap and efficient adsorbent with great adsorption capacity of Pb(2+). By pyrolysis at 800 °C for 0.5 h, the largest surface area (806.57m^2/g) of the adsorbent was obtained, enriched with organic functional groups [42].

6. Conclusion

Over the past two decades, environmental regulations have become more stringent, requiring an improved quality of treated effluent. In recent years, a wide range of treatment technologies such as chemical precipitation, adsorption, membrane filtration, electrodialysis, and photocatalysis, have been developed for heavy metal removal from contaminated wastewater. It is evident from the literature survey that adsorption by activated carbon has been found as one of the most effective conventional means to treat inorganic effluent with high metal concentrations. It has been found that after chemical or thermal modifications, industrial waste sludge exhibited tremendous heavy metal removal capability. Concentration of adsorbate, extent of surface modification and adsorbent characteristics are the factors responsible for metal adsorption capability. Cost effectiveness and technical applicability are the two important key factors for selecting effective low cost adsorbent for heavy metal removal.

Corresponding Author:
Dr. S.Kanchana,
Associate Professor,
Department of Civil Engineering,
RVS Technical Campus,
Coimbatore – 641 402, India
E-mail: kash10304@gmail.com

References

1. Hala Ahmed Hegazi, Removal of heavy metals from wastewater using agricultural and industrial wastes as adsorbents, HBRC Journal, 2013; 9(3); 276–282.
2. Ahmad Ashfaq and Mohd Kaifiyan, Application of Flyash for the Removal of Toxic Metals from Wastewaters through Biosorption, International Journal of Current Microbiology and Applied Sciences, 2016; 5(7); 121-125.
3. M.A. Barakat, New trends in removing heavy metals from industrial wastewater, Arabian Journal of Chemistry, 2011; 4(4); 361–377.
4. Reena Singh, Neetu Gautam, Anurag Mishra, Rajiv Gupta, Heavy metals and living systems: An overview, Indian Journal of Pharmacology, 2011; 43(3); 246-253.
5. Monisha Jaishankar, Tenzin Tseten, Naresh Anbalagan, Blessy B. Mathew, Krishnamurthy N. Beeregowda, Toxicity, mechanism and health effects of some heavy metals, Interdisciplinary Toxicology, 2014; 7(2); 60-72.
6. L. Nageswara Raoa, Dr G. Prabhakar, Removal of heavy metals by biosorption – an overall review, Journal of Engineering Research and Studies, 2011; 2(4); 17-22.
7. Siddiquee S, Rovina K, Azad SA, Naher L, Suryani S, Heavy Metal Contaminants Removal from Wastewater Using the Potential Filamentous Fungi Biomass: A Review. Journal of Microbiology and Biochemical Technology, 2015; 7; 384-393.
8. Fenglian Fu, Qi Wang, Removal of heavy metal ions from wastewaters: A review, Journal of Environmental Management, 2011; 92; 407-418.
9. Gunatilake S.K, Methods of Removing Heavy Metals from Industrial Wastewater, Journal of Multidisciplinary Engineering Science Studies, 2015; 1(1); 12-18.
10. Archana Dixit, Savita Dixit and Goswami CS, Eco-friendly Alternatives for the Removal of Heavy Metal Using Dry Biomass of Weeds and Study the Mechanism Involved, Bioremediation & Biodegradation, 2016; 6(3); 1-7.
11. Geetha Varma V, Dr. Ram Karan Singh and Vaishali Sahu, A comparative study on the removal of heavy metals by adsorption using fly ash and sludge: A review, International Journal of Application or Innovation in Engineering & Management, 2013; 2(7); 45-56.
12. Siti Nur Aeisyah Abas, Mohd Halim Shah Ismail, Md Lias Kamal and Shamsul Izhar, Adsorption Process of Heavy Metals by Low-Cost Adsorbent: A Review, World Applied Sciences Journal, 2013; 28(11); 1518-1530.
13. Geethakarthi, B. R. Phanikumar, Industrial sludge based adsorbents/ industrial byproducts in the removal of reactive dyes – A review, International Journal of Water Resources and Environmental Engineering, 2011; 3(1); 1-9.

