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ORIGINAL ARTICLE

A Comparative Study of the Adsorption Capacity of Tea Leaves and Orange Peel for the Removal of Fe (III) Ion from Wastewater

Kazi Rifat Mamun, Nirob kumar Saha, Sumon Chakrabarty*

Chemistry Discipline, Khulna University, Khulna-9208, Bangladesh

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KEYWORDS

Contamination;
Heavy Metal;
Adsorption;
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ABSTRACT: Adsorption is a very promising and interesting technique for removal of heavy metal ions. In this study orange peel and waste tea leaves were used as low cost adsorbents for removal of iron (III) ion from wastewater. Batch adsorption studies were employed to investigate the influence of pH, time, doges and initial metal ion concentration. The maximum removal capacity of orange peel and waste tea leaves were observed at pH 9 for iron (III) removal. For both adsorbents 75 min was required in order to achieve equilibrium for the adsorption of Fe (III) ion. The influence of adsorbent dose was checked by using different dosage of adsorbents. Adsorption parameters were investigated by using Langmuir and Freundlich isotherm. The removal of Fe (III) ion by using both adsorbents moderately fit the Langmuir and Freundlich isotherm. From the result it was observed that the adsorption capacity of waste tea leaves is higher than orange peel.

INTRODUCTION

The contamination of water, due to discharge of industrial wastewaters containing heavy metals, has become a serious environmental issue. This is a major problem as a result of heavy metals at high concentrations area unit are poisonous to aquatic eco-systems inflicting harmful effects to living organisms, plants and humans [1].The living organism, required various amounts of heavy metals in order to meet their basic needs. All metals are known to have toxic effects at higher concentrations and found to be associated with the occurrence of several harmful effects to the organism [2]. Nucleic acids, proteins, and small metabolites can easily bind with these metal ions. The polluted organic cells area unit altered or lost their biological functions with losing the equilibrium management of essential metals, leading to fatal health issues [3]. The discharge of enormous quantities of heavy metals into the nature has resulted during a variety of environmental issues and due to their non-biodegradability and persistence, will gather within the organic phenomenon, and so might create a big danger to human health [4, 5]. So the removal of those toxic metals from industrial wastewater is needed before discharging into water in order to avoid these complications.

Metal pollution is often found within the wastewaters of the many industries, such as textile mill products (Cr), organic chemicals (Cr, Pb), petroleum refining, pulp industries and fertilizers (Cr, Cu and Pb), iron and steel manufacturing plants (Fe) [6]. Our interest here is the removal of iron because in our country, most of the sources of drinking water are polluted by iron. 97% people in Bangladesh depend on ground water or tube-well water for their drinking functions. Meril et al. investigated the presence of iron in the tube-well water in the north western part of the Bangladesh. This studies showed that the concentration of iron in this area was very high (16.3 mg/L) and regular iron consumption for a person was determined approximate 41.1 mg [7].

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*Corresponding author: sumon.ku10@gmail.com (S. Chakrabarty)

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Chronic exposure to Iron through water makes increased risk to deliver for ladies in terms of Low Birth Weight (LBW) [8]. Moreover, high iron concentration in water conjointly menacing for dairy farm farms. Excessive presence of Iron in ground water caused scouring, loss of body weight and lower production of milk and butter fat for bovine animals [9].

The presence of iron within the liquid setting includes a doubtless damaging impact on human physiology and different biological systems once the appropriate levels area unit exceeded [10]. The presence of iron in ground and surface water will cause variety of issues that area unit associated with the health safety of water. Extreme amounts of iron in public water deliveries caused turbidity, offensive taste, and odor [11].The probability of developing of cancer is redoubled by excess iron uptake [12]. Therefore, removal of iron from waste water is necessary.

