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# Removal of iron from artificial groundwater by adsorption on charcoal

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***Abstract*— one of the causes of water pollution is the presence of heavy metals in water. In the presence study we use the charcoal as adsorbent to removal iron from an artificial groundwater. Adsorption studies were conducted in the batch mode at pH = 7, ferrous iron concentration (10mg/l) and an ambient temperature. The maximum adsorption was found to 9, 95 mg.g.**

**The Langmuir and Freundlich isotherm models were applied for this study. Adsorption kinetics studies revealed that pseudo-second order provided the best fit to experimental data compared with pseudo-first model .**

***Keywords*— Adsorption; Iron; Artificial groundwater; Adsorption Isotherm; Kinetic**

## I. Introduction

Iron is the fourth element of the earth's crust, the second most abundant metal in the earth [1], is mainly present in groundwater but also in the surface waters.

The presence of iron in the natural sources is due to the decomposition of rocks, acid mine drainage water [2], scrubbing of controlled discharges [3], effluents of the sewers [4] as well as industrial sectors.

The presence of this element in excess causes degradation of the water quality, the corrosion and clogging of piping and reservoirs of waters. In addition, the precipitation of iron promotes the growth of bacteria [5], [6].

Iron removal from groundwater is therefore, a major concern for most scientific researchers.

There are various methods for removing iron from water including ion exchange [7], oxidation by oxidizing agents [8], chemical precipitation [9], supercritical fluid extraction [10] and accumulation by aquatic macrophyte [11].

However, most of these technologies are either extremely expensive or too ineffective to reduce metal levels from water.

In this context, we have chosen the iron removal method of artificial water by adsorption on charcoal. Parameters such as pH, stirring speed, adsorbent dosage and contact time, were investigated at room temperature. While the adsorption isotherm and kinetic data were used to analyze adsorption process.

## II. Materials and Methods

### A. Adsorbent

Charcoal is a natural and inexpensive material result from the incomplete combustion of wood.

It is characterized by its highly porous structure gives it adsorbent properties: it has the ability to set and neutralize several substances, particularly toxic molecules, bacteria and fungi. The powder charcoal used as adsorbent in this study was produced from pine wood.

The main characteristics of the charcoal used in our tests are presented in Table I.

TABLE I. MAIN CHARACTERISTICS OF CHARCOAL USED IN ADSORPTION PROCESS

| Parameter | Value |
|---|---|
| pH | 7,93 |
| pHpzc | 10 |
| Rate of Ash (%) | 0,9 |
| Humidity (%) | 9 |

### B. Artificial ground water

The artificial ground water was prepared as per the work of Knocke (1990) [12], distilled water mixed with the following salts: iron sulfate ($FeSO_4 7H_2O$), sodium bicarbonate ($NaHCO_3$), calcium chloride ($CaCl_2$) and sodium sulfate ($Na_2SO_4$).

### C. Adsorption technique

The adsorption process has many advantages such as: low cost of adsorbent, easy application, use of natural, domestic and industrial waste as adsorbents.

The experiments were conducted in the system "Batch": we added to 100 ml of water analyzed a mass of charcoal and we stirred for 20 minutes at a speed of 50 turns / min.

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The suspension was filtered use whatman filter paper. Atomic adsorption spectro-photometer was used to analyze the concentration of iron.

### D. *Adsorption isotherm*

Adsorption isotherm is important model in the description of adsorption behavior. The adsorption isotherm can indicate the distribution of molecules between the solid phase and liquid phase.

In our study, Langmuir and Freundlich isotherm were employed to investigate the adsorption behavior

The Langmuir isotherm equation is given as (1): [13]

$$qe = q_m k_a c_e / (1+ k_a C_e) \quad (1)$$

Where:
$q_e$: The amount of iron adsorbed per unit mass at equilibrium (mg/g)
$q_m$: The maximum possible amount of iron that can be adsorbed par unit mass of adsorbent (mg/g)
$C_e$ : Concentration of adsorbate in the solution at equilibrium (mg/l)
$K_a$: equilibrium constant

The linearised form of equation (1) is:

$$C_e / q_e = 1/ (K_a q_m) + C_e / q_m \quad (2)$$

The essential characteristics of Langmuir isotherm can be expressed in the terms of dimension less separation factor $R_L$, which is defined as:

$$R_L = 1/ (1+ K_a C_0) \quad (3)$$

Where:
$R_L$: Dimension less separation factor
$K_a$: Langmuir constant
$C_0$ : The initial concentration of iron (mg/l)

According to the value of $R_L$, the isotherm shape can be interpreted as presented in table II

