

## Sorptive Removal of Phosphate From Wastewater Using Activated Red Mud

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**Abstract:** Red mud (RM), is a kind of industrial waste produced in the process of alumina production. Because of the increasing demand for alumina during economic development, more and more RM is being produced. Hence, the disposal and management of RM remains a challenging issue to the alumina industry. This study examined the effect of acid activated red mud on phosphate removal. Thus, its use in phosphate removal can be also considered as a way of disposal. The removal capacity of RM for phosphate ions was studied as a function of solution pH, contact time, adsorbent dosage and adsorbate concentration. The maximum adsorption of the phosphate ions on the RM was observed at the pH values between 8 and 12. The equilibrium time was attained after 60 min. and the maximum removal percentage was achieved at an adsorbent loading weight of 0.5 gm/100ml. The equilibrium adsorption capacity of adsorbent used for phosphate was measured and extrapolated using linear Freundlich, Langmuir isotherms and the experimental data were found to fit the Freundlich isotherm model. The morphological characteristics of the adsorbent were evaluated by using a scanning electron microscope. SEM image for RM after adsorption of phosphate shows that phosphate ions appeared to cover the surface of RM. The optimized method was applied for the removal of phosphate from Zenin wastewater treatment plant (ZWWTP) and proctor and gamble (P&G) company for household products. The removal efficiency achieved was 94 %,74% in the ZWWTP sample, and 97% in the P&G sample.

**Key words:** Adsorption; Batch; RM; phosphate; wastewater; Isotherm.

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### INTRODUCTION

Red mud (RM), is a kind of industrial waste produced in the process of alumina production, not only takes up a large amount of farmland but also causes serious environmental pollution due to its large quantities and high alkalinity (Qinyan Yue, 2010; Zhou, H., 2008). Because of the increasing demand for alumina during economic development, more and more RM is being produced. It is estimated that about 90 million tonnes of RM are produced annually on the earth (Kumar, S., 2006), hence, the disposal and management of RM remains a challenging issue to the alumina industry. At present, RM produced from alumina plants is mostly treated by land filling and ocean disposal (Wang, S., 2008), only a small amount was utilized for land composting (Lombi, E., 2002), cement (Tsakiridis, P.E., 2004), building material additive (Yang, H., 2009) and metal recovery (Cengeloglu, Y., 2003) in the past decades.

As RM is rich in Fe, Al and Ti oxides, which are active in the adsorption of anion (Liu, C., 2007), researchers, have shown much interest in making adsorbents from RM. It has been applied to removal of pollutants, such as arsenate and fluoride (Tor, A., 2009), heavy metals (like Pb, Cd and Zn) (Santona, L., 2006), and dyes (Tor, A., 2006), from aqueous solution. In addition, the use of activated RM as an adsorbent for phosphate removal has also been proved feasible.

Phosphate in wastewaters is an essential nutrient for the growth of photosynthetic algae and other biological organisms in water bodies. But excess phosphate concentration in the effluent discharge can lead to eutrophication of the receiving confined water bodies (Ying Zhao, 2003; Rittmann, B.E., P.L. McCarty, 2001). Eutrophication can in turn disturb the balance of organisms present in the water and affect water quality, mainly through oxygen depletion as the algae decay. A reduced oxygen level harmfully affects fish and other aquatic life, microorganism and insects' growth as well as it causes natural resorts degradation. Consequently, the amount of phosphate in domestic and industrial discharges must be controlled using wastewater treatment technology.

In wastewater treatment technology, many methods have been developed for phosphate removal (H.S. Altundogan, F. Tumen, 2002), which includes physical (Altundogan, H.S., F. Tumen, 2003), chemical (Mulkerrins, D., 2004) and biological methods (Li, Y., 2006). Physical methods have proved to be either too expensive, as in the case of electrodialysis and reverse osmosis (Altundogan, H.S., F. Tumen, 2003), or inefficient, removing only 10% of the total phosphorus (Mulkerrins, D., 2004). Enhanced biological treatment can remove up to 97% of the total phosphorus and it is low-cost. But the variability in chemical composition and

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temperature of wastewater would make the implementation of this process not feasible for wastewater treatment (Karageorgiou, K., 2007). Chemical removal techniques are the most effective and well-established methods up to date. Lime, aluminum sulfate, and ferric chloride are common precipitants used for phosphate removal (Altundogan, H.S. F. Tumen, 2002). However, the cost associated with the use of metal salts and sludge production may hinder the widespread application (Karageorgiou, K., 2007). Therefore, alternative techniques for phosphate removal are being developed.

