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Adsorptive Removal of Iron (II) from Aqueous Solution Using Raw and Charred Bamboo Dust

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Abstract

The current study focusing the removal of iron (II) from it aqueous solution using raw and charred bamboo dust has been studied by batch adsorption methods. The studies on adsorption of Fe (II) were conducted by varying the pH, contact time and initial concentration of solution. The results were obtained and indicate that the maximum sorption for iron (II) was found at pH 3.5 both raw and charred bamboo dust. The Langmuir and Freundlich adsorption models were used to represent the experimental data and equilibrium data. The maximum adsorption capacity of RBD and MBD were found to be 151.693 mg/g and 173.6453 mg/g respectively. The adsorption isotherm study reveal that the Langmuir adsorption isotherm can best explain the adsorption of the RBD and MBD for Fe (II). The kinetic data was analyzed by pseudo first order and pseudo second order kinetic models. It was found that the obtained data were best fitted by pseudo second order kinetic model. Functional group present in bioadsorbent was characterized by FTIR analysis. The RBD was characterized crystalline and MBD was amorphous type nature through XRD. The raw and charred bamboo dust used to calculate the removal efficiency and the maximum adsorption capacity (Qmax) of Fe (II) onto ground water samples in Samakhusi, Nepaltar and Mulpani are 93.79%, 97.83%, 81.81%, 85.49%, 96.06%, 97.80% and Qmax are 2.626 mg/L, 2.739 mg/L, 4.09 mg/L, 4.27 mg/L and 4.8030 mg/L and 4.89 mg/L for RBD and MBD respectively.

Keywords: *Adsorption isotherms, Bamboo Dust, Chemical Modification, Kinetic equation*.

1. Introduction

Heavy metals are natural components of the Earth's crust, and their concentrations in an aquatic environment have increased due to mining and industrial activities and geochemical processes. They are toxic or poisonous, if

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avail as more than the recommended enough amounts in water bodies [1]. Living organisms require trace amounts of some heavy metals, e.g., iron, copper, zinc etc., as they are essential to maintain the metabolism of the human body [2]. Iron is one of the most essential micronutrients for human beings. It helps to make RBCs, which carry oxygen around the body. The deficiency of iron causes Anemia. Free radicals due to iron overload can cause damage to a wide variety of cellular structures and ultimately kill the cells. Consequently, there is the need to achieve a controlled amount of iron in water to produce the desired taste and color of water as well as to prevent iron overload.

Iron deficiency anaemia is caused by lack of iron, often because of blood loss or pregnancy. Some common symptoms of iron deficiency anaemia are: Headaches, tiredness and lack of energy, shortness of breath, noticeable heartbeats (heart palpitations), pale skin, hearing ringing, buzzing or hissing noises inside your head (tinnitus), food tasting strange etc. In order to solve heavy metal such as iron pollution in the environment, it is important to bring applicable solutions. Several treatment technologies such as chemical precipitation, ion exchange, coagulation, bioremediation and sorption/adsorption are available for the removal of heavy metal ions from its aqueous solutions [3].

1.1 Adsorption isotherms

1.1.1 The Langmuir isotherm

Langmuir equation which is valid for monolayer adsorption onto the surface of finite number of identical sites is given by,

$$q_e = \frac{q_m b C_e}{1+bC_e} \tag{1}$$

where, q_e = maximum adsorption capacity of biosorbent (mg/g), b = Langmuir biosorption constant related to affinity between biosorbent & biosorbate (mg/L) and C_e = equilibrium concentra (mg/L). The linear form of Langmuir isotherm is shown in Equation (2) and (3). The linear plots of C_e/q_e & Ce give straight line [4].

$$\frac{1}{q_e} = \frac{1}{q_m b C_e} + \frac{1}{q_m} \tag{2}$$

$$\frac{C_e}{q_e} = \frac{1}{q_m b} + \frac{C_e}{q_m} \tag{3}$$

1.1.2 Freundlich adsorption isotherm

The Freundlich adsorption isotherm describes the equilibrium on the heterogeneous surfaces and does not assume monolayer capacity [5]. The linear form of Freundlich isotherm equation is used to evaluate the biosorption data and represented as,

$$\log q_e = \log K + (1/n)\log C_e \tag{5}$$

The equilibrium data for the biosorption is plotted as $\log q_e$ vs $\log C_e$ [6].

