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Research Article

Heavy Metal Removal and Dye Decolourization by Adsorption using *Mangifera indica*

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Abstract

The removal of heavy metal (Cu) and decolourisation of dye (Congo red, acid violet, reactive yellow) from aqueous solution using an adsorbent prepared from Mango leaf was investigated in this study. The influence of time of mechanical shaking, mass of adsorbent (0.5, 1, 1.5,2 mg), initial pH, initial concentration (2000, 1500, 1000,500,250 mg/L) on adsorption has been evaluated. It is shown that adsorbent prepared from Mango leaf powder has a relatively high adsorption capacity for these adsorbates. For 500 mg/L of solution prepared, the percentage of decolourisation for 2 g of adsorbent and 1 hour of mechanical shaking was found to be 39.4% for the metal, and 41.4, 50.9 and 22.7% for Congo red, acid violet, reactive yellow, respectively. All the experiments were carried out at normal room temperature (25 -28 ºC) and neutral pH. A set of readings taken by varying pH shows that the adsorption capacity is also influenced by pH. Of the two kinds of adsorbent prepared, adsorbent prepared by oven drying is found to be more effective than adsorbent by natural drying. A kinetic models applied to the adsorption by mango leaf powder was evaluated and it was found that the equilibrium data were well described by Type-I adsorption model.

Keywords: Adsorption; Heavy metal; Dye; Decolourization; Mango leaf.

Introduction

The industrial activities have been increased by causing many water bodies receive loads of heavy metals exceeding the maximum permissible wastewater discharge limit. Pollution by heavy metal ions such as mercury (Hg (II)), lead (Pb (II)) and Copper (Cu (II)) etc., has become major issue in many countries due to their possible toxic effects [1]. Theses metals are non-biodegradable and may enter into food web causing cancer and other diseases [2,3].

Contaminated water with metallic effluent can cause several health problems. It can affect nerves and brain even at low concentrations. Any change in pH of water bodies as a result of influx of effluent, can cause serious change in water chemistry that affects resources especially around the coastal areas. Such metals in the effluent may increase fertility of the sediment and water column and consequently lead to eutrophication where it can progressively lead to oxygen deficiency, algal bloom and death of aquatic life. Dyes in water bodies also affect photosynthetic organisms and consequently impact negatively on the food chain. Textile effluents can seep in to the aquifer and pollute the underground water. They can therefore affect aquatic life in several ways.

Water plays a vital role in most of the processes in industries. The ever increase in demand for water has led to the pressure in resource development. This development in turn disturbs the environment. The major industries that consume water are textile, pulp and paper, rubber, plastic, tannery, sugar, petrochemicals etc… The various constituents of waste water from these industries are potentially harmful to the environment and to the human health [4,5]. In environment the animal and plant life are disturbed due to this pollution. Drinking water is also threatened by increasing level of pathogenic organisms and the toxic chemicals. The important parameters of water pollution are temperature, pH, BOD, COD, suspended solids and toxic substances.

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There are many methods available for the removal of heavy metals from aqueous solutions and it includes the reduction process, sulfide treatment, ferrous chloride treatment, magnetic ferrites treatment, ion exchange and ion exchange followed by collating resin [6]. It came to know that adsorption is one of the most efficient methods for the removal of heavy metals from wastewater. Activated carbon is most widely used adsorbent for heavy metals [7,8] but use of this method is limited due to the high cost, which makes them unfavorable for the needs of developing countries. Plant wastes are in expensive as they have very low economic value [9]. Many reports had been published on the low-cost adsorbents for heavy metals from aqueous solutions [10].

Adsorption of Cadmium, Zinc and Lead from aqueous solutions on inexpensive adsorbents has been investigated by many authors [11]. Ion exchange is one of the primary analytical methods used to identify and quantify the concentration of ions in a wide range of environmental, biological, and industrial samples [12]. Electro-winning is an electrochemical process that can be employed to remove metallic ions from concentrated rinse water, spent process solutions, and ion exchange regenerate [13]. A large number of adsorbents are available for removing heavy metals. One important adsorbent is activated Carbon [14]. However, the use of these methods is often limited due to the high cost, which makes them unfavorable. A number of enzymes and other biological materials are used to adsorb heavy metal. This has the advantage of cheap availability and it is eco-friendly. But this cannot be applied in all the cases as it is time consuming [15].