TABLE II. LANGMUIR ISOTHERM CONSTANT PARAMETER RL

| $R_L$ Value | Type isotherm |
|---|---|
| $R_L > 1$ | Unfavorable |
| $R_L = 1$ | Linear |
| $R_L = 0$ | Irreversible |
| $0 < R_L < 1$ | Favorable |

The Freundlich isotherm equation is given as [14]

$$q_e = K_F C_e 1/n \quad (4)$$

The linear form of the equation (4) is:

$$\text{Ln } q_e = \text{Ln } K_F + 1/n \log C_e \quad (5)$$

Where:
$q_e$: The amount of adsorbate adsorbed at equilibrium (mg/g)
$K_F$ and n: Freundlich constants
$C_e$: The equilibrium concentration of adsorbate in the solution (mg/l)

## III. RESULTS AND DISCUSSION

### A. *Study of laser granulometry*

The results of the characterization of material used shows that it has a fairly fine texture with an average of 60%.

From the table (Tab.III) above, uniformity coefficient is greater than 1.8, the tested adsorbent is heterogeneous.

TABLE III. ADSORBENT PARTICLES BY LASER GRANULOMETRY

| Size particle (µm) | Percentiles |
|---|---|
| $d_{10}$ | 4 |
| $d_{50}$ | 60 |
| $d_{90}$ | 65 |
| Uniformity coefficient ($d_{90}/d_{10}$) | 16,25 |

The study of laser granulometry is an indirect measurement technique commonly used to determine the size distribution of the granular material indicated if our adsorbent is homogenous or not.

### B. *Effect of contact time*

The effect of contact time on the amount of $Fe^{2+}$ adsorbed by charcoal was studied using an initial concentration (10mg/l)

The results show that adsorption process is clearly time dependent (Fig. 1) , as contact time increases, the adsorption capacity of iron in the solution increased rapidly at the beginning and later slows down until it remained constant at about 20min.

The initial rapid phase of iron adsorption may be due to the large number of sites available at the initial period of the adsorption. [15]

After 20 minutes, extending the contact time has no effect on the residual concentration of iron in the solution; this explains the saturation of adsorbent.

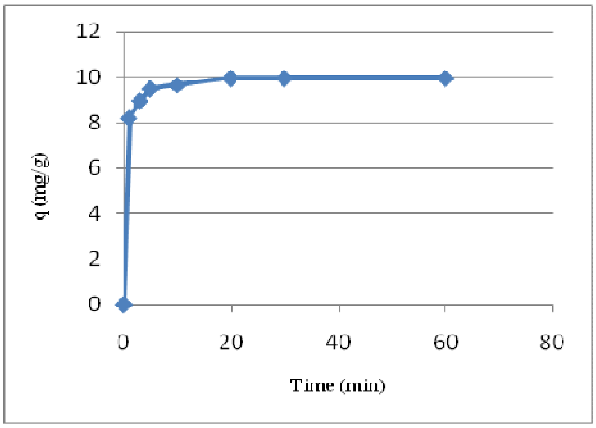


Fig .1 Effect of contact time on the adsorption of iron by charcoal (pH = 7; agitation speed = 50 turns/min; Mass = 0,1g)

### C. *Effect of stirring speed*

Stirring speed was varied from 50 turns/ min to 300 turns /min, to study the effect of this parameter on the adsorption of iron.

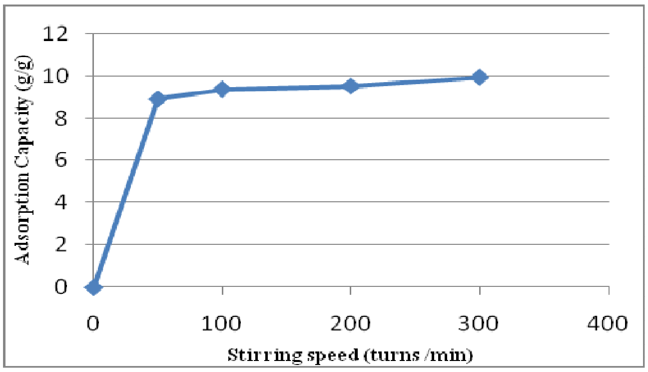


Fig.2. Effect of stirring speed on the iron adsorption
(pH = 7; Mass = 0, 1 g)

Increasing the stirring speed (Fig.2) promotes the contact of adsorbent/adsorbate and improves oxygenation of the solution, consequently improving iron removal rates. In addition to that increase in stirring rate enhanced the metal ion diffusion to the surface of the adsorbent.