Due to the simplicity, convenience, and high removal efficiency of adsorption techniques are found to be the most popular in removal of heavy metal as compared to other techniques [13] such as gravity settling, the method within which particulates area unit settled all the way down to the liquid as sediment; flotation or filtration, the removal method of suspended matter like oil or solids from wastewaters to clarify the water; action (adsorption, particle alternate); membrane processes, the method within which a membrane having porousness, property and electrical phenomenon is employed to separate the elements of an answer or a suspension; electrolytic restoration and liquid-liquid extraction, the tactic that is employed to separate compounds or metal complexes, betting on their relative solubility in two different immiscible liquids, usually water and an organic solvent [14-16]. Granular Active Carbon (GAC), Bone Meal (BM) or Iron Fines (IF) has also been used for removal of heavy metal from aqueous solution. The GAC technique is costly and there's a risk of arsenic (As) unleash, whereas, BM is a smaller amount effective for metal removal and unleash great amount of organic carbon that is damaging for health.. In case of IF method, the scrap iron are used and the oxidation state of that iron are strictly maintained otherwise co-precipitation with iron corrosion products would dominate the removal mechanism of metals [17].

Recently, researchers have more interested in removing polluted metal from wastewater using less expensive materials as a sorbent. Using biosorbents like agricultural waste sawdust [18], coconut shell [19], modified sawdust of walnut [20], papaya wood [21], maize leaf [22], rice husk ash and neem bark [23], fly ash [24] etc. could also be an alternate effluent technology as a result of they're cheap and capable of removing trace levels of heavy-metal ion.

In this paper, the adsorption of iron (III) ion onto Orange Peel and Tea powders has been investigated. The adsorption capability was evaluated under numerous conditions of pH scale, contact time, initial iron concentration, and adsorbent dosage. The adsorption isotherms were additionally investigated to clarify the probable mechanism of adsorption.

MATERIALS AND METHODS

Reagent and material

Iron Chloride,were purchased from Research-Lab Fine Chem Industries, Mumbai, India. Hydrochloric acid were obtained from Sigma-Aldrich India. NaOH pellets were of analytical grade, purchased from Loba Chemie Pvt. Ltd., India.

Equipment

The concentrations of Fe^{3+} ions in the solutions before and after equilibrium were determined by using UV-absorption spectrometer having model no.: UVD-3200, Labomed, U.S.A. Batch adsorption studies were performed with a UV-absorption spectrometer having model no.: UVD-3200, Labomed, U.S.A. The pH of the solution was examined using a pH meter model: pH-5011, Hanna. The solution was centrifuged by using a centrifuge machine model no.: 800 Centrifuge, China.

Preparation of adsorbents

Tea leaves were collected from the local market, washed thoroughly with hot and cold water to remove dust and color using hot and cold water. After removal of dust the adsorbents dried in an air oven at 100°C for 24 h. Finally, the tea leaves were blended and the different sized adsorbents were separated by using different pore sized sieves.

Orange peels were cut into little pieces, dried, pulverized, and washed completely with distilled water to eliminate the impurities. Finally the adsorbents were dried in an air oven at 100°C for 24 h. After drying, the size of the adsorbents was separated (particle sizes 0.1 and 0.5 mm).

Adsorption experiments

1000 ppm Fe (III) stock solution was prepared by dissolving an appropriate amount of $FeCl_3$ salt in deionized water. By using deionized water the stock solution was diluted in order to achieve the required concentrations. The pH of the Fe^{3+} solution was adjusted using 0.10 M HCl or 0.10 M NaOH.

In order to demonstrate the adsorption capacity of the adsorbents, experiments were carried out in a series of 100 mL conical flask containing 50 mL iron solution. Then 0.3g of adsorbent was added and shaken at room temperature. After shaking, the solution was centrifuged by a centrifugal machine and the filtrate was collected. The removal percentage of iron was calculated by using the following equation [25].

$$\% R = \frac{C_i - C_f}{C_i} \times 100$$

Where, C_i and C_f are the initial and final concentrations of iron respectively in the solution. The amount of iron adsorbed was calculated by using the following equation.

$$W_e = \frac{C_i - C_f}{M} \times V$$

Where, W_e is the metal uptake capacity (mg/g), V the volume of the metal solution in the flask (L) and M is the dry mass of adsorbent (g).