In the current study, mango leaf powder was used to remove heavy metal from aqueous solution and for the decolourisation of dye. The equilibrium and kinetics of adsorption were investigated. The influence of adsorption time, initial pH, and initial concentrations was evaluated. Some of the methods, which are, in general, known to be effective for the treatment of liquid effluents are discussed.

Materials and methods

Preparation of Adsorbent

Type I: By natural drying

Mango leaves were collected, dried under sunlight for 3-4 days and ground to smaller size in ball mill. It was then washed with 0.1 N HCl and with double distilled water for more than 6 times to remove the acid content in the adsorbent. Again it was dried and screened using mesh number-150 screen. By sieve analysis, its average size was found to be 0.322 mm.

Type II: By Oven drying

Adsorbent by oven drying is also prepared by the same method except that it is dried in hot oven. The adsorbent is kept at a temperature of 105°C for nearly 6 hrs. The size of the Type II adsorbent is found to be 0.2715 mm by sieve analysis.

Preparation of Solutions

A solution of various concentrations containing copper was prepared by dissolving known quantity of the metal in double distilled water [16].

Batch adsorption studies

Adsorbents of different masses were added to the solutions of known concentration and placed in orbital shaker at 100 rpm. They were filtered using Whatman 40 filter paper and the solutions were analyzed using photometer. The optical density for different concentration of the solution was measured using photometer. To analyze the light, the photometer measures the light after it has passed through a filter or through a monochromator for determination at defined wavelengths or for analysis of the spectral distribution of the light. Visible light reflectance photometry was used for measuring the reflectance of a surface as a function of wavelength. The surface was illuminated with white light, and the reflected light was measured after passing through a monochromator. This type of measurement has many practical applications, for instance in the paint industry to characterize the color of a surface objectively. This procedure was repeated for dyes such as Congo Red, acid violet and reactive yellow and various isotherms were drawn.

Adsorption Isotherms

The experimental equilibrium data were correlated with Langmuir and Freundlich isotherm models [17]. The Langmuir isotherm is represented by the equation (1).

$$\frac{P}{V} = \frac{1}{KVm} + \frac{P}{Vm} \quad \text{..... (1)}$$

The Freundlich adsorption isotherm is represented by the equation (2).

$$log\frac{x}{m} = logK + \frac{1}{n}logP \quad \text{..... (2)}$$

Results and discussion

Copper sulphate and dye (Congo-red, acid violet and reactive yellow) solutions of various concentrations were gently shaken with various mass of mango leaf powder (size ~ 0.2 mm) at room temperature (25 - 28°C). Small samples of solution (20 mL) were withdrawn at fixed times to determine the remaining concentration of Cu and dye in bulk solution [17]. Adsorption was monitored for half and one hour. The parameters varied are Initial concentration of the solution, Mass of adsorbent, Time of Mechanical shaking, pH.

Copper sulphate

The obtained equilibrium data were fitted to the Langmuir isotherm (Fig. 1 and Fig. 2), where q is the amount of heavy metal adsorbed per mass unit of adsorbent at equilibrium (mg/g), p is the equilibrium concentration of the remaining heavy metal in solution (mg/mL). The data fits the Langmuir Isotherm. The R^2 value was close to 1, revealing the extremely good applicability of the Langmuir model to the present adsorption process. The Fig. 3 and Fig. 4 indicate the fitness of data for Freundlich adsorption Isotherm with R^2 value approaching 1 (Table 1). It was observed that as the pressure increases the extent of adsorption also increases. The optimum parameter for Copper sulphate was 1500 mg/L of initial concentration and 60 min mechanical shaking.