Recently, attention has been focused on phosphate adsorbents because of the most economical and applicable of adsorption. Successful results have been obtained using aluminum oxide (Galarnaeau, E., R. Gehr, 1997; Tang, W.P., 1997; Johnson, B.B., 2002), iron oxide (Hongshao, Z., R. Stanforth, 2001; Lin, S.H., 2004; Juang, R.S., J.Y. Chung, 2004; Huang, X., 2004), fly ash (Agyei, N.M., 2000), slag (Oguz, E., 2005; Yamada, H., 1986), red mud (Akay, G., 1998; Koumanova, B., 1997), silicates (Shin, E.W., 2004; Kasama, T., 2004), activated carbon (Bhargava, D.S., S.B. Sheldarkar, 1993), and gas concrete (Oguz, E., 2003).

Although the RM was found to be a good phosphate removal medium for wastewater the direct use of RM without activation as adsorbent for water treatment is not appropriate due to the high dosage (LIU Chang-jun, 2007). In this study, phosphate was removed using activated red mud. One of the main advantages of phosphate removal by using red mud over the other chemical treatment is the abundance of red mud and its easy availability.

The aim of this study is to assess the potential of RM to adsorb phosphate ions from wastewater. The effect of the solution pH, contact time, initial phosphate ions concentrations and adsorbent doses on the removal of phosphate ions was studied. The surface characteristics of RM were studied. The adsorption isotherm and probable mechanism are explained.

## MATERIALS AND METHODS

### Adsorbent:

The red mud used in this study was taken from lececo company. The red mud samples were dried, ground and sieved to pass through a sieve pore size 90  $\mu\text{m}$ . The effect of hydrochloric acid concentration on activation was tested by acidified raw red mud with a specified amount of known concentration (1 mol/L HCl) The samples was loaded into the glass reactor and the ratio of HCl to red mud was 20 ml/g. At the end of the experiment, the residue was washed with distilled water and dried at 100°C overnight.

The chemical compositions of the raw and activated samples are summarized in table (1).

This table showed that red mud is primarily a mixture of Ca, Si, Fe and Al oxides and the CaO content is the highest.

**Table 1:** Chemical composition of the raw and activated red mud as oxides.

Element	Quantitative composition (%) of raw red mud		Quantitative composition (%) of activated red mud
SiO <sub>2</sub>	19.14		17.96
Fe <sub>2</sub> O <sub>3</sub>	12.76		12.91
Al <sub>2</sub> O <sub>3</sub>	6.93		9.85
CaO	46.02		32.33
MgO	1.15		1.73
TiO <sub>2</sub>	3.43		4.22
K <sub>2</sub> O	1.20		0.56
Na <sub>2</sub> O	2.37		1.73
L.O.L*	5.73		1.98
Ph	11.70		7.63

Lol =loss of ignition

- The activated red mud before and after adsorption were identified by Xray diffraction (XRD). using Philips X ray vertical diffract meter (type PW 1373, Holland). The analysis was run using Ni-filter and Cu-K $\alpha$  radiation ( $\lambda = 1.5405 \text{ \AA}$ ) at 40 KV and 40mA.
- SEM was carried out to obtain morphology information of red mud before and after adsorption, using Inspects Scanning Electron Microscope USA, accelerated voltage = 30KV, beam current = 0.11nA.

### Preparation of phosphate Solutions And Analytical Methods:

Phosphate solution has been prepared and used in the laboratory. Simulated stock solution of phosphate ions (1000 mg/l) was prepared by dissolving required quantity of annular grade of respective salt in the distilled water. The salt used is: Anhydrous Potassium dihydrogen phosphate KH<sub>2</sub>PO<sub>4</sub> (0.2195 g). The stock solution was further diluted with distilled water to desired concentrations of 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20 and 25 mg/l were prepared.

Phosphate was determined by using the molybdate blue method according to standard methods for the examination of water and wastewater (Standard methods for the examination of water and wastewater, 2005).

Ammonium molybdate react with phosphate to give molybdo phosphoric acid which reduced by stannous chloride to give molybdenum blue measured at 690 nm.

All the chemicals and reagents used in this study were of analytical grade. All glassware and sample bottles were soaked in diluted HCl solution for 12 h, washed and then rinsed four times with deionised water. Deionised water was used for the preparation of solutions. All experiments were conducted in duplicate and the average values were used for data analysis.

In order to widen the applicability of the proposed method, it was tested for the removal of phosphate from:-

1-Municipal wastewater.

2-Industrial wastewater.

\* Municipal wastewater

Municipal wastewater sample were collected from primary and secondary treatment plant at Zenin wastewater treatment plant ZWWTP, El-Giza Governorate, Egypt Table 2 showed Physico-chemical analysis of municipal wastewater sample.

