Waste Water Treatment by Unconventional Adsorbents

Prabhat Kumarr Tiwari[1] Sanjay Saraswat[2] Ajeet Kumar[3] Dr. A.K. Saxena[4] Neha Surya[5]

Abstract— Fluoride is a major pollutant of groundwater globally. Adding to the problem is the issue of reduced 'portable water' availability. The fluoride content in water bodies and ground water is further increased by effluent discharge from factories that work with fluoride and its compounds as the major raw material and from municipal bodies. Fluoride consumed is limited amounts id protective for the dentition and the bones. The healthy or acceptable limits of fluoride range from 0.8 to 1.2 mg/L of water. Levels exceeding 1.5 mg/L start impacting the human health adversely. Fluorosis, a disease characterized by mottling of the dentine enamel and ligaments coupled with neurological complications, has crippled many individuals. The problem is especially pronounced in countries like India and China. Various treatment methods have been devised to remove fluoride from water. Initially chemical methods were used to treat water. With advancement in technology, several newer and better techniques emerged. Few of them are coagulation, membrane filtration and ion exchange. These methods, though highly effective, are very costly. Developing countries like India cannot afford such techniques. The attempt to find more cost effective ways ended with the discovery of adsorbents to remove fluoride. Efforts are now being made to find the best adsorbent that falls within the budgets of our pockets and is effective in removing the excessive fluoride. Studies are conducted to assess the efficacy of naturally available adsorbents like activated carbon, agricultural wastes and even red laterite soil.

Key words: Soil, Testing, Unconventional, adsorbent

I. Introduction

Fluoride in water is a double-edged sword. While, on the one hand it is extremely beneficial for the dental health, it can be equally deleterious for teeth and the skeleton. Fluoridation of water is a process of fortifying water with fluoride to prevent teeth decay and reduce the risk of cavities. Fluoride is one of the most potent natural contaminant of groundwater globally (1). Pollution is mainly through two channels, which are natural and anthropogenic sources (14). Toxic wastes containing fluoride are generated in all industries using fluoride or its components as raw materials (15).

An intake of more than 1.5mg/L may cause fluorosis along with neurological complications (2). This is the upper permissible limit of fluoride consumption according to the WHO (5). It has been known to cripple individuals for a lifetime in some states of Northeast India. Along with enamel mottling and neuropathy, it can adversely affect the bone growth and the skeletal functions. According to the WHO, the most severe impact is seen in India and China (16). The government of India has ordered stringent measures of the control of fluoride levels in water in some of these states. Defluorination can be using a variety of methods like coagulation, membrane filtration, ion exchange etc. (2). The high cost of using these techniques reduces their feasibility in developing countries like India (3).

Research is being done nationwide to find cost effective ways of removing fluoride for water. One such low cost technology is adsorption (1). Over the past few years, the studies have focused on finding low cost adsorbents and have experimented with activated alumina (5), titanium-rich bauxite (6), manganese oxide coated alumina (7) and carbon nanotubes (8). Effort is being laid on the use of agricultural wastes for this purpose. It is expected to put unused resources to good use (2). Numerous biomass waste sources are available in different parts of the country, on which some experimental adsorption properties have been reported (2). These include rice husk (9), rice husk ash (10), peanut shells (11), eggshell (12), corn-cobs (13) and many more. Different studies in various parts of the world have been carried out to test the efficacy of different adsorbents and weigh them against their cost.

Not just fluoride, unconventional adsorbents have been employed to treat wastewater and remove other toxins as well. Some of the toxins experimented to be removed by adsorbents include 3,5 Dichlorophenol (20), red chromium etc. Yet, it is clear that the studies done on defluoriding water are not comprehensive and need further research to get at a cost effective method of treating water. The potential for the following study is thus understood as it targets researching cheap adsorbents that are effective in removing fluoride from the water.

II. Review of Literature

1) Studies on defluoridation of water by Tea Ash (2012) by Naba Kumar Mondal (1)

This study investigates the potential of tea waste as an unconventional adsorbent for removal of excessive fluoride from the water. Tea residues were obtained from the leftovers of a nearby tea-shop (highlighting the cheap cost and easy availability). Optimum conditions including equilibrium data and sorption kinetics for fluoride removal were obtained. Samples were obtained from laboratory aqueous solutions as well as groundwater.