1.2 Batch adsorption Experiment

The adsorption of adsorbate varies in different parameters such as pH, contact time, amount of adsorbent used, concentration, temperature, etc. The amount of adsorbate in mg/g at equilibrium is determined by using following equation.

$$q_t = (C_i - C_e) \times \frac{V}{m_s} \ mg/g \tag{6}$$

where, W = weight of adsorbent (g), C_i = initial concentration of adsorbate (mg/L), C_e = equilibrium concentration

of adsorbate (mg/L) and V = volume of adsorbate.

The adsorbate removal percentage is defined as ratio of adsorbate ion concentration before and after adsorption to the initial concentration concentration of metal in aqueous solution [7]. Percentage removal is given by,

$$\text{Removal percentage (A \%)} = \frac{C_i - C_e}{C_i} \times 100\ \% \quad (7)$$

where, C_i = initial concentration of adsorbate (mg/L), C_e = equilibrium concentration of adsorbate (mg/L).

1.3 Adsorption kinetics

1.3.1 Pseudo First order Model

A pseudo first order kinetics model and integrating the linearized form of equation becomes

$$\text{Log } (q_e - q_t) = \log q_e - K_1 t/2.303 \quad (8)$$

The plot of the log $(q_e - q_t)$ vs. t gives a straight line from which K_1 and q_e can be determined [8].

1.3.2 Pseudo second order model

A kinetic model for sorption analysis in the pseudo second order model expression is,

$$dqt/d_t = K_2 (q_e - q_t)^2 \quad (9)$$

Integrating this eqution at boundary condition gives,

$$t/q_t = 1/K_2 q_e^2 + (1/q_e)t \quad (10)$$

$$v_0 = K_2 q_e^2 \quad (11)$$

$$\text{Or, } t/q_t = 1/v_0 + 1/q_e\ t \quad (12)$$

From the linear plot of t/qt vs. t gives value of q and K_2 [9].

2. Experiment

*2.1 Preparation of Adsorbent from Raw Bamboo Dus*t

Bamboo Dust of Bambusa vulgaric was collected from the Daldale at Nawalparasi, Nepal. This was cleaned with distilled water and dried in sunlight for 2-3 days.

2.2 Preparation of Chemically Modified Adsorbents

About 100 g of RBD was treated with 100 ml of conc. H2SO4. It was allowed to left for 24 hours at room temperature and wash with rain water several times until neutral pH was obtained. This chemically modified bamboo dust (MBD) was then dried in sun light for 4-5 days.

2.3 Adsorption Study

2.3.1 Effect of pH

1 mg/L of Fe (II) solution was taken in each 7 conical flasks of capacity 50 ml. Then pH of 1.0, 2.0, 3.0, 3.5, 4.0, 5.0, and 6.0. 20 ml this pH maintained metal solution was pipette out in volumetric flask which contain 25 mg of raw or modified bamboo dust. It was shaken in the mechanical shaker 24 hours in room temperature and filtered.

2.3.2 Effect of Initial Concentration

25mg of both RBD and MBD was taken in the conical flask and 20ml of metal solution of different concentration. Then the solution was shook using mechanical shaker for 3 hours at 120 rpm and leaved for 24 hours.

2.3.3 Kinetics Study of Adsorption of Fe (II)

100 ml conical flask with 25ml adsorbent and was shaken in a mechanical shaker for 5, 20, 40, 60, 90, 120, 180,

240 and 300 min respectively.

3. Results and Discussion

3.1 Effect of pH

The effect of pH on the sorption efficiencies of Fe (II) on the bioadsorbent are shown in Figure 1.

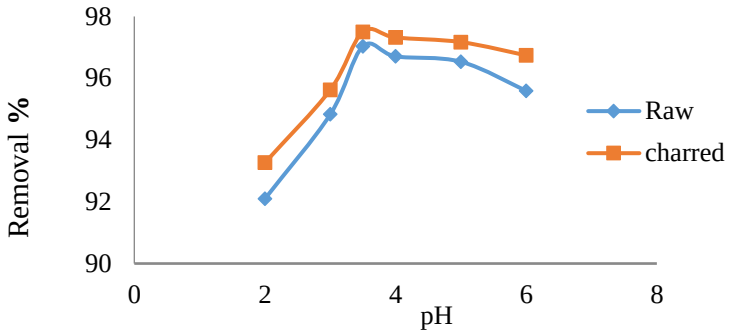


Figure 1. Effect of pH on the Adsorption of Fe (II) onto RBD and MBD.