*D. Effect of pH on iron adsorption onto charcoal*

The pH is an important parameter that controlled the adsorption process. The effect of pH on the iron removal was examined by using varied pH from 2 to 9.

Iron adsorption onto charcoal was measured by conducting batch experiments at initial iron concentration of 10 mg/l at different pH values, to assess the effect of pH on iron adsorption. The effect of pH on the adsorption of iron is presented in the Figure 3, the adsorption capacity increased with increasing pH values.

At pH = 9, maximum removal was obtained for the metal ion, with adsorption capacity = 9, 8 mg/g.

The increase of the amount of iron removal maybe explained by the fact that at higher pH, the adsorbent surface is deprotonated and negatively, metal cations occurred. [16]

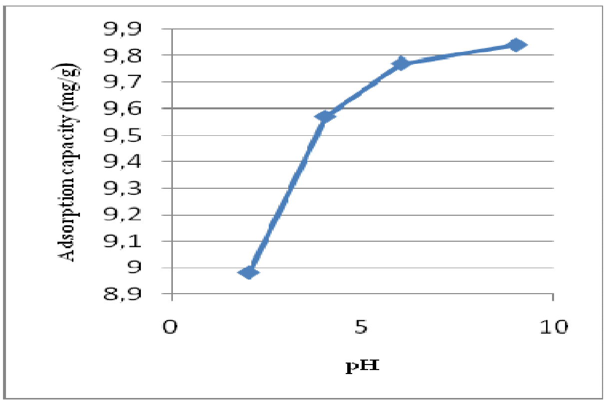


Fig.3. Effect of pH on adsorption iron by charcoal
(Mass = 0, 1; agitation speed = 50 turns/min)

*E. Effect of adsorbent dosage*

The adsorbent dosage is an important parameter in adsorption studies because it determines the capacity of adsorbent for a given initial concentration of iron solution

From the figure 4, it can be deduced that the adsorption capacity increase with decrease in adsorbent dose. At the 0, 1 mg of adsorbent, the adsorption capacity was 9, 55 mg/g witch decreased to 0, 9 9 mg/g at 1g of charcoal.

Removal of iron increased rapidly with increase in adsorbent dose due to greater availability of exchangeable sites or surface area

The increase in the amount of adsorption leads to an increase of the surface adsorption zone which provides a greater number of active sites for adsorption [17].

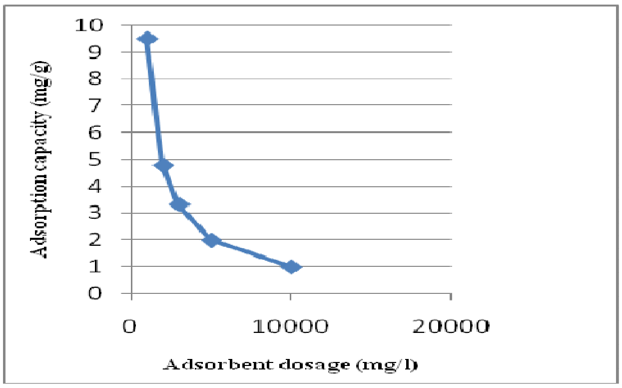


Fig .4. Effect of adsorbent dosage on the adsorption of iron by charcoal (pH = 7; agitation speed = 50 turns/min)

*F. Adsorption Isotherme*

The study of the adsorption isotherm is fundamental to determining the capacity and the nature of adsorption. They indicate how the metal ions are partitioned between the adsorbent and liquid phases at equilibrium as a function of increasing metal concentration.

The Langmuir isotherm model (fig.6) and table 5 shows the high correlation coefficient ($R^2$=0, 9) indicated the applicability of Langmuir model. As well as the determination of dimension less separation factor $R_L$ from the equation (3) for the Langmuir model that 0 <$R_L$< 1, the model of Langmuir is favorable.

Freundlich isotherm model determined the values of $K_F$ and n as 1, 3 and 2 respectively (Fig 5). The constant 2<n<10 observed from Freundlich isotherm indicated that the adsorption is unfavorable.