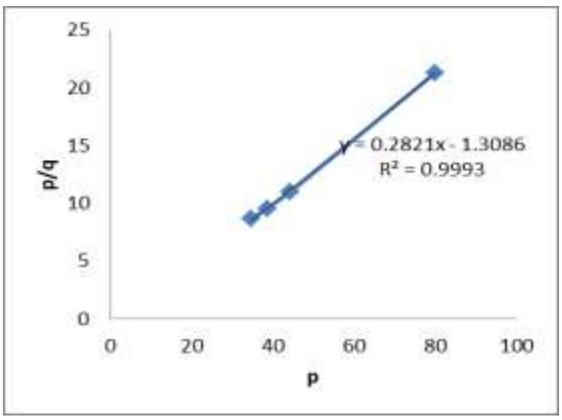

Fig. 1. Langmuir isotherm for natural dried adsorbent (Concentration=1500 mg/L, Time=60 min)

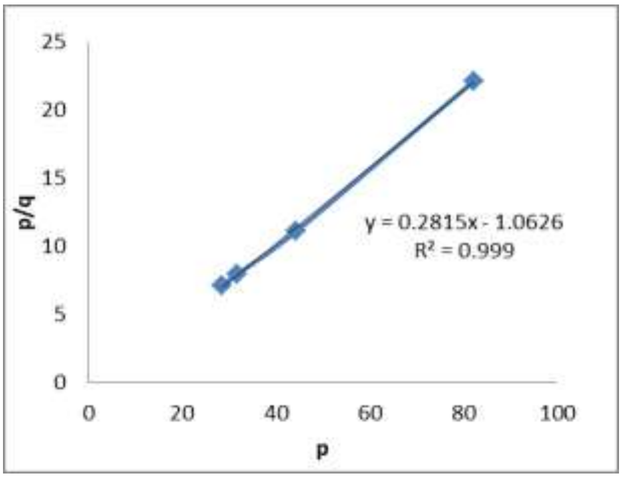

Fig. 2. Langmuir isotherm for oven dried adsorbent (Concentration=1500 mg/L, Time=60 min)

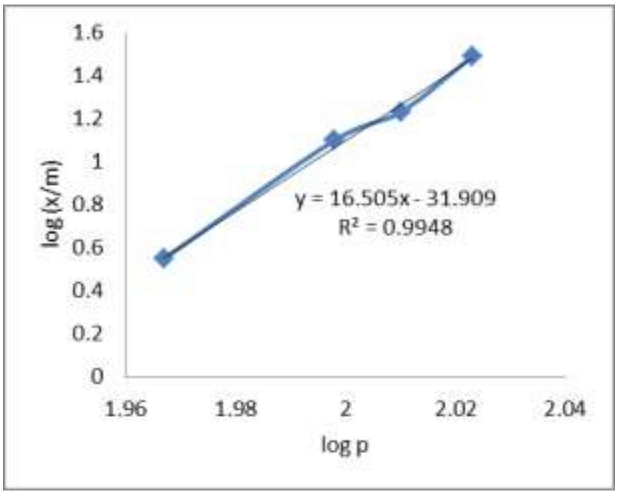

Fig. 3. Freundlich isotherm for natural dried adsorbent (Concentration=1500 mg/L, Time=60 min)

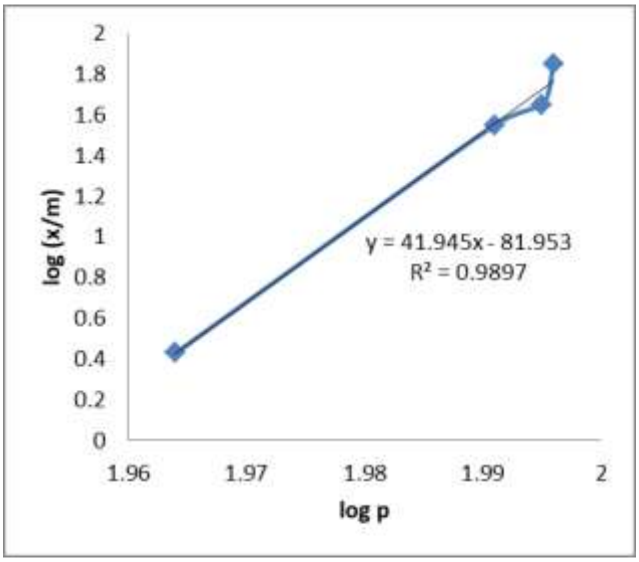

Fig. 4. Freundlich isotherm for oven dried adsorbent (Concentration=1500 mg/L, Time=60 min)

Acid violet

Similar 1000 mg/L of initial concentration was found to be the optimum parameter for both Congo Red and Acid Violet. The obtained data were plotted to fit the Langmuir isotherm (Fig. 5). It was observed that as the amount of dye concentration increases the extent of adsorption also increases. The R^2 value indicates the good applicability of Langmuir isotherm (Table 1). Fig. 6 indicates the Freundlich adsorption isotherm for the data obtained. It can be inferred that the extent of adsorption increases with the pressure.