From this study the maximum pH was found to be 3.5 for both RBD and MBD. Similarly, % adsorption by RBD was 97.0315 % and that of MBD was 97.5 %.

3.2 Effect of Initial Concentration

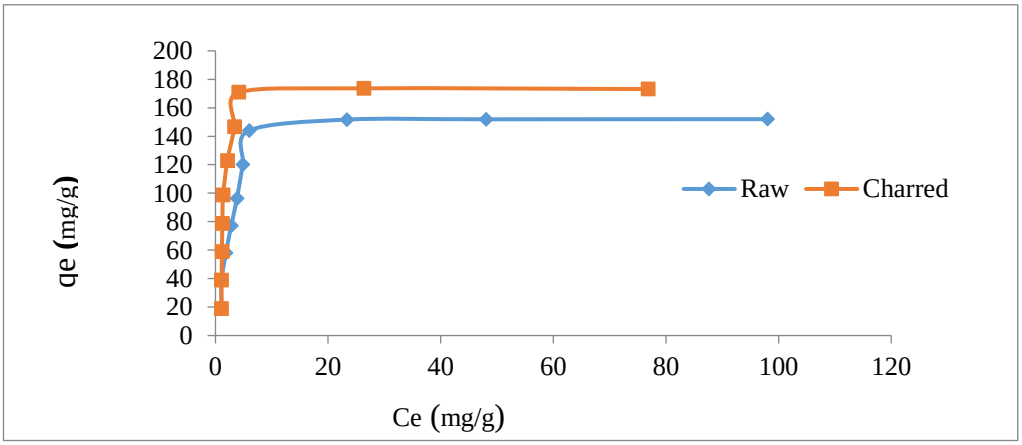


Figure 2. Effect of initial concentration of Fe (II) onto RBD and MBD.

The Figure 2 showed that the adsorption of Fe (II) increased with an increase in initial concentration of iron solution and attained equilibrium after which the adsorption becomes almost constant. The equilibrium concentration of Fe (II) for RBD was found to be 151.693 mg/g and for MBD was found to be 173.6453 mg/g at optimum pH 3.5.

3.3. Adsorption isotherm studies

Adsorption of Fe (II) onto RBD and MBD give linear relationship with Langmuir and Freundlich isotherm which are shown in Figure 3.

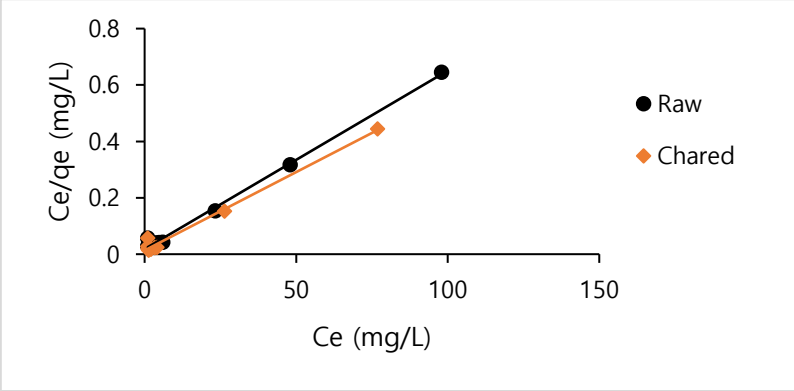


Figure 3. Langmuir adsorption isotherm for adsorption of Fe (II) onto RBD and MBD.

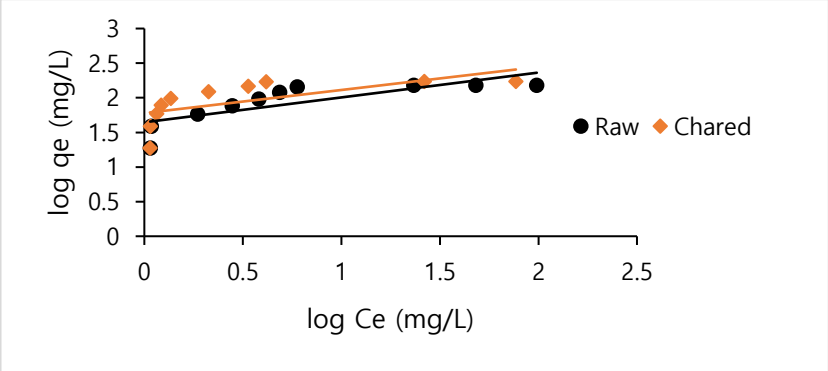


Figure 4 Freundlich adsorption isotherm for adsorption of Fe (II) onto RBD and MBD.

