REMOVAL OF PHOSPHATES FROM WASTEWATER USING CONSTRUCTION AND DEMOLITION WASTES

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ABSTRACT: *Construction activity generates large quantities of waste consisting of concrete, steel, asphalt, brick, clay tiles, wood and plaster applied to buildings, roads and infrastructure.*

Waste from construction demolition or renovation represents about 30-40% of total solid waste. Poor management of this waste can produce a negative impact on the environment, the economy, and the health of the population. One method of recycling construction waste could be to use it as an adsorbent material to remove various pollutants from wastewater (Shiran P. et.al, 2023).

The present paper aimed to test the efficiency of phosphate removal from wastewater using various materials from the demolition of constructions: artisanal brick, burnt brick and roof tile.

Under the investigated experimental conditions, the tested materials proved a high ability to remove phosphates from wastewater. The removal efficiency depends on the dose of coagulant and contact time.

The experimental results obtained in this paper have shown that building materials have a high ability to remove phosphorus compounds from wastewater, but this significantly depends on the dosage and chemical composition of the material.

Keywords: *phosphate; demolition waste; brick; roof tile; wastewater;*

1. Introduction

Despite humanity's dependence on flowing water, human activities have drastically degraded the quantity and quality of rivers and streams worldwide, diminishing their capacity to provide valuable ecosystem services and driving species to extinction.

Today, waters, as well as the entire environment, are subject to aggressive impacts generated by the development of society based on polluting technologies (Shiran P., et.al, 2023, Watanabe T., et al, 2009.).

The increased content of phosphorus compounds in surface waters leads to eutrophication of water, which manifests itself in excessive algal growth followed by the consumption of oxygen needed to oxidise organic material, with serious effects on the natural balances of ecosystems. (Cîr în° D. and Mitran R., 2011).

Phosphorus inputs to aquatic systems can come from natural processes and human activities. Natural sources of phosphorus include rock weathering processes, decomposition of organic matter and soil leaching. Sources from human activities include fertilizers, animal wastes, detergents from washing machines, car emissions, industrial discharges and sewage water (Lim S., 2011).

The phosphorus load in the influent of wastewater treatment plants consists of orthophosphate-phosphorus (PO4-P) (Holba et al., 2012), polyphosphates and organic phosphorus compounds. Together, these add up to "total phosphorus (Ptot) (Correll D. L., 1998,).

Because it causes eutrophication of surface waters, phosphorus must be removed from wastewater.

Phosphorus removal as an advanced treatment process can be achieved both chemically (precipitation and adsorption with coagulants) and biologically (using micro-organisms).

The most common technique for removing organic phosphorus, polyphosphates and orthophosphates from wastewater is chemical, based on precipitation and adsorption processes using coagulants (Correll D. L., 1998,).

Chemical precipitation of phosphorus is achieved by the addition of salts of multivalent metal ions, which lead to the formation of poorly soluble phosphate precipitates. The most common metal salts used are in the form of alum (aluminium sulphate), sodium aluminate, ferric chloride, ferric sulphate, iron sulphate, and ferrous chloride (Dongsheng L., et al, 2020).

A number of studies have been reported in the literature using natural materials based on metal salts and metal oxides for phosphorus removal from wastewater, which have been shown to be effective in removing phosphorus as chemical compounds: bauxite (Altundogan, H.S, et al., 2002; Altundogan, H.S, et al., 2003), diatomite (Xie, F.Z.; et al., 2013,); laterite (Wood, R.B.,et al, 1996) and gravel (Vohla, C., et al, 2005). To reduce the consumption of natural resources, prevent pollution and reduce costs, there is a trend to use different types of waste in the wastewater treatment process.

The use of construction materials generates significant amounts of waste consisting of concrete, steel, asphalt, brick, clay tiles, wood and plaster applied to buildings, roads and infrastructure. Several construction wastes such as fly ash (Myllymäki et al., 2019), slag (Blanco et al., 2016), red mud (Ahmed et al., 2019), concrete (Dongsheng L., et al, 2020) have been evaluated in the process of phosphate removal from wastewater. In this context, in the present work, the phosphate removal capacity of wastewater was tested using construction demolition materials.

2. Experimental

Laboratory experiments were conducted using a synthetic aqueous solution with a PO _4^(3-) ion concentration of 50 mg/L prepared from KH2PO4 (monopotassium phosphate).