The treatment process of ZWWTP can be summarized in the following step:

- Screening stage, which consist of four manual screens ,four mechanical screens and seven grift removal to prevent big solids like wood, plastics, papers and sand from the row wastewater.
- Primary treatment stage, which consists of four primary aerator tanks to hold the wastewater to about 30 min, to prevent harmful gases and to activate the aerobic bacteria, and four primary sedimentation tanks each of 36 meter diameter. In this stage the treatment TSS reduced to 20% of the influent content and the BOD reduced to about 40% of the influent content.
- Seacondary treatment stage,which consist of 30 final aeration tank, in which the effluent of the primary sedimentation tanks mixed with return activated sludge for four hours, and four final sedimentation tanks.
- Final dosage stage ,which consist of a chlorinating system of treated wastewater before its final disposal in Nahia drain and a pumping system to the excess sludge to Abu Rawash treatment plant.

**Table 2:** Physico-chemical analysis of municipal wastewater sample.

Parameter	Influent	Effluent
PH	8	8.2
COD mg/l	210	148
BOD mg/l	124	98
Ammonia mg/l	10.5	5.0
Nitrite mg/l	20	15
Nitrate mg/l	0.5	0.5
Total Phosphate mg/l	10	1.7
CL mg/l	141	110
SO4 mg/l	88	75

\*\*Industrial wastewater

Industrial wastewater sample were collected from effluent of proctor and gamble P&G company for household products, El-Giza Governorate, Egypt Table 3 showed Physico-chemical analysis of industrial wastewater sample.

**Table 3:** Physico-chemical analysis of industrial wastewater sample.

Parameters	Result
PH	10.25
COD mg/l	560
BOD mg/l	190
Ammonia mg/l	14.2
Nitrite mg/l	24
Nitrate mg/l	32
Total Phosphate mg/l	40

#### **Batch Adsorption Studies:**

The adsorption of phosphate onto red mud was studied by batch technique. A known weight of adsorbent (e.g.0.1–3 g adsorbent) was equilibrated with 100mL of the phosphate ions solution of known concentration (0.1–25 mg/l) in 250mL of Erlenmeyer flasks and shacked at (60-200 rpm) at a room temperature of  $27 \pm 2$  °C for a known period (5–120 min) of time. The effect of pH of the initial solution with an initial phosphate concentration of 25 mg/l on the uptake of phosphate ions was analyzed over a pH range from 3 to 12. pH of the solutions was adjusted with 0.1M NaOH or 0.1M HCL. After equilibration, the suspension of the adsorbent was separated from solution by filtration using Whatman No. 1 filter paper. Blank experiments were conducted to ensure that no adsorption was taking place on the walls of the flasks used. The concentration of phosphate remaining in solution was measured by spectrophotometer using molybdate blue method. All experiments were

conducted in triplicate and mean values were used. The percentage of phosphate removal was calculated using the following equation:

$$\text{Sorption (\%)} = [C_o - C_e/C_o] \times 100 \quad (1)$$

Where  $C_o$  is the initial concentration (mg/l) of phosphate ions in solution and  $C_e$  is the equilibrium concentration (mg/l) of phosphate ions in solution. The amount of phosphate sorbed by weight of red mud was calculated using the following equation:

$$q_e \text{ (mg/g)} = [(C_o - C_e)V]/m \quad (2)$$

Where  $q_e$  is the equilibrium adsorption capacity (mg/g),  $V$  is the volume of aqueous solution (L) and  $m$  is the dry weight of the adsorbent (g).

#### **Adsorption Isotherm Models:**

Adsorption isotherms are important to describe the adsorption mechanism of a solute on adsorbent surface thus aid in optimizing the design of a specific adsorption process. In the present study, the equilibrium data obtained for phosphate removal using red mud was tested with two isotherm models available in the literature to reveal the best fitting isotherm. Adopted isotherm models were Langmuir and Freundlich. Isotherm coefficients and correlation coefficients ( $R^2$ ) were computed from linearized equations of these isotherms in Microsoft Excel.

#### **Langmuir Isotherm:**

Langmuir isotherm has been extensively used for the adsorption of heavy metals, dyes, organic pollutants, etc. [38, 39]. It is applicable for monomolecular layer adsorption. This isotherm is described as a homogeneous one assuming that all the adsorption sites have equal adsorbate affinity and that the adsorption at one site does not affect the adsorption at an adjacent site (Langmuir, 1918). The Langmuir isotherm is used to obtain a maximum adsorption capacity produced from the complete monolayer coverage of adsorbent surface. The linear isotherm equation is represented as