14. Paolo De Filippis, Luca Di Palma, Elisabetta Petrucci, Marco Scarsella, Nicola Verdone, Production and Characterization of Adsorbent Materials from Sewage Sludge by Pyrolysis, Chemical Engineering Transactions, 2013; 32; 205-210.
15. Kalyani Mahapatra, Dr. D. S. Ramteke, Dr. L. J. Paliwal, Adsorption of heavy metals from aqueous solutions onto activated carbon prepared from sludge of food processing industry, International Journal of Research in Science and Technology, 2015; 5(4); 49-67.
16. G. Anusha, J. Raja Murugadoss, Modeling for Removal of Nickel and Lead from Industrial Wastewater by Adsorption, Journal of water pollution & purification Research, 2014; 1(3); 13-17.
17. Anirudh Gupta, Anurag Garg, Primary sewage sludge-derived activated carbon: characterization and application in wastewater treatment, Clean Technologies and Environmental Policy, 2015; 17(6); 1619–1631.
18. N. A. Najlaa Yaccob, N. Ngadi, R. Abd Rahman, Preparation and Characterization of Textile Sludge-Based Activated Carbon for Dyes Removal, Applied Mechanics and Materials, 2016; 818; 250-253.
19. Yili Li, Yanling Li,Liping Li, Xiujuan Shi, Zhan Wang, Preparation and analysis of activated carbon from sewage sludge and corn stalk, Advanced Powder Technology, 2016; 27(2); 684–691.
20. B Chakradhar, Sonia Srivastava, Colour removal of pulp and paper effluents, Indian Journal of Chemical Technology, 2004; 11; 617-621.
21. Hwa-Young Kang, Sang-Sook Park, Yu-Sup Rim, Preparation of activated carbon from paper mill sludge by KOH-activation, Korean Journal of Chemical Engineering, 2006; 23(6); 948–953.
22. Campbell M, Gola J, Khalili NR, Sandi G. Production of micro and mesoporous activated carbon from paper mill sludge, I: Effect of zinc chloride activation, Carbon, 2000; 38(2); 1905-15.
23. Liliana Giraldo-Gutierrez, Nestor Rojas, Tomas Uribe-Moreno, Juan C. Moreno-Pirajan, Preparation of activated carbon from industrial wastewater treatment sludge and its possible use in retention of Cr(VI) and Pb(II), Journal of Environmental Engineering and Management; 2009; 19(2); 99-105.
24. Pikkov L, Kallas J, Ruutmann T, Rikmann E., Characteristics of activated carbon produced from biosludge and its use in wastewater post-treatment, Environmental Technology, 2001; 22(2); 229-36.
25. Charothon Jindarom, Vissanu Meeyoo, Boonyarach Kitiyanan, Thirasak Rirksomboon, Pramoch Rangsunvigit, Surface characterization and dye adsorptive capacities of char obtained from pyrolysis/gasification of sewage sludge, Chemical Engineering Journal, 2007; 133(1–3); 239–246.
26. Mykola Seredych, Teresa J. Bandosz, Removal of copper on composite sewage sludge/industrial sludge-based adsorbents: The role of surface chemistry, Journal of Colloid and Interface Science, 2006; 302(2); 379–388.
27. Z. Al-Qodah, R. Shawabkah, Production and characterization of granular activated carbon from activated sludge, Brazilian Journal of Chemical Engineering, 2009; 26(1).
28. Mali Hunsom, Chaowat Autthanit, Preparation of sludge-derived KOH-activated carbon for crude glycerol purification, Journal of Material Cycles and Waste Management, 2017; 19(1); 213–225.
29. Lin Gu, Yachen Wang, Nanwen Zhu, Daofang Zhang, Shouqiang Huang, Haiping Yuan, Ziyang Lou, Miaolin Wang, Preparation of sewage sludge based activated carbon by using Fenton's reagent and their use in 2-Naphthol adsorption, Bioresource Technology, 2013; 146; 779–784.
30. Wen-Hong Li, Qin-Yan Yue, Bao-Yu Gao, Zuo-Hao Ma, Yan-Jie Li, Hai-Xia Zhao, Preparation and utilization of sludge-based activated carbon for the adsorption of dyes from aqueous solutions, Chemical Engineering Journal, 2011; 171(1); 320–327.
31. Mohammad Hassan Shahmoradi1, Behnoush Amin Zade, Ali Torabian and Mahdi Seyed Salehi, Removal of nitrate from ground water using activated carbon prepared from rice husk and sludge of paper industry wastewater treatment, ARPN Journal of Engineering and Applied Sciences, 2015; 10(17).
32. Z. Al-Qodah, R. Shawabkah, Production and characterization of granular activated carbon from activated sludge, Brazilian Journal of Chemical Engineering, 2015, 10(17); 7856-7863.
33. Kasra Pirzadeh, Ali Asghar Ghoreysh, Phenol removal from aqueous phase by adsorption on activated carbon prepared from paper mill sludge, Desalination and Water Treatment, 2014; 52(34-36); 6505-6518.
34. K. S. A. Sohaimi, N. Ngadi, Removal of Oil Using Activated Carbon from Textile Sludge Biochars, Applied Mechanics and Materials, 2016; 818; 237-241.
35. Jianlong wang and Canchen (2009), Biosorbents for heavy metals removal and their future, Biotechnology Advances, 2009; 27(2); 195-226.

36. Elouear Z, Bouzid J, Boujelben N, Removal of nickel and cadmium from aqueous solutions by sewage sludge ash: study in single and binary systems, Journal of Environmental Technology, 2009; 30(6); 561-70.
37. Zhai Y, Wei X, Zeng G, Zhang D, Chu K, Study of adsorbent derived from sewage sludge for the removal of Cd2+ and Ni2+ in aqueous solutions, Journal of Separation and Purification Technology, 2004; 38; 191-196.
38. Otero M, Rozada F, Calvo L F, Garcia A I, Moran A, Elimination of organic water pollutants using adsorbents obtained from sewage sludge, Journal of dyes and pigments, 2003; 57; 55-65.
39. Smith K M, Fowler G D, Pulket S, Graham N J D, Sewage sludge-based adsorbents: A review of their production, properties and use in water treatment applications, Journal of Water Research, 2009; 43(10); 2569-2594.
40. Gasco G, Mendez A, Gasco J M, Preparation of carbon based adsorbents from sewage sludge pyrolysis to remove metals from water, Journal of Desalination, 2005; 180; 245-251.
41. Rozada F, Otero M, Moran A, Garcia A I, 2008, Adsorption of heavy metals onto sewage sludge derived materials, Journal of Bioresource Technology, 2008; 99; 6332-6338.
42. Tao HC, Zhang HR, Li JB, Ding WY, Biomass based activated carbon obtained from sludge and sugarcane bagasse for removing lead ion from wastewater, Bioresource Technology, 2015; 192; 611-617.

4/21/2017