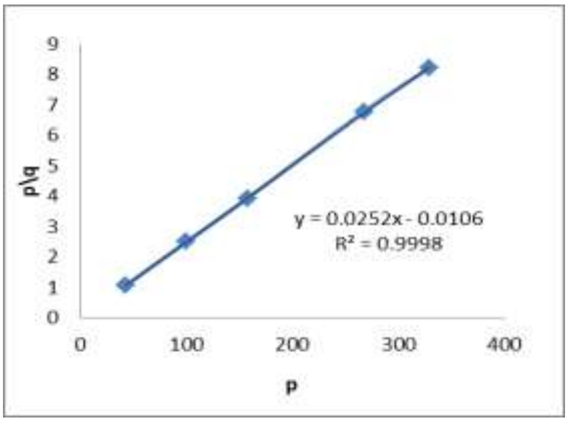

Fig. 5. Langmuir isotherm for natural dried adsorbent (Concentration=1000 mg/L, Time=60 min)

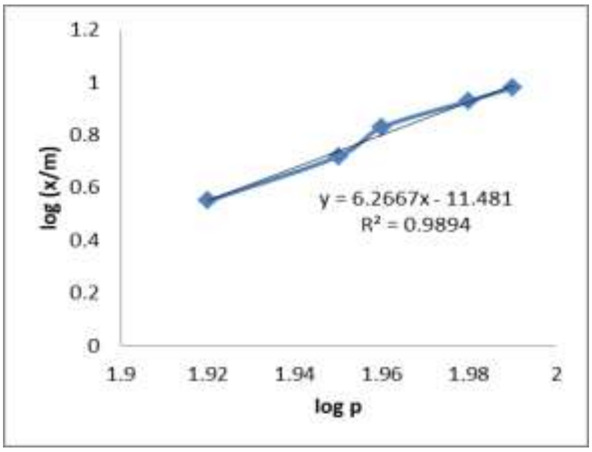

Fig. 6. Freundlich isotherm for oven dried adsorbent (Concentration=1000 mg/L, Time=60 min)

Congo red

The Fig. 7 indicates the increase in extent of adsorption with the gradual increase in equilibrium concentration of the remaining Congo red dye in solution. The effect of pressure on the extent of adsorption was given in the Fig. 8. The Adsorption isotherm shows that the extent of adsorption depends on pressure and it increases with the pressure.

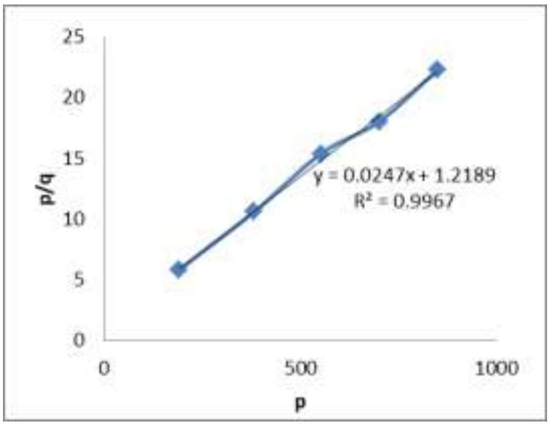

Fig. 7. Langmuir isotherm for oven dried adsorbent (Concentration=1000 mg/L, Time=60 min)