Experiments Parameters

The experiments were brought about to determine the effect of pH, concentrations, contact time, adsorbent dose and adsorbent size of the iron solution onto tea leaves and orange peels. All studies except adsorbent dose and concentrations of iron were carried out by using 50 mL metal solutions of 100 ppm iron, containing 0.3g 0f adsorbents. The effect of contact time was investigated by contacting the solution with adsorbents about 15, 30, 45, 60, 75 and 90 minutes. The pH dependent studies were brought about between the pH, varied from 3 to 10 and the contact time was 30 minutes. The effect of dose was investigated by using 0.1, 0.2, 0.3, 0.4 and 0.5g adsorbents in 50 mL 100 ppm solution having contact time about 90 minutes. The influence of adsorbent size was determined by using the adsorbents having 0.1mm and 0.5 mm diameter. The effect of concentrations was determined by using the solutions of 50, 100, and 150 ppm [13, 25].

RESULTS AND DISCUSSION

Influence of pH

The pH is one of the basic variables governing the adsorption of the metal ions which influences the functional groups protonation and furthermore, the metal chemistry [26]. The removal percentage of iron from the solution at varying pH range from 3 to 10 under the precise conditions (metals concentrations 100 mg/l, at constant contact time of 90 min, with 0.3 g of the adsorbents used, and at a room temperature) is shown in the Figure 1. The percent removal was remarkably increased from 46.41 to 89.11% with the increase of pH from 3 to 10. The maximum removal of Fe (III) was observed at pH 9 for both adsorbents. The removal efficiency of tea leaves was 89.11% at pH 9 after that the efficiency gradually decreases with the increase of pH. This is due to the fact that at that point the Fe (III) ions started to precipitate. On the other hand maximum removal efficiency of Fe (III) ion was attained by using orange peel was achieved 2.27% at pH 9. It obvious from the results the removal capacity of the waste tea leaves was greater than orange peel.

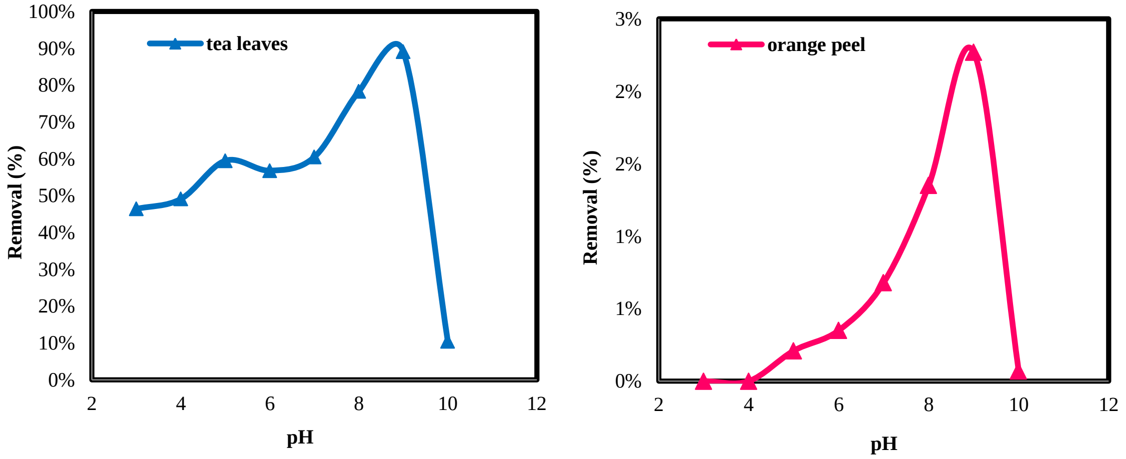

Figure 1. Influence of pH for removal Iron (III) ion by using tea leave and orange peel.