2.1. Adsorbents

For the removal of phosphorus from the aqueous solution by coagulation, wastes from building demolitions were tested as possible coagulants: homemade brick, burnt brick and roof tile.

Brick is a building material, made from a mixture of clay, sand and water or from other materials such as concrete, slag, etc., dried in the sun or oven.

Sun-dried brick is a homemade brick that goes by the name of “chirpici”.

The chemical composition of materials from construction demolition was determined by X-ray fluorescence spectrometry (XRF) using an ARL Quant`X EDXRF model spectrometer and the results are summarized in Table 1.

As can be seen from Table 1 the major components of the materials used are oxides of silicon, aluminium, iron, calcium, potassium

Table1. Chemical composition of waste demolition materials

Burnt brick		Homemade brick		Roof tile	
Oxid	Conc (%)	Oxid	Conc (%)	Oxid	Conc (%)
SiO_2	53.21	SiO_2	55.49	SiO_2	49.88
Al_2O_3	18.02	Al_2O_3	16.52	Al_2O_3	18.87
CaO	7.015	Fe_2O_3	6.66	CaO	12.58
Fe_2O_3	6.52	CaO	6.32	Fe_2O_3	9.18
K_2O	2.87	K_2O	3.13	K_2O	3.43
MgO	1.66	MgO	1.25	MgO	2.14

and magnesium.

Silicon dioxide is the compound with the highest concentration in all three samples analysed, with a concentration of more than 50%.

Aluminium oxide is found in concentrations above 18% in fired brick and tile, and in homemade brick the percentage of aluminium oxide is 16.5%.

Iron oxide is found in percentages of over 6% in brick and over 9% in roof tiles.

Only elements with a concentration above 1% are shown in the table.

To use these materials as possible coagulants to remove phosphorus from wastewater, prior to the experiments, they were ground to a very fine powder and dried in an oven at 1000 C to constant mass.

The tested materials were used as dry powder.

2.2. Batch sorption experiment

The removal of phosphorus compounds from the aqueous solution was investigated by a coagulation - flocculation process.

In order, to estimate the optimal working conditions, the tested coagulants were put in contact with the synthetic solution of concentration 50 mg/L PO_4^{3-} in different dosages.

Experiments were carried out at room temperature (20±2ºC) under mechanical shaking for 1 minute at 160 rpm, then 20 minutes at 60 rpm using a Jar Test FC4S apparatus (Velp Scientifica).

More doses of sorbent of 2, 4 and 6g were put in contact with a volume of 500 ml synthetic solution. Samples were taken at various time intervals, from 1hour to 24 hours. The concentration of phosphate ions in water samples before and after contact with the tested coagulating agents was determined by UV-VIS spectrophotometry at wavelength U = 890 nm.

For the spectrophotometric analysis a spectrometer model T80 UV-VIS produced by PG Instruments Ltd. was used.

The removal efficiency R.E. (%) of phosphate ions by the adsorbent was calculated using the following equation:

$$R.E.(\%) = \frac{C_i - C_f}{C_i} * 100$$

where, ci and cf are the concentrations of the phosphate ions in the initial and final solutions, respectively.

All materials and chemical reagents used were weighed using an analytical balance model WPS 510/C/2.

3. Results and discussions

3.1. Removal of phosphate from water using waste homemade brick

Concentration variation and the removal efficiency for PO_4^{3-} in water solution during the contact time with the homemade brick in quantities of 2, 4 and 6g/ 500 ml synthetic solution is presented in Figure 1.

As can be seen from Figure 1, the phosphate concentration in the synthetic solution is influenced by the coagulant dose and contact time.

When adding a 2g dose of homemade brick to the synthetic solution there is a decrease in phosphate concentration from 50.27 mg/l to 43.06 mg/l after 24 hours, which corresponds to a removal efficiency of 14.34%.

Increasing the amount of coagulant to 4g results in a more pronounced decrease in phosphate concentration after 24 hours to 15.89mg/l, representing a removal efficiency of 68.39%. Further increasing the coagulant dose to 6g, the phosphate concentration decreases to 12.63 mg/l after 24 hours, giving a removal efficiency of 74.87%.