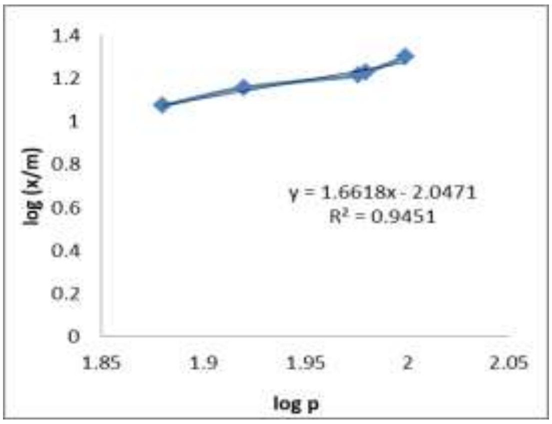

Fig. 8. Frendulish isotherm for natural dried adsorbent (Concentration=1000 mg/L, Time=60 min)

Reactive yellow

For reactive yellow, graphs drawn for initial concentration of 1000 and 2000 mg/L gives perfect fit of isotherm. Fig. 9 represents the fitness of obtained data for Langmuir adsorption isotherm. It was observed from the Fig. 10 that the obtained data fits the Freundlich adsorption isotherm (Table 1). The extent of adsorption increases as the pressure increases.

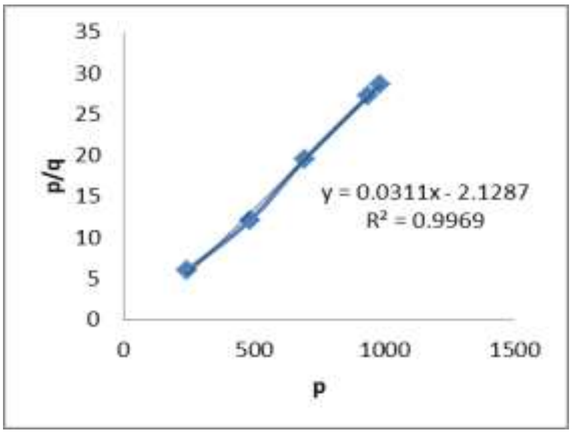

Fig. 9. Langmuir isotherm for oven dried adsorbent (Concentration=1000 mg/L, Time=60 min)

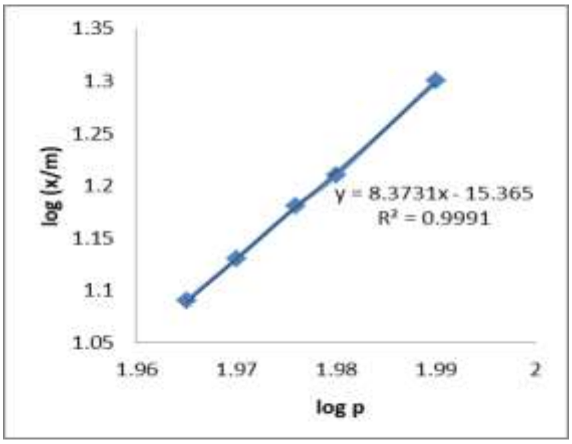

Fig. 10. Freundlich isotherm for oven dried adsorbent (Concentration=1000 mg/L, Time=60 min)

Effect of initial pH on uptake of metal and dye

Various mass of the adsorbent is added to 1000 mg/L of metal solution at various initial pH, which was adjusted with 1 N NaOH and measured using conductivity cell. 2 g of adsorbent is used and 60 min mechanical shaking is followed throughout. It is found from the Fig. 11, Fig. 12, Fig. 13 and Fig. 14 that the amount of metal adsorbed increases with increasing pH. At lower pH (pH<3) adsorption of metal is negligible. With the increase of pH, adsorption increases but different proportions depending on the solution.

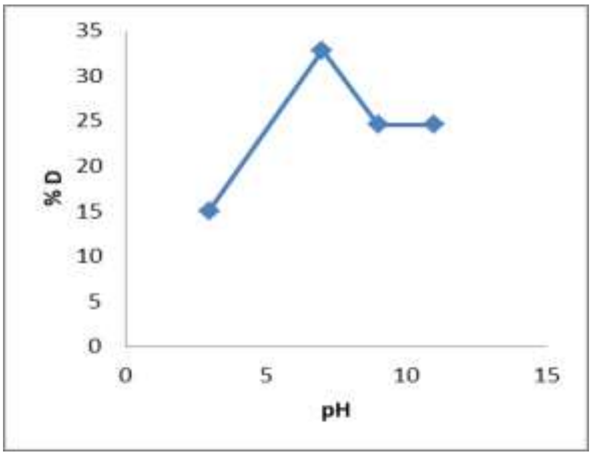

Fig. 11. Effect of pH on decolourisation of copper sulphate (Concentration=1000 mg/L, Time=60 min)

Effect of initial concentration

The effect is discussed for 1000 mg/L of solution, 1 hour of mechanical shaking and 2 g of adsorbent. At lower concentration of solution, the adsorbent is found to produce good percentage of decolourisation and a small decrease is noticed at higher value of concentration.

