Removal of Iron from Groundwater by Using Low Cost Adsorbents:A Review

Dr.C.G.Hemamalini[1] , P.Lavanya[2], S.Kesana[3], R.Kishore kumar[4], R.Ajith Kumar[5]
[1]Professor Dept of Civil
[2, 3, 4, 5]Dept of Civil
[1, 2, 3, 4, 5] Easwari Engineering college,Chennai,Tamilnadu,India.

Abstract- *The removal of iron from groundwater using low cost adsorbents to serve the rural places and to provide decentralized water treatment plant is the main focus of the study. The desirable and permissible limit of iron in drinking water is 0.3 mg/l and 1 mg/l respectively as per BIS. The low cost adsorbents which are prepared from agricultural waste and medicinal plants are used to remove iron from groundwater to make affordable to rural people. The objective of the current paper is to review the different methods which are used to remove excess iron from water.*

Keywords- Iron removal, Groundwater, Adsorption, Adsorbents, Isotherm.

I. INTRODUCTION

Iron is the second most abundant metal in earth's crust. Natural water contains variable amounts of iron depending on the geological area and other chemical components of waterway. Iron in groundwater is normally present as bivalent form, which is soluble. It is easily oxidized to ferric iron or insoluble iron upon exposure to air (1).
Generally, the iron concentration in rivers is around 0.7 mg/litre and in groundwater, it varies between 0.5 and 10 mg/litre (2). Consuming water which contains excess iron causes health hazards to human being (3). However, iron present in water may cause change in taste and staining clothes. Excess Iron in water causes deposits of iron in pipelines, pressure tanks ,water heaters and water softeners and also causes pressure drop in the system. Concentration of iron in drinking water are normally less than 0.3mg /lit but may be higher in countries where cast iron, steel and galvanized iron pipes are used for water distribution (4).

II. METHODS

BIOLOGICAL FILTRATION

Removal of soluble iron and manganese from water is achieved by conventional media filters (either pressurized or rapid gravity) and are operated as bio-filters. The biological oxidation process is impacted by the presence of other constituents in water, notably ammonium, hydrogen sulphide, and zinc(5).

UPFLOW ROUGHING BIOFILTER

Hand pump attachable iron removal plant(IRP) were installed based on upflow roughing biofilter principle. Up-flow roughing filters(URF) are the sand filters which is used for the removal of course particulate or sediments from water. URF consists of 3 layers of gravels(2-18mm) with 30 cm depth .These layers rest on the supporting gravels (20-50 mm) in the bottom .Maintenance of the plant includes backwash of the filters, clearing sludge from sedimentation chamber,removal of slimes and algal growths on the external surfaces, clearance of openings header lateral pipes of aeration chamber, correction of leaks. The iron content reduced upto 1 mg/l to from 3-6.8 mg/l(6).

NAOCL OXIDATION AND MICROFILTERATION

The aeration, chlorine oxidation process and membrane filtration (MF) was carried out for removal of iron and manganese from groundwater. Jar test and the pilot-scale experiments were carried out. The iron concentration was dramatically dropped from 0.3-1.5 mg/l to 0.08 mg/l.(7).

SILICA SAND

The removal of iron and ammonium ions from groundwater by silica sand was carried out. The silica sand is of 0.7-2.0 mm and the depth is of 750mm. The removal efficiency is 95% at 3 m/h filtration from 2 mg/l to 0.8 mg/l(8).

OXIDIZING BACTERIA

The removal of arsenic during iron and manganese oxidation takes place. This method relies on the use of indigenous non-pathogenic iron and manganese-oxidizing bacteria. Dissolved iron and manganese species often coexist with arsenic in groundwater (9).

ADSORPTION

Adsorption is a process in which a solid surface in contact with a solution tends to accumulate a surface layer of solute molecules because of unbalance of surface force. The substance on which the adsorption occurs is known as adsorbent and the substance which gets adsorbed are adsorbate.It is a low cost and simple to handle method(10).