$$C_e/q_e = 1/bq_{max} + (1/q_{max}) C_e \quad (3)$$

Thus, a plot of  $C_e/q_e$  versus  $C_e$  should yield a straight line if Langmuir isotherm is obeyed by the adsorption equilibrium.  $q_{max}$  and  $b$  values will be calculated from the slope and intercept of the graphed line, respectively where  $b$  is the adsorption equilibrium constant in L/mg related to the apparent energy of adsorption,  $q_{max}$  is the maximum quantity of adsorbate required to form a single monolayer on unit mass of adsorbent in mg/g. A further analysis of the Langmuir equation can be made using a dimensionless equilibrium parameter, the separation factor  $R_L$  as given by Eq. (4):

$$R_L = 1/1 + b C_o \quad (4)$$

For a favorable adsorption, the value of  $R_L$  should lie between 0 and 1;  $R_L > 1$  represents an unfavorable adsorption,  $R_L = 1$  represents linear adsorption, whereas  $R_L = 0$  translates into irreversible adsorption (Gupta, S., B.V. Babu, 2009).

#### **Freundlich Isotherm:**

Freundlich expression is an exponential equation and therefore assumes that, the concentration of adsorbate on the adsorbent surface increases with the adsorbate concentration. Theoretically, using this expression, an infinite amount of adsorption can occur (Freundlich, H.M.F., 1906). The equation is widely applied in heterogeneous surfaces with sites that have different energies of adsorption and are not equally available. The Freundlich isotherm is more widely used but provides no information on the monolayer adsorption capacity in contrast to the Langmuir model and can be written in linearized form as:

$$\log(q_e) = \log K_f + 1/n \log(C_e) \quad (5)$$

Where:  $K_f$  = experimental constant (Freundlich constant indicative of the adsorption capacity of the adsorbent (l/mg) and  $n$  = experimental constant indicative of the adsorption intensity of the adsorbent. By plotting  $\log q_e$  versus  $\log C_e$ , values of  $K_f$  and  $n$  can be determined from the slope and intercept of the plot. The magnitude of the exponent  $1/n$  gives an indication of the favorability of adsorption. Values of  $n$ , where  $n > 1$  represent favorable adsorption condition. In general, as the  $K_f$  value increases, the adsorption capacity of the adsorbent, for the given adsorbate, increases,  $n$  values between 1 and 10 show beneficial adsorption if  $n$  is close

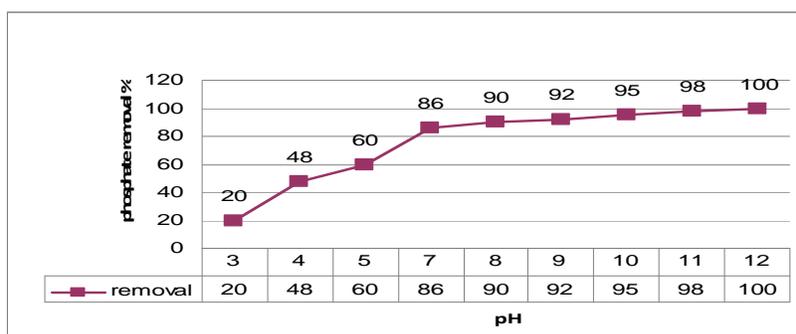
to 1, the surface heterogeneity could be assumed to be less significant and as  $n$  approaches 10 the impact of surface heterogeneity becomes more significant (Davila-Jimenez, M.M., 2005).

## RESULTS AND DISCUSSION

### Influence of Process Variables:

#### Effect of pH:

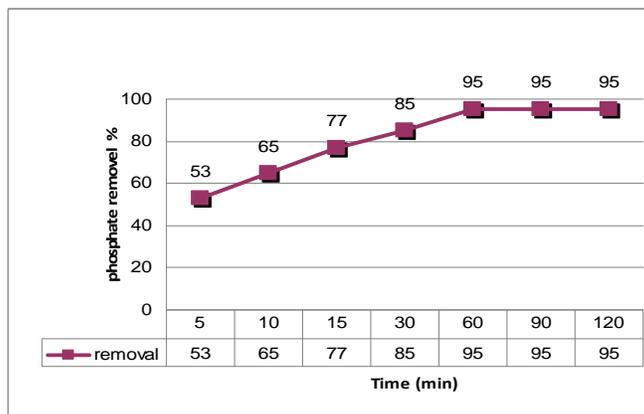
The pH value of the aqueous solution is an important controlling parameter in the adsorption process. These pH values affect the surface charge of adsorbent, the degree of ionization and speciation of adsorbate during adsorption. Thus the effect of pH ( $H^+$  ion concentration) in the solutions on the adsorption percentage of phosphate ions was studied at different pH ranging from 3 to 12. Results are shown in Fig. 1. It was observed that the sorption was 20% at an initial pH value of 3. Phosphate adsorption by red mud increased with the increase in pH and reached a maximum in the pH range of 8–12. It is known that both high pH and high calcium concentration are crucial for calcium precipitation and reaction mechanism with calcium ingredients was through deposition as phosphate salt rather than trapped in calcium hydroxides floc. These results and explanations were in agreement with H Soner Altundoğan *et al.*, (2002).