Effect of time of mechanical shaking and mass of adsorbent

Adsorption increases with increase in mechanical shaking and mass of adsorbent.

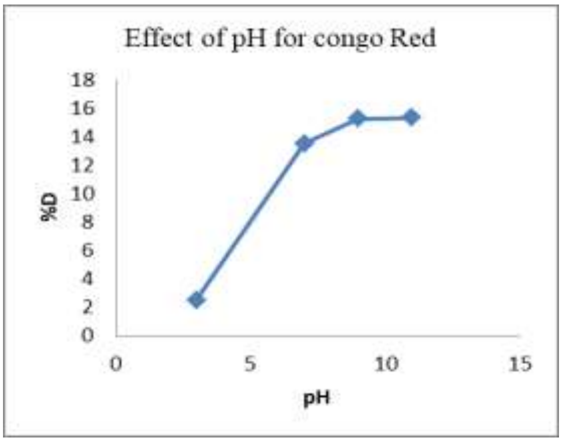

Fig. 12. Effect of pH on decolourisation of congo Red (Concentration=1000 mg/L, Time=60 min)

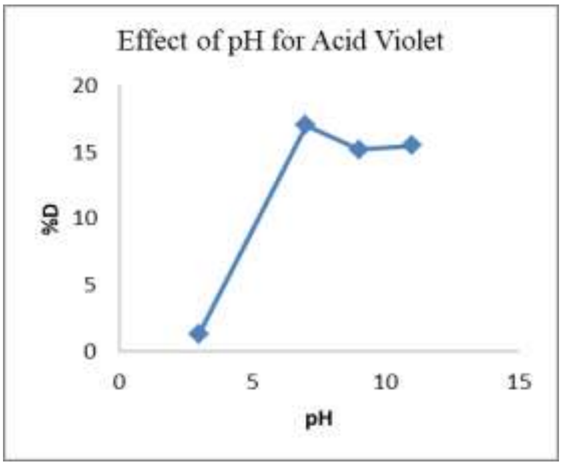

Fig. 13. Effect of pH on decolourisation of Acid Violet (Concentration=1000 mg/L, Time=60 min)

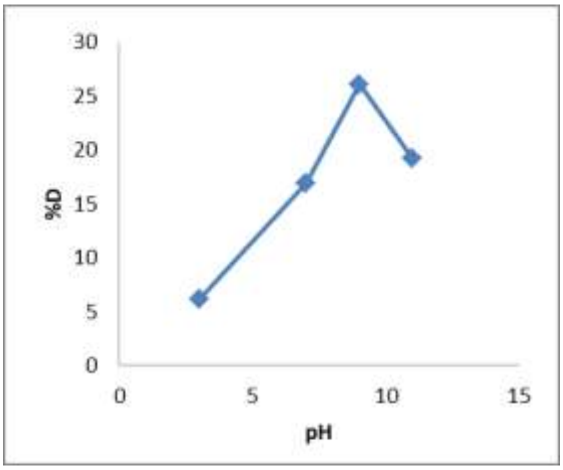

Fig. 14. Effect of pH on decolourisation of Reactive Yellow (Concentration=1000 mg/L, Time=60 min)

Table 1. Summary of R^2 Values

Dye /Heavy Metal	R^2 value			
	Langmuir		Freundlich	
	Naturally dried	Oven dried	Naturally dried	Oven dried
Copper sulphate	0.999	0.999	0.994	0.989
Acid violet	0.999	0.993	0.995	0.989
Congo red	0.990	0.996	0.945	0.960
Reactive yellow	0.970	0.996	0.980	0.999