III. MATERIALS

RICE HUSK ASH

Rice husk is a byproduct in rice mills and creates disposal and pollution problems. It is reported that about 30 million tons of rice husk per annum is produced in India. Therefore, an efficient utilization of RH is urgently needed The major constituents of rice husk are cellulose, lignin and ash. Husk contains 17%-20% silica in complex form and RHA contains 85%-95% amorphous silica. Silica is widely used as adsorbent (11).

Rice husk is an organic fibre contains cellulose(45-50%), lignin(25-30%), ash (15-20%) and moisture(8-15%).The removal efficiency of rice husk ash is reported as 98.89%(12).

Adsorption method for iron removal was carried out varying time after burning rice husk at 200℃ in an oven for 6 hours and the removal efficiency is reported as 79%(13)

Adsorption studies of iron removal by rice husk from aqueous solution have been carried out varying pH, adsorbent dosage, initial concentration and contact time. The optimum values which were recommended for the removal of iron, are pH of range neutral, adsorbent dosage of 8 mg/L, lower removal with increase in initial iron concentration and the increase of contact time. Also, it was reported that Freundlich isotherm equation very well fitted, confirming adsorption capacity of iron onto rice husk as 2.999 mg/g (14).

SUGARCANE BAGASSE

Sugarcane bagasse is a agricultural waste product from sugar refining industry. The activated carbon prepared from sugarcane bagasse is used as adsorbent for the removal of iron from groundwater. The removal efficiency of sugarcane bagasse is reported as 93% at pH of 5(15).

The major constituents of sugarcane bagasse is cellulose, hemi-cellulose, pentosans, lignin, sugars, wax and minerals.the removal efficiency of bagasse is reported as 98.89%(16).

Adsorpion studies of iron removal by sugarcane bagasse have been carried out varying pH, contact time, dose and concentration. The removal efficiency of sugarcane bagasse is reported as 80 to 87% at pH 3, 10 minutes contact time, concentration of 40 to 50mg/l and 9g/100ml.(17)

TULSI

The activated biocarbon prepared from Ocimum sanctum is used for the removal of iron and lead from aqueous solution. The percentage removal efficiency of iron was reported as 73.62%(18).

VETIVER

The vettiver is used in the removal of heavy metals like manganese, iron, zinc, copper and lead by phytoremediation. The removal efficiency of iron is reported as 27.63%(19).

COCONUT COIR

Coconut coir is used as a solid phase extractor for iron removal as it exhibits remarkable binding characteristics under static and dynamic condition. The groundwater containing 17mg/l iron was taken as sample and the removal efficiency of coconut coir is reported as 96% of pH of 4-5(20).

IV.TEST PROCEDURE

BATCH TEST

Batch experiments were carried out to determine the adsorption isotherms of metal ions by mixing fixed amount of adsorbent with the iron solution in a glass flask. The flasks were shaken at a constant rate allowing sufficient time for adsorption equilibrium. The mixture is then filtered and the supernatant liquid is determined spectrometrically. All experiments were carried out in triplicate and the average value was used for further calculation. The pH of the solution was measured. The effects of various parameters on the rate of adsorption process were observed by varying contact time, adsorbent concentration, temperature and pH of the solution. The solution volume(V) was kept constant. The amount of metal adsorbed per unit mass is calculated as

$$Q_e = \frac{(C_i - C_e)V}{m}$$

Where C_i and C_e are the initial and equilibrium concentration (mg/L), m is the mass of the adsorbent (g) and

V is the volume of the solution (mL). Metal ion removal percent (%MR) was calculated using equation(21)

$$\%MR = \frac{(C_i - C_e)}{C_i} * 100$$

COLUMNS TEST

The adsorption experiments were carried out in columns that were equipped with a stopper for controlling the column flow rate. The sample solution was passed through the adsorption column. The flow rate was kept constant by controlling the stopper valve.(22)

V.ADSORPTION ISOTHERM

Adsorption is usually described through isotherms, that is functions which connect the amount of adsorbate on the adsorbent. Distribution of metal ions between the liquid phase and the solid phase can be described by several isotherm models such as Langmuir model, Freundlich model, Dubinin-Radushkevich model, Temkins model.