**Fig. 1:** Effect of initial pH (initial concentration of phosphate, 3 mg/L; red mud dosage, 0.1 mg/L; contact time, 120 min., Rpm 180).

#### Effect of Contact Time:

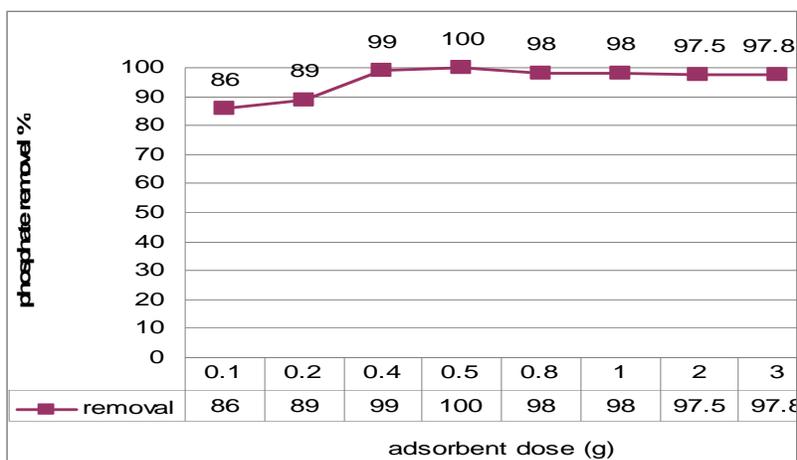
Figure (2) shows the effect of contact time on the removal of phosphate ions from aqueous solutions by RM. The uptake is rapid in the first 30 min. of contact period. Beyond the 60 min. contact time, the amount of phosphate adsorbed on the RM remains constant as shown in Figure (2) these data indicate that, the equilibrium is attained after 60 min. The nature of adsorbent and the available adsorption sites affect the rate of adsorption of phosphate. The mechanism of solute transfer to the solid includes diffusion through the fluid film around the adsorbent particle and diffusion through the pores to the internal adsorption sites. In the initial stages of adsorption of phosphate, the concentration gradient between the film and the available pore sites is large, and hence the rate of adsorption is faster. The rate of adsorption decreases in the later stages of adsorption probably due to the slow pore diffusion of the solute ion into the bulk of the adsorbent (Genc, H., 2006).



**Fig. 2:** Effect of contact time (initial concentration of phosphate, 3 mg/L; red mud dosage, 0.1 mg/L; pH, 7, Rpm 180).

**Effect of Adsorbent Dosage:**

The effect of RM dose was studied by varying the dose between 0.1 and 3 g/100ml. It was observed that the adsorption percentage of phosphate ions onto the RM increased rapidly with the increasing of adsorbent concentration (Fig. 3). This result is expected because the increase of adsorbent dose leads to greater surface area. When the adsorbent concentration was increased from 0.1 to 0.5 g/100ml, the percentage of phosphate ions adsorption increased from 86% to 100%. At higher dosage, the equilibrium uptake of phosphate ions did not increase significantly with increasing RM dosage. Such behavior is expected due to the saturation level attained during an adsorption process. This finding agrees with B. Koumanova *et al.*, (1977). For subsequent studies, a dose of 0.5 g/100ml of RM was selected.

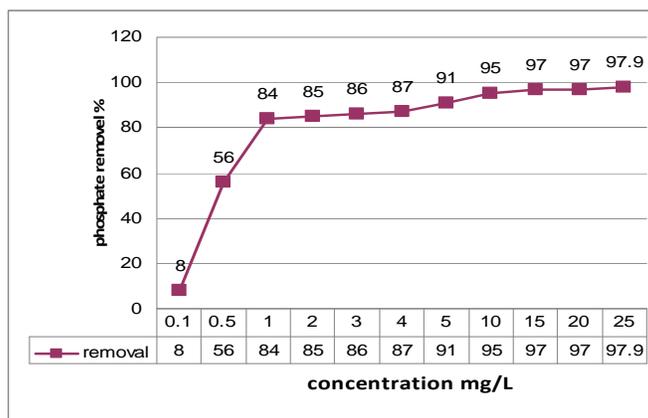


**Fig. 3:** Effect of red mud dosage (initial concentration of phosphate, 3 mg/L; pH, 7; contact time, 120 min., Rpm 180).