It found the efficacy of adsorption increased with decreasing particle size. Due to the large particle size of Tea Ash it formed an important and potential adsorbent. It worked well under acidic conditions to remove fluoride from the water and the adsorption efficacy reduced at higher pH. In accordance with the Langmuir adsorption isotherm, tea ash adsorption decreased with increasing temperature. The distribution coefficient results show the heterogeneous nature of tea ash. This adsorbent could remove fluoride from aqueous laboratory samples as well after which, fluoride could be recovered from its adsorptive surface. This study proved that tea ash is a promising material for effective removing of fluoride from contaminated water samples.

2) Removal of fluoride from aqueous solution by using red mud (2002) by Yunus Cengeloglu (14)

This study focuses on the efficacy of red laterite mud in removing fluoride from samples. Red mud emerges as an unwanted by-product during alkaline leaching of bauxite. Large dumping into nearby water plants created serious environmental issues. Hence, this study was conducted to understand the potential of red mud in removing fluoride from water.

The relative binding ability of various anions on the red mud surface was estimated. The studies showed reduced adsorption activity (in relation to fluoride) of red mud in the presence of nitrate, sulphate and externally added ions. But on the whole, 82% fluoride in the given water sample can be removed using activated red mud. Though not as effective as precipitation and ion exchange, adsorption using red mud is a cost effective method of removing fluoride.

3) Ganvir et al. (2011)

have studied the removal of fluoride by using aluminium hydroxide coated rice husk ash. Rice husk ash is obtained by burning rice/paddy husk which is available in large quantity and is a low cost material. The fluoride adsorption capacity of adsorbent was 15.08 mg/g in batch and 9.5 mg/g in column study. The maximum fluoride removal was achieved at pH 5.0±0.5 and it showed that adsorption was not dependent on initial fluoride concentration. The adsorption capacity of materials used in filter was found to be 9 mg/g. A filter made of 750 g coated RHA was treated with 1250 L of 5 mg/l of fluoride spiked tap water and it was brought down to 1.5 mg/l. Freundlich isotherm with multilayer adsorption and pseudo second order kinetic were best fitted as per the study (17).

4) Murugan and Subramanian (2006)

have investigated the potential of tamarind seed, a household waste that was left after removing the tamarind pulp for food preparation that mainly contains polysaccharide. The maximum defluoridation was achieved at pH 7 and defluoridation capacities decreased with an increase in temperature and particle size. The defluoridation followed first order kinetics and Langmuir adsorption isotherm with an adsorption capacity of 6.37 mg/g at 20oC. Desorption was carried out with 0.1N HCL and was 90%. Tamarind seed powder of 25 g encapsulated in single ceramic candle of domestic water filter was treated approximately with 40 liter of water containing fluoride concentration of 5 mg/l. Thus, for the treatment of 10 liter of drinking water per day for a three members of a family having a fluoride concentration of 5 mg/l required 2.75 g of Tamarind seed per day (18).

5) Defluoridation of water using amended clay by Meetu Agarwal in 2003.

This study focused on exploring the possibility of using clay vessels for water defluoridation. Silty clay fraction was amended to enhance potential for water defluoridation. A method that when extrapolated to fabrication of vessels would have enhanced potential of utilizing vast naturally occurring Absorbent for water defluoridation (21).

This study highlighted the significant potential of clay vessels for fluoride removal from stored water. Amending by adding calcium, aluminum, iron and carbon significantly improved the adsorption properties. Thus, it proved that clay rich soil, containing aluminum oxide, ferric chloride and calcium carbonate, can enhance fluoride removal capacity of clay pots considerably.

III. Conclusion

Most of the developing countries including India depend on groundwater to meet the daily water requirements (19). This paper reviews the utilization of unconventional adsorbents including activated red mud, industrial by-products, agricultural wastes and plant biomass. An attempt has been made to find the most cost efficient adsorbent for the removal of fluoride from groundwater. The efficiency of Defluorination increases with smaller particle size. Modifying the conditions by addition or removal of ions and suitable chemicals resulted in optimization of conditions for effective fluoride removal. Equilibrium studies were very much in accordance with the Langmuir isotherms.