The R_L values of Langmuir isotherm model were found to be 0.684 and 0.939 for RBD and MBD respectively for Fe (II) adsorption. The value of qm was calculated for RBD, q_m = 158.730 mg/L and for MBD, q_m= 178.571 mg/L.The value of Langmuir constant 'b' was obtained from intercept (for RBD, b=0.346 and for MBD, b=0.421) in the graph shown in figure 3. In case of Freundlich isotherm the value of 1/n equals to 0.3593 and 0.3339 for RBD and MBD respectively for the adsorption of Fe (II). The 1/n value was obtained from the graph shown in the figure 4.

3.4. Effect of Contact Time (Kinetic Study)

It means the required equilibrium time for the maximum adsorption of Fe (II) onto RBD and MBD was 90 min and 120 min respectively and equilibrium level was reached (Figure 5).

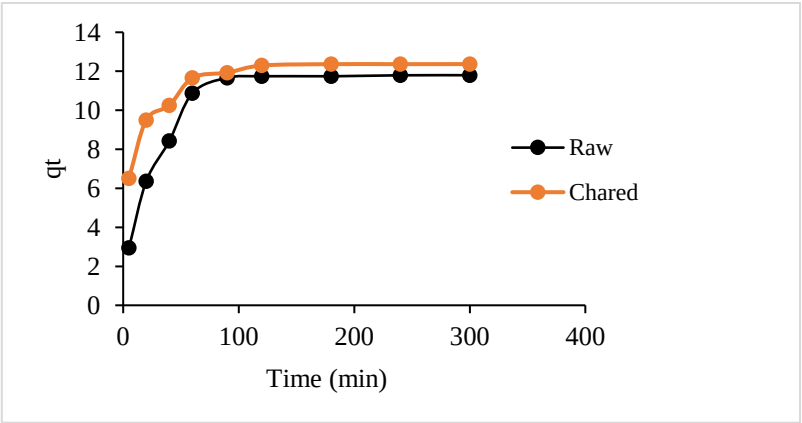


Figure 5. Effect of contact time on the adsorption of Fe (II) onto RBD and MBD.

3.5 Batch Kinetic Studies

The figure 6 (a) and (7) are shown for the analysis of pseudo first and second order kinetic model for the RSB respectively.

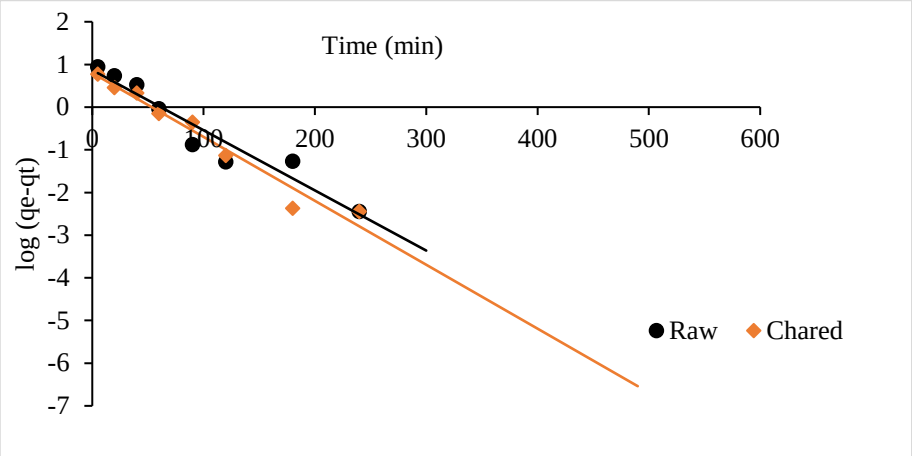


Figure 6. Pseudo first order of absorption of Fe (II) by RBD and MBD.