Influence of concentration

The adsorption capacity of metal ion onto adsorbents as a function of the initial concentration of the metal ions is determined in order to achieve an effective adsorption. Figure 2 illustrates the removal percentage of iron from the solution as a function of initial concentration of the metal ions. From the result it was observed that for tea leaves the removal percentage of iron increase with increase of initial metal ion concentration. At 50 ppm tea leaves adsorbed 73.04% of iron and it adsorbed highest 89.45% at 100 ppm. At 150 ppm tea leaves adsorbed 80% of iron from water. On the contrary at 50 ppm orange peel adsorbed 2.14% of iron but at 100 ppm it adsorbed maximum amount of iron (2.27%). The increase in adsorption is due to fact that the resistance to mass transfer between adsorbate and adsorbent is stunned by concentration gradient which perform like a driving force.

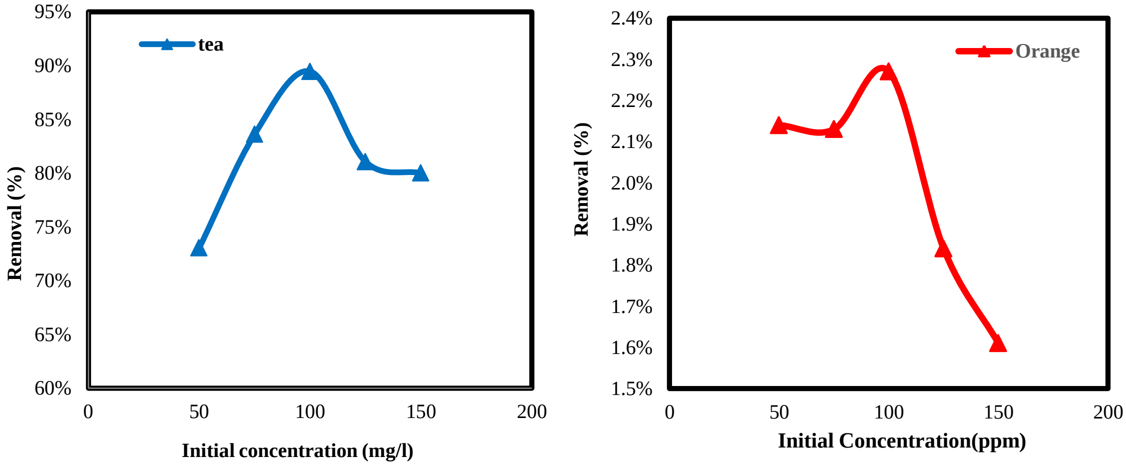

Figure 2. Influence of Initial concentration (mg/l) for removal Iron (III) ion by using tea leave and orange peel.

Influence of contact time

The effect of contact time on removal capacity of heavy metal ions using tea leaves and orange peel is represented in Figure 3. The obtained results reveal that the metal ions removal efficiency were increased as increases of contact time This is because of elongated interaction between the surface of the adsorbent and also the metals ions [27].

From the Figure it is noticed that the percentage metal ions removal approached equilibrium within 75 min for waste tea leaves with maximum removal efficiency reached to 89%, while for orange peel recorded 75 min with removal efficiency of 2.27%.