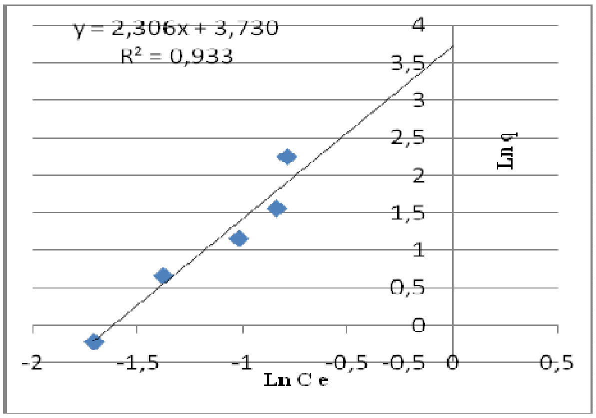


Fig.5. Freundlich isotherm

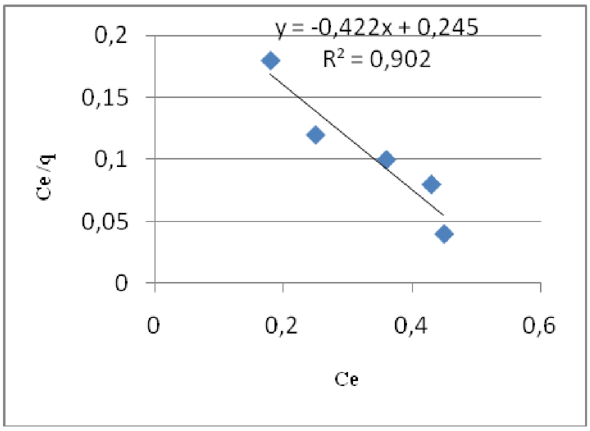


Fig.6. Langmuir Isotherm

Table IV and V, shows the parameters of the isotherm models for the iron adsorption by charcoal.

TABLE IV. PARAMETERS OF FREUNDLICH MODEL

| Parameters | $K_F$ | n | $R^2$ |
|---|---|---|---|
| Values | 1,3 | 2 | 0,93 |

TABLE V. PARAMETERS OF LANGMUIR MODEL

| Parameters | $K_a$ | $q_m$ | $R^2$ | $R_L$ |
|---|---|---|---|---|
| Values | 1,25 | 2,5 | 0,9 | 0,07 |

### *G. Adsorption kinetics*

Adsorption kinetics studies revealed that pseudo-second order provided the best fit to experimental data compared with pseudo-first model, the removal of iron by charcoal does not obeys the first order model (Fig 7 and 8).

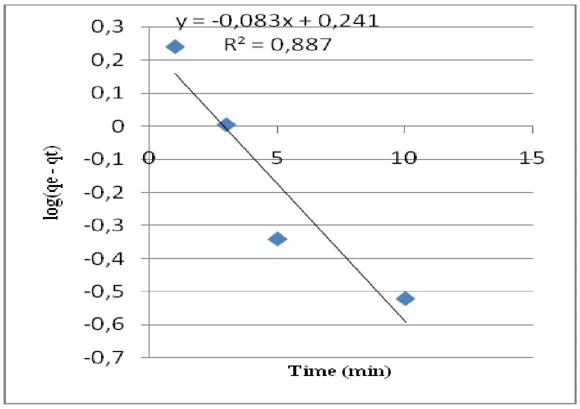


Fig.7. Pseudo first order model for adsorption of iron by charcoal

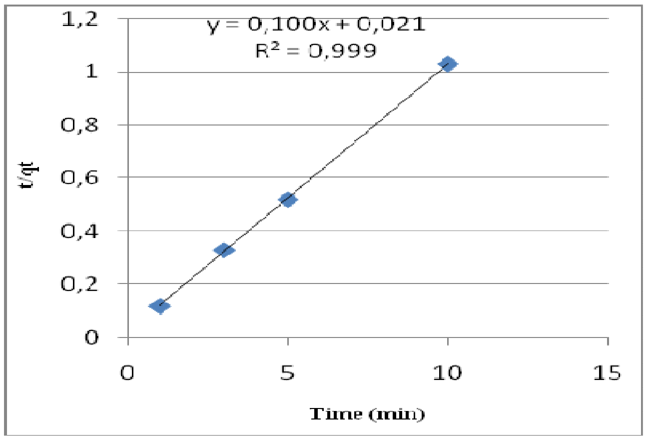


Fig.8. Pseudo Second order model for adsorption of iron by charcoal

The table VI summarizes the parameters of pseudo second order model for adsorption of iron by charcoal.

TABLE VI. PARAMETERS OF PSEUDO SECOND ORDER MODEL

| Parameter | $K_{II}$ | q2 |
|---|---|---|
| Value | 0,3 | 0,1 |

## IV. CONCLUSION

From the obtained results, it is evident that charcoal is a good adsorbent for removal of iron. The amount of iron removal increased with increasing adsorbent dosage, pH and stirring speed.

The isotherm study indicates that the adsorption data can be adequately modeled by Langmuir.

The removal of iron by charcoal obeys the second order model.

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