**Effect of Adsorbate Concentration:**

The effect of initial adsorbate concentration on the adsorption was investigated by varying the initial concentration of phosphate between 0.1 and 25 mg/L. The experimental data were illustrated in Figure 4.

The results show that, with an increase in the phosphate concentration from 0.1 to 25 mg/L, the percentage removal increases from 8% to 97.7% and the increase in the percentage removal of phosphate can be explained with the fact that, the higher adsorption rate and utilization of all active site available for the adsorption at higher concentration (Koumanova, B., *et al.*, 1997).

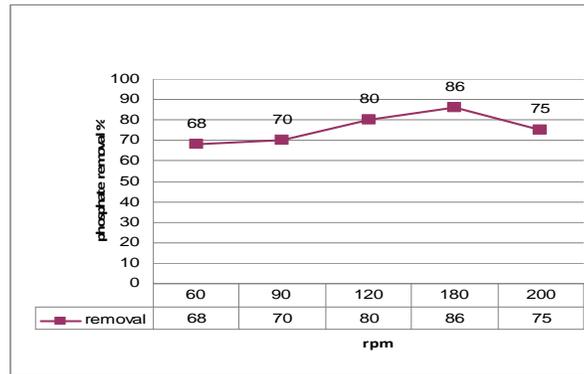


**Fig. 4:** Effect of initial concentration of phosphate (pH 7; red mud dosage, 0.1 mg/L; contact time, 120 min., Rpm 180).

**Effect of Agitation Speed:**

The effect of agitation speed was studied by varying Rpm between 60 and 200. It was observed that the adsorption percentage of phosphate ions onto the RM increased with the increasing of agitation speed reaching maximum 86% at 180 Rpm then decreased with the increasing of agitation speed reaching 75% at 200 Rpm (Fig.5).

It found that the removal of metal ions increased with increased in rpm to some extent. This is due to disperse of the adsorbent particles in the aqueous solution which lead to reduce the boundary of mass transfer and even it may increase the velocity of particles, so that increases the percent removal of metal ions (Kwon, J.S., 2005).

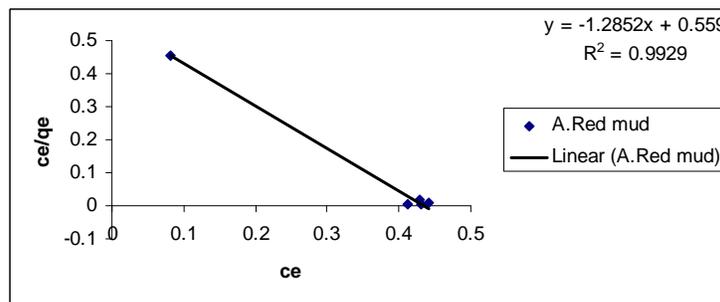


**Fig. 5:** Effect of Agitation Speed (initial concentration of phosphate, 3 mg/L; red mud dosage, 0.1 mg/L; contact time, 120 min., pH7).

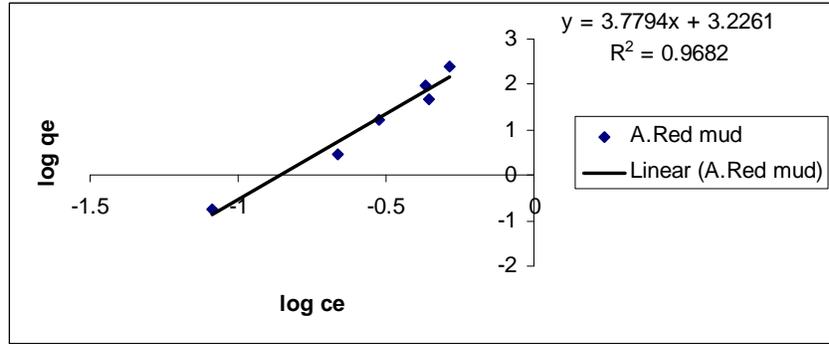
**Adsorption Isotherms:**

The Langmuir and Freundlich adsorption isotherms were determined at pH 7 for phosphate ions concentrations range of 3 mg/l. All solutions contain a fixed specific mass of RM (0.1 g/100ml). The adsorption constants and correlation coefficients of the Langmuir and Freundlich isotherms were given in Table 5. The Langmuir constants,  $b$  and monolayer sorption capacity,  $q_m$  were calculated from the slope and intercept of the plot between  $C_e/q_e$  and  $C_e$  (Fig. 6). The Langmuir constant  $q_m$ , which is a measure of the monolayer adsorption capacity of RM, is obtained as -0.78 mg/g. The Langmuir constant,  $b$  which denotes adsorption energy, is found to be -1.39L/mg. The high value of coefficient of determination  $R^2 = 0.9929$  obtained indicates a good agreement between the experimental values and isotherm parameters but, negative values for the Langmuir isotherm constants indicate the inadequacy of the isotherm model to explain the adsorption process (Mohamed, M.A., 2006).