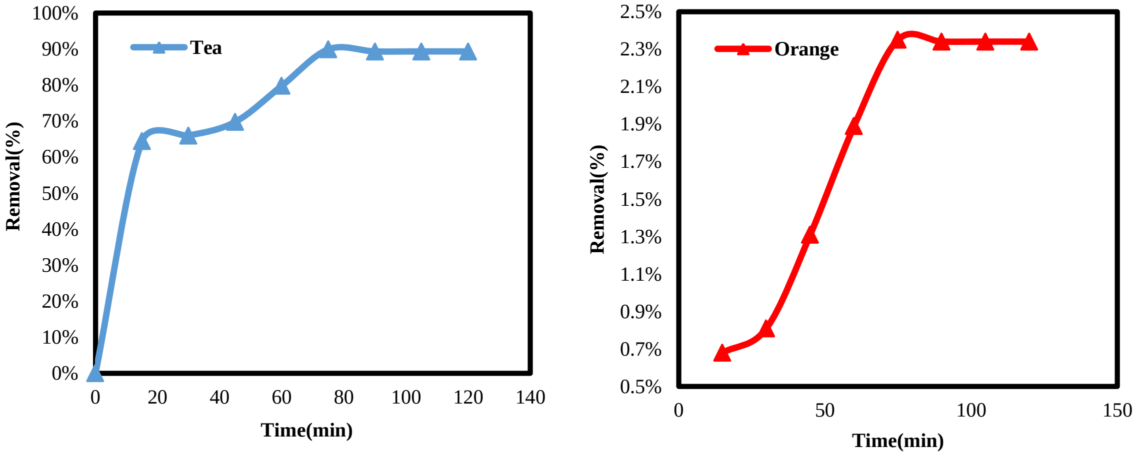

Figure 3. Influence of contact time for removal Iron (III) ion by using tea leave and orange peel.

Influence of dose

The reduced percentage of iron from water is shown in the Figure 4. as a function of dose. Generally more amount of adsorbent causes more removal of iron. The removal percentage of iron for both adsorbents was primarily increased due to increase the amount of tea. This is principally due to fact that with increase in adsorbent dose, the sorptive surface space and the accessibility of additional active binding sites on the surface of the adsorbent is also increased [28]. On the other hand, a reverse trend was also obtained for tea leaves as shown in the Figure, which could be explained by the fact that some sorption site can be remained unbound or coagulated during adsorption.

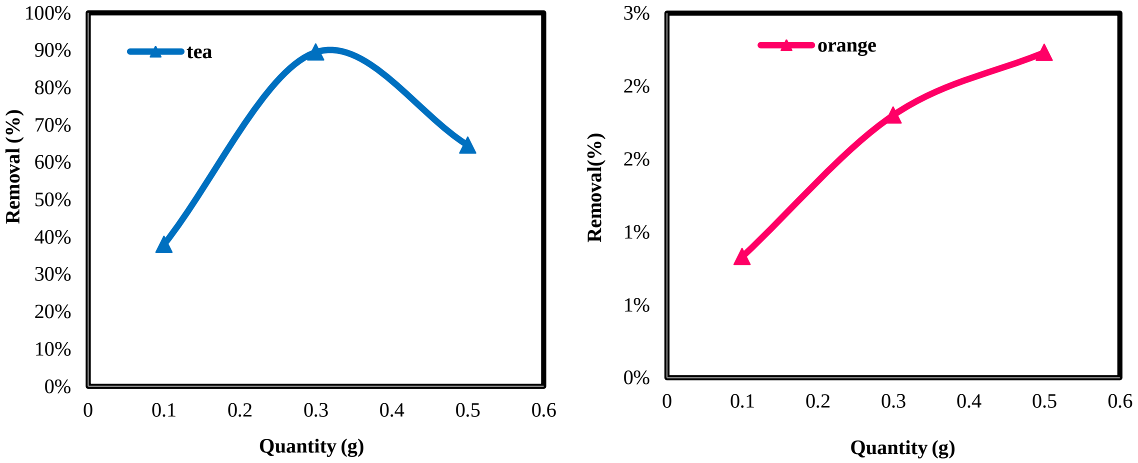

Figure 4. Influence of adsorbents dose for removal Iron (III) ion by using tea leave and orange peel.

Influence of adsorbent size

The effect of varying the adsorbent particle size on the adsorption of metal ion for both adsorbents is shown in Figure. 5. The orange peel, having diameter 0.1mm adsorbs 2.2% of iron while 0.5mm adsorbs 1.48%. In this case the adsorption percentage of iron by orange peel is decreased with the increase of the size of the adsorbent. On the contrary, the adsorption percentage of iron by tea leaves is increased with the decrease of surface area. From the Figure we notice that when the diameter of tea leaves is 0.1mm, the removal percentage is 67.82% but when the diameter is increased to 0.5mm then the removal percentage is increased to 89%. This is perhaps because of the increase in the total surface area which delivered extra active sites for adsorption.