Conclusions

Removal of heavy metals (copper) from aqueous solution and decolourisation of dye was possible using a powder prepared from leaves of *Mangifera indica*. It is shown that the adsorbent prepared from mango leaves has a relatively high adsorption capacity at room temperature and neutral pH [10] .This method has an advantage that it can be applied in developing countries due to the low cost and availability of mango leaves. The experimental data carried out by varying pH shows that adsorption capacity increases with increase in pH. The effect of pH is almost negligible at lower pH (<3), increases up to pH of 7-9 and then remains constant. The adsorption also increases with increase in time of mechanical shaking and mass of adsorbent. It is found to be very effective for smaller concentration and there is a small decrease with increasing concentration of solution. This adsorption is described by an isotherm of type I and is fully verified by Langmuir and Freundlich isotherm. Depending on the value of correlating factor R2, Langmuir is found to give perfect fit. Type II adsorbent i.e. adsorbent prepared by oven drying is found to be more effective.

Conflicts of Interest

Authors declare no conflict of interest.

References

[1] Bailey SE, Olin TJ, Bricka RM, Adrian DD. A review of potentially low cost sorbents for heavymetals. Water Res. 1999;33:2469-2479.

[2] Khairia M. Al-Qahtani. Water purification using different waste fruit cortexes for the removal of heavy metals. J Taibah Univ Sci. 2016;10:700-708.

[3] Gupta VK, Gupta M, Sharma S. Process development for the removal of lead and chromium from aqueous solution using red mud – an aluminum industry waste. Water Res. 2001;35:1125-1134.

[4] Huang CP and Smith EH. Removal of Cd (II) from plating wastewater by an activated Carbon process. Env Sci Technol. 1981; 25: 437-446.

[5] Bhattacharya K, Venkobachar C. Removal of cadmium (II) by low cost adsorbents. J Env Eng. 1984;110:110-112.

[6] Xin Y, Guoren X, Huarong Y. Removal of lead from aqueous solutions by ferric activated sludge-based adsorbent derived from biological sludge. Arabian Journal of Chemistry. 2016; https:\\doi.org\10.1016\j.arabjc.2016.04.017.

[7] Karnitz O, Gurgel LVA, de Melo JCP, Botaro VR, Melo TMS, de Freitas Gil RP, Gil LF. Adsorption of heavy metal ion from aqueous single metal solution by chemically modified sugarcane bagasse. Bioresour Technol. 2007;98:1291-1297.

[8] Cao X, Ma L, Gao B, Harris W. Dairy-Manure Derived Biochar Effectively Sorbs Lead and Atrazine. Env Sci Technol. 2009;43:3285-3291.

[9] Azimi A, Azari A, Rezakazemi M, Ansarpour M. Removal of heavy metals from industrial wastewaters: A review. Chem Bio Eng Rev. 2017;4:37-59

[10] W.S. Wan Ngah , M.A.K.M. Hanafiah. Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents: a review. Bio Technol. 2008;99:3935-3948

[11] Cowan CE, Zachara JM and Resch CT. Cadmium adsorption on iron oxides in the presence of alkaline-earth element. Env Sci Technol. 1991;25:437-446.

[12] García-Rosales G, Colín-Cruz A. Biosorption of lead by maize (Zea mays) stalk sponge. J Environ Manage. 2010;91(11):2079-2086.

[13] Low KS, Lee CK and Leo AC. Removal of metals from electroplating wastes using banana pith. Bioresour Technol. 1995;51:227-231.

[14] Patterson JW, Allen and John J.Scala. Carbonate precipitation for heavy metal pollutants. J Water Pollut Control Fed. 1977;49:2397-2410.
[15] Creamer AE, Gao B, Zhang M. Carbon dioxide capture using biochar produced from sugarcane bagasse and hickory wood. Chem Eng J. 2014;249:174-179.
[16] Hidayu AR, Mohamad NF, Matali S, Sharifah ASAK. Characterization of Activated Carbon Prepared from Oil Palm Empty Fruit Bunch Using BET and FT-IR Techniques. Procedia Eng. 2013;68:379-384.
[17] Liu C, Tang Z, Chen Y, Su S, Jiang W. Characterization of mesoporous activated carbons prepared by pyrolysis of sewage sludge with pyrolusite. Bioresour Technol. 2010;101:1097-1101.

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