The Langmuir isotherm assumes monolayer adsorption onto a surface containing a finite number of adsorption sites. Once a site is filled, no further sorption can take place at that site. This indicates that the surface reaches a saturation point where the maximum adsorption of the surface will be achieved. The isotherm is represented by

$$\frac{C_e}{q_e} = \frac{1}{bq_{max}} + \frac{C_e}{q_{max}}$$

The constants b and q_{max} are the co-efficient related to the affinity between sorbate and sorbent and maximum adsorption capacity respectively, and their values are obtained from the slope and interception of the plot of C_e/q_e and C_e(23) The Freundlich isotherm is an empirical equation describes the removal of metal ions occurs on a heterogenous adsorbent surface and can be applied to multilayer adsorption.

$$q_e = K_f C_e^{\frac{1}{n}}$$

The equation can be linearized,

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

Where K_f and n are Freundlich constants which correspond to adsorption capacity and adsorbent intensity respectively. 1/n is the heterogeneity factor and n is a measure of the deviation from linearity of adsorption. The adsorption capacity(K_f) and the adsorption intensity (1/n) are directly obtained from the slope and theintercept of the linear plot of log q_e vs log C_e.(24)When 1/n>1, the adsorption coefficient increases with increase in concentration. When 1/n<1, the adsorption coefficient decreases with increase in concentration(25).

The essential features of Langmuir adsorption isotherm parameter can be used to predict the affinity between the sorbate and sorbent using dimensionless constant called separation factor or equilibrium parameter (R_L), which is expressed by the following relationship

$$R_L = \frac{1}{bC_i}$$

Where b is the Langmuir constant and C_i is the initial concentration. The value of R_L indicated the type of Langmuir isotherm to be irreversible (R_L=0), linear (R_L=1), unfavourable (R_L>1), or favourable (0<R_L<1) (26).

VI.CONCLUSION

This review provides information about the various methods used in the process of removal of iron from water and the various adsorbents used for the removal of iron. Adsorption technique can be used effectively for the removal of iron from groundwater.. The removal efficiency of a adsorbents depend on different parameters in batch and column analysis study. This review also concludes that the use of commercially available adsorbents can be replaced by the inexpensive and effective bioadsorbents of Rice husk and sugarcane bagasse(Agricultural waste) and tulsi and vettiver(Medicinal plants) which are easily available in rural areas were taken .

REFERENCES

[1] Mr.Brian Oram, P.G metals in surface water watershed projects, Water Research Centre.
[2] National Research Council, Iron, Baltimore, MD, University Park press,1979.
[3] Berbenni P, Police A, Canziani R, Stabile L, Nobili F. “Removal of iron and manganese from hydrocarbon contaminated ground waters”, Bioresources Technology, 74,109-114,2000.
[4] Das B.P.Hazarika, G.Saikia, H.Kalita, D.C.Goswami, das H.B .Dube S.N.Dutta, R.K “Removal of iron from groundwater by ash: A Systematic study of a traditional method”, Journal of Hazardous materials, 141,834-841,2007.

[5] Geoff du Toit, Hanre Blignanut ,Brendon Theunissen, Julian Briggs "Biological filtration for sustainable treatment of groundwater with high iron content –a case study".

[6] G.K Khadse ,V.W .Lande,S.P .Andey and P.K Labhasetwar "Performance of Up –Flow Roughing Biofilter in Iron Removal from Groundwater",International Journal of Water Resources and Arid Environments 2 (1):09 -14,2013 ISSN 2079-7079.

[7] Chi-Chuan Kan , Wen –Hsiang Chen ,Meng-wei wan , Piaw Phatai, Jatuporn Wittayakun,and Kun –Feng Li "The preliminary study of iron and manganese removal from groundwater by NaOCl oxidation and MF filtration".

[8] Marina Valentukeviciene "Experimental research on removal of iron and ammonium ions from groundwater by natural silica sand" geologija 2008 .vol 50 .No 3(63).p.201-205.