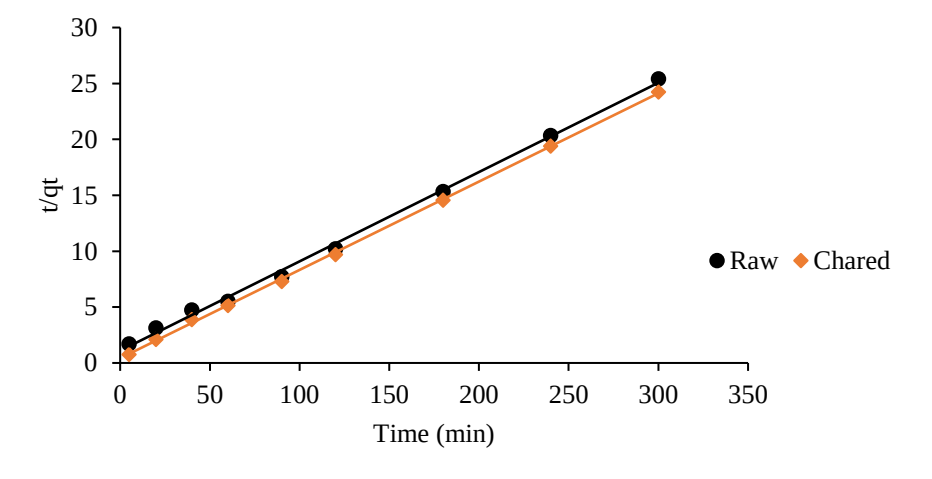


Figure 7. Pseudo second order of absorption of Fe (II) by RBD and MBD.

In figure 6, the experimental data for pseudo first order kinetics on adsorption of Fe (II) was studied in RBD and MBD. The plot of log (q_e-q_t) vs. time showed a downward straight line. In figure 7, the experimental data for pseudo second order kinetics on adsorption of Fe (II) was studied in RBD and MBD. The plot of t/qt vs. time showed a straight line with correlation coefficient 0.9976 and 0.9996 respectively.

3.6. Characterization of adsorbent

3.6.1 Fourier Transform Infrared (FTIR) Spectroscopy

The stronger bonds and light atoms will vibrate at a high stretching frequency (wave number) [10]. The FTIR spectra of bioadsorbent before and after acid treatments were measured in the range of 4000 – 600 cm^{-1} as in figure 8.

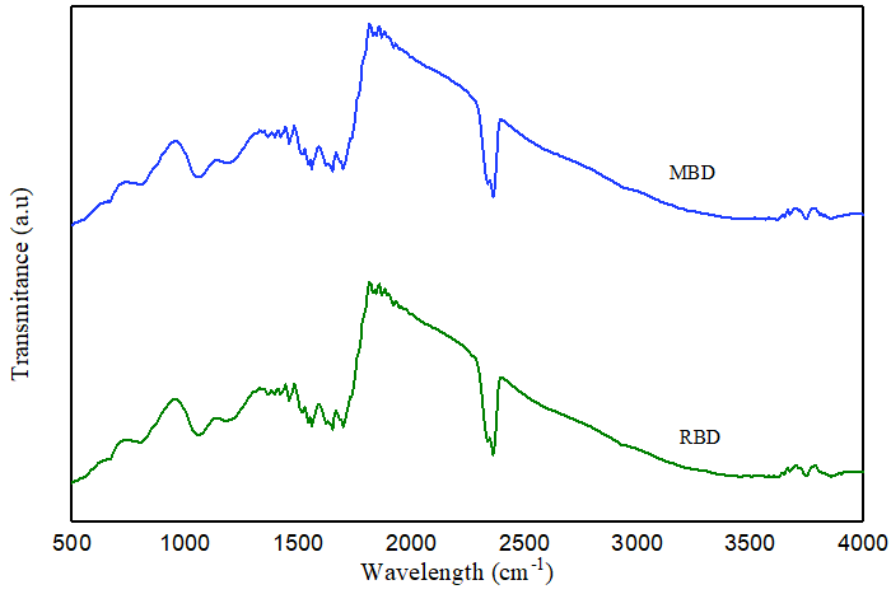


Figure 8. FTIR spectra of RBD and MBD.