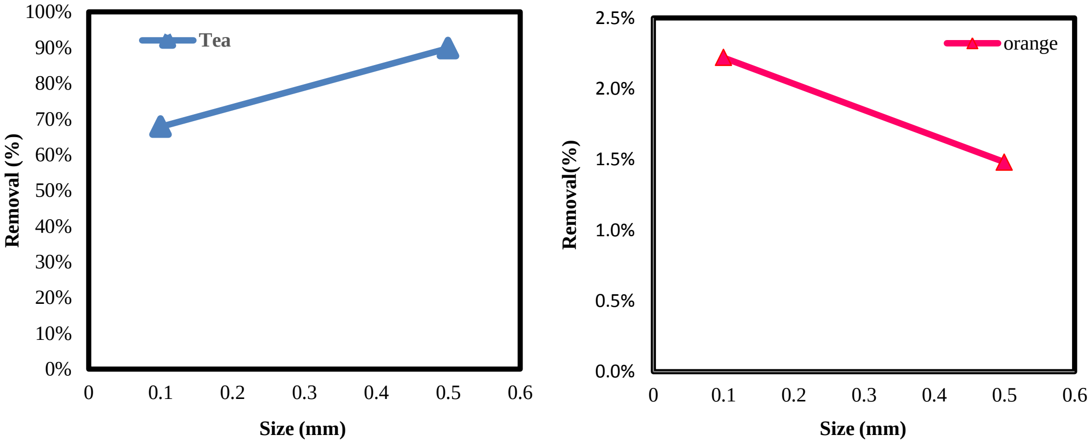

Figure 5. Influence of adsorbents size for removal Iron (III) ion by using tea leave and orange peel.

Freundlich sorption isotherm

The Freundlich sorption isotherm, one of the most widely used mathematical descriptions, is used to explain adsorption on surface having heterogeneity and the exponential distribution of active sites and their energies. The linearized form of Freundlich sorption isotherm is described by equation

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

Where C_e is the equilibrium concentration in mg/l, Q_e = amount of metal adsorbed per unit weight of adsorbent (mg/g). ‘‘k_f’’ is a parameter related to the binding energy and ‘‘n’’ is a is a measure of a deviation for the adsorption system under study, Freundlich parameters can be determined from The plots of log Qe against log Ce are shown in Figure 6; the adsorption of iron ions onto the tea leaves show a straight line; values of ‘‘n’’ between 1 and 5 represent good adsorption [29]. Whereas the value of ‘‘n’’ for orange peel was recorded < 5 which represent weak adsorption. Table 1 demonstrates the Freundlich isotherm constants and their correlation coefficients R^2.

Table 1. Freundlich constants for the adsorption of Fe (III) ion onto different adsorbents

Heavy metal	**Adsorbent**	**Freundlich constants**		
		k	**n**	**R^2**
Fe^{3+}	Tea leaves	7.48	3.75	0.12
	Orange peel	84.00	24.87	0.006

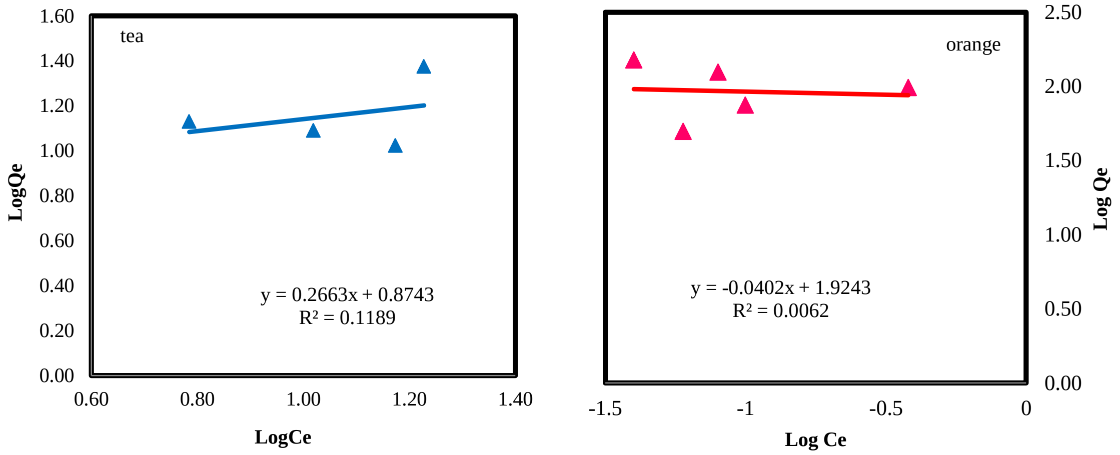

Figure 6. Freundlich plot for adsorption of Iron (III) onto tea leave and orange peel.