The Freundlich constants,  $K_f$  and  $n$  are obtained by plotting the graph between  $\log q_e$  versus  $\log C_e$  as shown in Fig. 7. Freundlich parameters ( $KF$  and  $n$ ) indicate whether the nature of sorption is either favorable or unfavorable (Nese Öztürk, T. Enn'il Bektas, 2004). The intercept  $KF [(mg/g)/(mg/l)1/n]$  is an indicator of sorption capacity and the slope  $1/n$  is an indicator of sorption strength and a measure of the deviation from linearity of the adsorption. Smaller values of  $n < 0.264 (<1)$  (i.e.  $1/n > 1$  a steep slope) mean that, sorption intensity is good or (favorable) at high concentrations but much less at lower concentrations (Nese Öztürk, T. Enn'il Bektas, 2004), the adsorption bond is weak, a physical adsorption rather than chemical is probably dominant in phosphate adsorption by RM. It can be seen from the obtained data that, Freundlich equation can be fitted with a desirable  $R^2 = 0.9682$ .



**Fig. 6:** Langmuir isotherm model for the phosphate adsorption onto red mud.



**Fig. 7:** Freundlich isotherm model for the phosphate adsorption onto red mud.

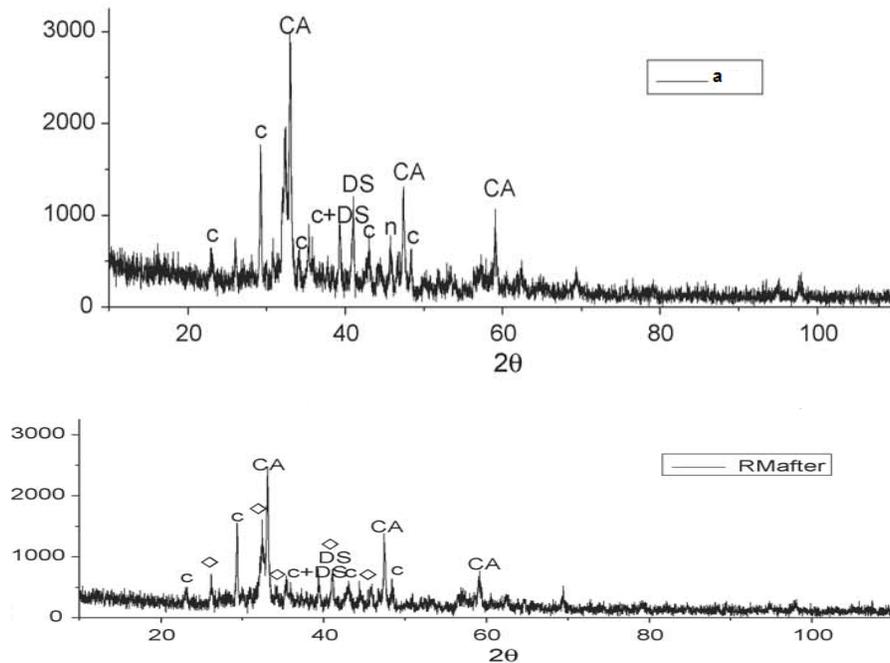
**Table 5:** Isotherm constants and regression data for adsorption isotherms for adsorption of phosphate on red mud.

Langmuir parameters	$q_{max}$	b	$R^2$
	-0.77809	-1.39	0.9929
Freundlich parameters	$K_f$	n	$R^2$
	0.5086	0.2645	0.9682

**Surface Characterization of Red mud:**

- **X Ray Diffraction:**

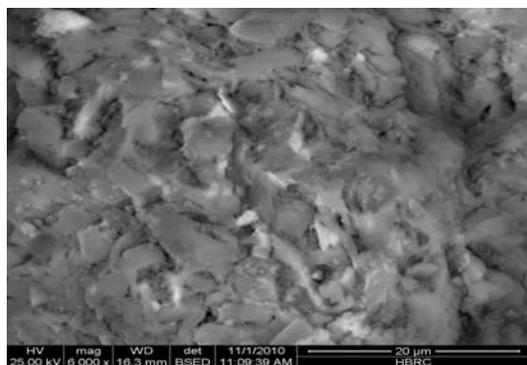
x ray diffraction of activated red mud before and after adsorption as shown in Figs. 8 reveal the presence of phosphate after adsorption process