3.6.2 X-ray diffraction (XRD)

In the figure 9, sharp diffraction peaks are obvious in RBD while in the MBD diffraction peak slightly less. It indicated that RBD adsorbent is crystalline in nature whereas MBD showed some amorphous type of nature.

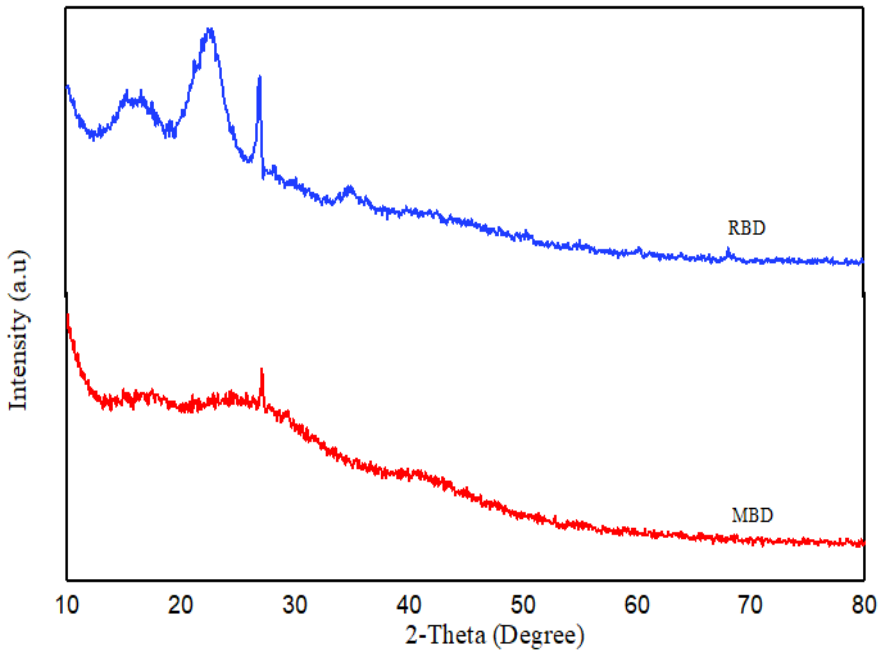


Figure 9. XRD spectra of RBD and MBD.

3.7 Ground water analaysis of different location in Kathmandu valley

The initial and final concentrations, removal efficiency and the maximum adsorption capacity (Q_{max}) of Fe (II) onto ground water samples in Samakhusi, Nepaltar and Mulpani are shown in Table 1.

Table 1. The removal of Fe (II) from ground water using raw and charred bamboo dust.

S.N	Location of water sample	Adsorbent	Initial Concentration (C_i) mg/L	Final Concentration (C_e) mg/L	% Removal	Q_{max} mg/L
1	Samakhusi	RBD	2.8	0.173797	93.79	2.626
		MBD	2.8	0.0606	97.83	2.739
2	Nepaltar	RBD	5	0.9091	81.81	4.09
		MBD	5	0.72549	85.49	4.27
3	Mulpani	RBD	5	0.19697	96.06	4.803
		MBD	5	0.109626	97.8	4.89

4. Conclusion

The optimum pH for iron using both raw and modified bamboo dust was found to be 3.5 and the % adsorption at optimum pH was 97.0315% and 97.5% for RBD and MBD respectively. The equilibrium time for adsorption of Fe (II) onto RBD and MBD were found to be 90 min and 120 min respectively.The maximum adsorption capacity of RBD and MBD were found to be 151.6934mg/g and 173.6453mg/g respectively. The adsorption isotherm study reveal that the Langmuir adsorption isotherm can best explain the adsorption of the RBD and MBD for Fe (II). The kinetic data was found that the obtained data were best fitted by pseudo second order kinetic model. Functional group present in bioadsorbent was characterized by FTIR analysis. The RBD was characterized crystalline and MBD was amorphous type nature through XRD. The raw and charred bamboo dust used to calculate the removal efficiency and the maximum adsorption capacity (Qmax) of Fe (II) onto ground water samples in Samakhusi, Nepaltar and Mulpani are 93.79%, 97.83%, 81.81%, 85.49%, 96.06%, 97.80% and Qmax are 2.626 mg/L, 2.739 mg/L, 4.09 mg/L, 4.27 mg/L and 4.8030 mg/L and 4.89 mg/L for RBD and MBD respectively.

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