One basic criterion for remediation method application in practice is an economic factor (20). The review of studies has shown the potential of unconventional adsorbents for removal of fluoride. Future studies and in depth research is required to find economical and efficient industrial or agricultural wastes that can replace the commercial adsorbents for developing countries.

References

[1] Murugan M and Subremanian E, J Water Health, 2006, 4, 453-461.
[2] Naba Kumar Mandal, Ria Bhaumik, Tanmoy Baur, Biswajit Das, Palas Roy, Jayanta Kumar Dutta; Studies on Defluoridation of Water by Tea Ash: An Unconventional Biosorbent, 2012
[3] Miretzky P, Munoz C and Carrillo-Chavez A, J Environ Chem., 2008, 5, 68-72.
[4] WHO, 2006, World Health Organization, Geneva.
[5] Chauhan V S, Dwivedi P K and Iyengar L, J Hazard Mater., 2007, 139(1), 103-107.
[6] Das N, Pattanaik P and Das R, J Colloid Interface Sci., 2005, 292, 1-10.
[7] TEng S X, Wang S G, Gong W X, Liu X-W and Gao B-Y, J Hazard Mater, 2009;168, 1004-1011
[8] Li Y H, Wang S, Zhang X, Wei J, Xu C, Luan Z and Wu D, Mater Res Bull., 2003, 38, 469-476.
[9] Mohammad A, Rao R A K, Anwar S, Ahmad J and Ahmad R, Bioresour Technol., 2003, 86(2), 147-149.
[10] Mondal N K, Bhaumik R, Banerjee A, Datta J K and Baur T, Int J Environ Sci., 2012, 2(3), 1643-1661.
[11] Bhaumik R, Mondal N K, Das B, Roy P, Pal K C and Das C, C.E-J Chem., 2011, 97, 21–25.
[12] Bhaumik R, Mondal N K, Das B, Roy P, Pal K C and Das C, C.E-J Chem., 2011, 97, 21–25.
[13] Vaughan T, Seo C W and Marshall W E, Bioresour Technol., 2001, 78, 133-139.
[14] Yunus Cengeloglu, Esengul Kir, Mustafa Ersoz; Removal of fluoride from aqueous solution by using red mud, 2012.
[15] Kirk Othmer Encyclopaedia of Chemical Technology, third ed., vol. 10, Wiley-Interscience, New York, 1980.
[16] R. Piekos and S. Paslawska, "Fluoride uptake characteristics of fly ash," Fluoride, Vol. 32, No. 1, pp. 14– 19, 1999.
[17] V. Ganvir and K. Das, "Removal of fluoride from drinking water using aluminum hydroxide coated rice husk ash," J. Hazard.Mater., Vol. 185, Issues 2-3, pp. 1287–1294, Jan. 2011.
[18] E Subramanian and R Dhana Ramalakshmi, "Pristine, purified and polyaniline-coated tamarind seed (Tamarindus indica) biomaterial powder for defluoridation: Synergism and enhancement in fluoride adsorption by polyaniline coating," Journal of Scientific & Industrial Research, Vol. 69, pp. 621-628, Aug. 2010.

[19] S. S. Waghmare, T. Arfin, N. Manwar, D. H. Lataye, N. Labhsetwar and S. Rayalu, "Preparation and Characterization of Polyalthia longifolia Based Alumina as a Novel Adsorbent for Removing Fluoride from Drinking Water," Asian J. Adv. Basic Sci., Vol. 4(1), pp. 12-24, 2015.
[20] Hana Kobeticova, Blanka Galbickova, Janka Sevcikova and Maros Soldan, Removing 3,5 Dichlorophenol from wastewater by alternative adsorbents, Volume 22, 2014
[21] Meetu Agarwal, Kavita Rai, Rohit Shrivastav, Sahab Dass, Defluoridation of water using Amended Clay, Journal of cleaner Production; 2003