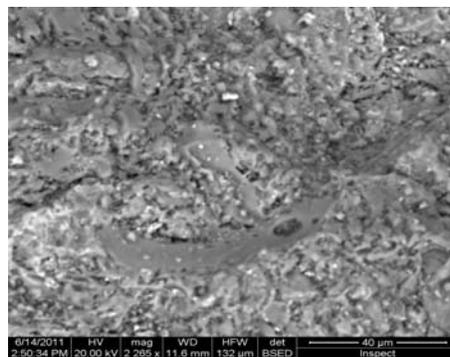
**Fig. 8:** x ray diffraction of activated red mud before and after adsorption. Symbol: CA: calcium aluminate; c: calcite; n: nepheline; DS: dicalcium silicate; phosphates are marked by rhombus (♦).

- **Scanning Electron Microscopy Analysis (SEM):**

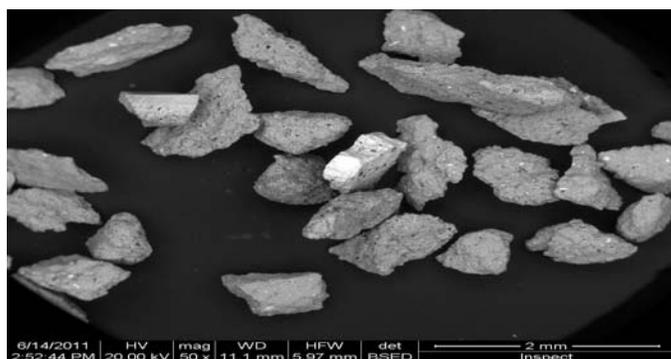
The morphological characteristics of the adsorbent were evaluated by using a scanning electron microscope. SEM images for RM before and after adsorption of phosphate are shown in Figure (10 a,b,c). As shown in figure (10 a) RM before activation has a relatively smooth and flat surface contract to the acid treated specimen RM-HCl, provides clear evidence for the new surface area generated by acid treatment figure (10 b), from figure (10 c) after adsorption of phosphate ions appeared to cover the surface of RM (Yahya, S. Al-Degsa, 2006).



a



b



c

**Removal of Phosphate From Municipal and Industrial Wastewater:**

In order to widen the applicability of the removal technique, the optimized method was applied for the removal of phosphate from ZWWTP and P&G (Table 6). The removal efficiency achieved was 94%,74% in the ZWWTP sample, and 97% in the P&G sample, As shown in table 6 RM also achieved good results for removal of COD, BOD and Nitrite at ZWWTP and at table 7 RM achieved good result for removal of pH, COD, BOD, Ammonia, Nitrite and Nitrate at P&G.

The present study thus reveals that, the RM is an excellent adsorbent for phosphate removal from aqueous solution. The investigations are quite useful in developing an appropriate technology for designing a wastewater treatment plant. The process is economically feasible and easy to carry out.

**Table 6:** Physicochemical analysis of ZWWTP before and after treatment with RM.

Parameter	Influent (before)	Influent (after)	Removal %	Effluent (before)	Effluent (after)	Removal %
pH	8	8.2	-	8.2	8.3	-
COD mg/l	210	100	52.4	148	22	85.1
BOD mg/l	124	75	39.5	98	14	85.7
Ammonia mg/l	10.5	6	42.9	5.0	0.6	88
Nitrite mg/l	20	13	35	15	8	46.7
Nitrate mg/l	0.5	0.2	60	0.5	0.2	60
Total Phosphate mg/l	10	0.55	94.5	1.7	0.44	74.1
CL mg/l	141	30	78.7	110	101	8.2
SO4 mg/l	88	54	38.6	75	65	13.3

**Table 7:** Physicochemical analysis of P&G before and after treatment with RM.

Parameter	industrial adsorption	wastewater	Before	industrial adsorption	wastewater	after	Removal %
pH		10.25			9.97		-
COD mg/l		560			320		42.8
BOD mg/l		190			131		31
Ammonia mg/l		14.2			11.8		16.9
Nitrite mg/l		24			22.9		4.5
Nitrate mg/l		32			24		25
Total Phosphate mg/l		40			1.17		97

### **Conclusions:**

Based on the present study, it is clearly shown that red mud produced in the process of alumina production is an effective adsorbent for the removal of phosphate ions from wastewater. The adsorption process is strongly affected by parameters such as time, pH, adsorbent dosage, and initial phosphate ions concentrations and agitation speed. The equilibrium time for phosphate ions is determined as 60 min. The adsorption isotherms followed the Freundlich model predict the physical nature of the adsorption. Taking into consideration of the above results, it can be concluded that the red mud is a suitable adsorbent for the removal of phosphate ions from wastewater in terms of low cost, industrial byproduct and abundant availability.

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