[9] Ioannis A.katsoyiannis "Use of iron and manganese-oxidizing bacteria for the combined removal of iron, manganese and arsenic from contaminated groundwater", Water Quality Research Journal of Canada 41(2) Jan 2006.

[10] Monik Kasman , Shaliza Ibrahim Salmariza "removal of iron from aqueous solution rice husk : isotheram and kinetic study".

[11] Rajesh Ghosh and Sounak Bhattarcherjee, "A review study on precipitated silica and activated carbon from Rice Husk", Chemical engineering and process technology.

[12] Deepika B.V and Pradeep Kumar K J, "Iron removal for drinking water using low cost adsorbents-A comparative study", in International Journal of Innovative Research in Science, Engineering and Technology, vol 5, Issue 12, December 2016.

[13] Ajayi O.O, Omole D.O, Emenike C.P, "Use of agricultural wastes and limestone for the removal of iron from drinking water", 3rd International Conference on African Development Issues(CU-ICADI 2016).

[14] Monik Kasman , Shaliza Ibrahim Salmariza "removal of iron from aqueous solution rice husk : isotheram and kinetic study".

[15] P.Iyshwarya, R.G.Ramya Gayathri, N. Sangeetha "Removal of iron content from drinking water by using coconut coir and sugar bagasse", 2016 IJARMATE.

[16] Deepika B.V and Pradeep Kumar K J, "Iron removal for drinking water using low cost adsorbents-A comparative study", in International oournal of Innovative Research in Science, Engineering and Technology, vol 5, Issue 12, December 2016.

[17] Sandhya Thatavarthy and Anima Dadhich, "An assessment of efficiency of nonconvectional adsorbents in removal of iron(II): A study done with sugarcane bagasse", Research Journal of Pharmaceutical, Biological and Chemical Sciences, ISSN:0975-8585, 2015.

[18] Sreelakshmi C.D "Heavy Metal Removal From Wastewater using Ocimum Sanctum" International journals of latest Technology in Engineering,Management & Applied Science (IJLTEMAS) Volume VI, Issue, April 2017 ,ISSN 2278- 2540.

[19] Nualchavee Roongtanakiat and Ridhee Meesat "Utilization of Vetiver grass for removal of heavy metals from industrial wastewaters", Research article, scienceasia 1513-1874 2007.33.397.

[20] P.Iyshwarya, R.G.Ramya Gayathri, N. Sangeetha "Removal of iron content from drinking water by using coconut coir and sugar bagasse", 2016 IJARMATE.

[21] Leena Deka and Krishna G. Bhattacharyya, "Batch adsorption studies for iron removal from aqueous solution by sand and charcoal mixtures" in Journal of Applied and Fundamentals Sciences.

[22] Mulu Berhe Desta, "Batch sorption experiment: Langmir and Freundlich Isotherm studies for the adsorption of textile metal ions onto Teff Straw agricultural waste" Journal of Thermodynamics, volume 2013.

[23] Dawodu F.A, Akpomie G.K and Ogbu I.C, "Isotherm modelling on tge equilibrium sorption of cadmium(II) from solution by Agbani Clay", International Journal of Multidisciplinary sciences and engineering, vol.-3, No.9, September 2012.

[24] Leena Deka and Krishna G. Bhattacharyya, "Batch adsorption studies for iron removal from aqueous solution by sand and charcoal filteration" in Journal of Applied and Fundamentals Sciences.

[25] Mohammad Ghazi Bin Hj Ismail, "Freudlich Isotherm Equilibrium Equation in Determining effectiveness a low cost absorbent to heavy metal removal in wastewater at Teluk kitang Landfill, Pengkalan Chepa, Kelantan, Malaysia", Journal of geography and earth science.

[26] B.H.Hameed, A.T.M.Din and A.L.Ahmad, "Adsorption of methylene blue onto bamboo based activated carbon: kinetics and equilibrium studies", Journal of Hazardous materials, vol.141,no.3,pp. 819-825,2007.