Langmuir isotherm

Langmuir isotherm model assumes that maximum adsorption occurs to a saturated mono-layer surface with a finite number of identical sites and the adsorption energy is constant. In the plane of the surface, there is no transmigration of adsorbate occurred [30]. The linearized form of Langmuir equation is defined as

$$\frac{C_e}{Q_e}=\frac{C_e}{Q_m}+\frac{1}{bQ_m}$$

Where Q_m and b represent Langmuir constants interrelated to the adsorption capability, and adsorption energy, respectively, C_e is the equilibrium concentration of Fe (III) in mg/l, and Q_e is the amount of metal adsorbed per unit weight of adsorbent (mg/g). The plots of Ce/ Qe against C_e are displayed in Figure 7. The evaluate parameter such as Langmuir isotherm constants and their correlation coefficients R^2 are given in Table 2. The values of R^2 confirm that adsorption of Fe (III) onto orange peel and tea leaves are moderately favorable for Langmuir model.

Table 2. Langmuir constants for the adsorption of Fe (III) ion onto different adsorbents

Heavy metal	**Adsorbent**	**Langmuir constants**		
		b	Q_m	R^2
Fe^{3+}	Tea leaves	0.03	42.37	0.05
	Orange peel	0.02	0.037	0.6

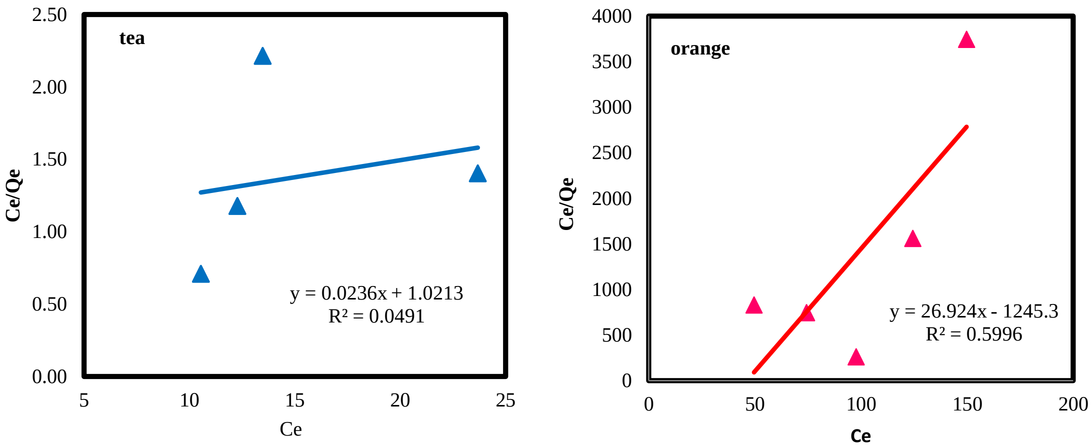

Figure 7. Langmuir plot for adsorption of Iron (III) onto tea leave and orange peel.

CONCLUSIONS

This work reports adsorption capacity of tea leaves and orange peel for removal of Fe (III) ion. Batch adsorption study was performed as a function of influence of pH, contact time, and initial metal concentration. The optimum pH for both adsorbents was observed at pH 9 with maximum removal efficiency 89.11% (tea leaves) and 2.27% (orange peel) respectively. In terms of equilibrium, the removal of iron ion was attained in 75 minutes for both adsorbent. From the result it was obvious that Langmuir isotherm and Freundlich isotherm were moderately fitted for both adsorbents.

ACKNOWLEDGEMENTS

None.

Conflict of interest

The authors declare no conflict of interest.

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