3.2. Removal of phosphate from water using waste burnt brick

In order, to establish the influence of the burnt brick dose on the PO_4^{3-} removal process, variable quantities (2, 4 and 6 g) of dry

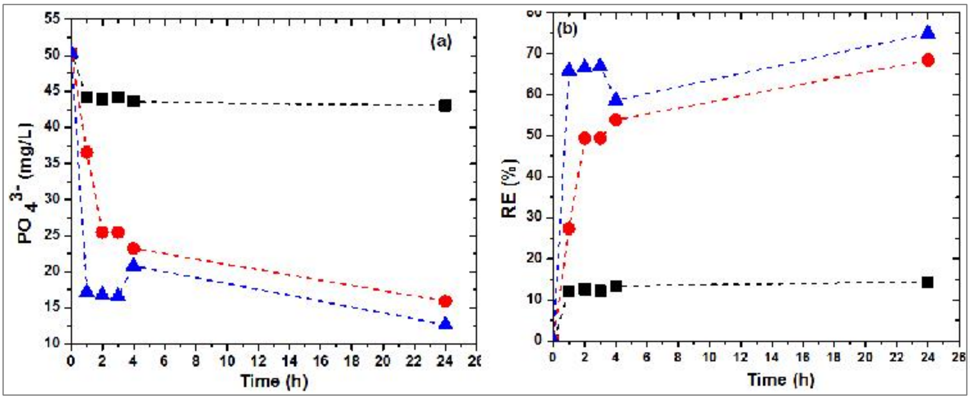

Fig. 1. Variation of concentration (a) and removal efficiency (b) of phosphate in the synthetic solution during its contact time with different doses of dry homemade brick (g): (■)2;(●)4; (Ó)6.

burnt brick were used, put into contact with 500 ml of synthetic solution with a concentration of 50 mg/L PO _4^(3-).

During the process, the influence of the burned brick dose on the concentration of PO _4^(3-) and the influence of the burned brick dose on the removal efficiency were followed.

The variation in concentration and phosphate removal efficiency of the synthetic solution during its contact with various doses of dry burnt brick are shown in Figure 2.

The concentration of phosphate in the synthetic solution decreases over contact time with the different doses of coagulant used, while the removal efficiency increases.

The addition of 2g dry burnt brick leads to a decrease of the phosphate concentration in the synthetic solution from 50.27 mg/l to 34.26 mg/l after 24 hours, corresponding to a removal efficiency of 31.84%.

Increasing the amount of coagulant to 4g results in a decrease in phosphate concentration. After 24 hours, it reaches 15.5 mg/l, representing an efficiency of 69.16%.

Further, increasing the coagulant dose to 6g does not improve the phosphate removal values of the wastewater. After 24 hours, the phosphate concentration is 17.13% and the removal efficiency remains around 60%.

In the case of dry burnt brick, the maximum

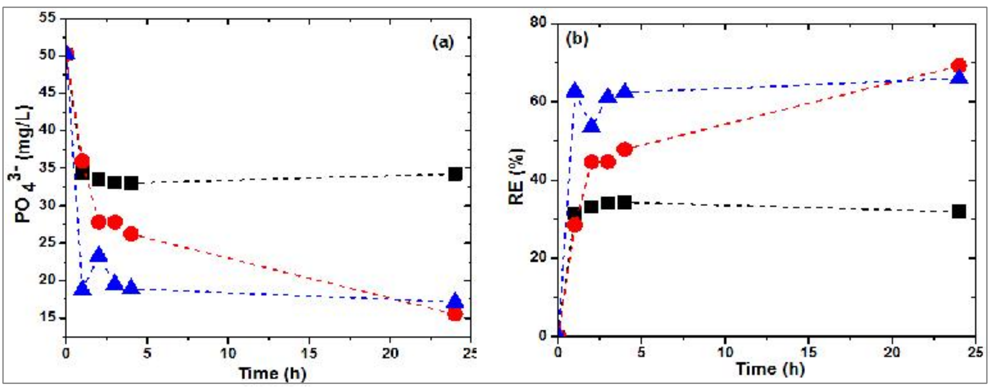

Fig. 2. Variation of concentration (a) and removal efficiency (b) of phosphate in the synthetic solution during its contact time with different doses of dry homemade brick (g):(■)2;(●)4; (Ó)6.

value of phosphate removal efficiency from wastewater was obtained for the 4g dose.

3.3. Removal of phosphate from water using waste roof tile

The effect of the waste roof tile dosages on the concentration and removal efficiency of the phosphate ions from the synthetic solution (containing 50 mg/l PO _4^(3-)) after various contact times is illustrated in Figure 3.

As can be seen in Fig. 3, the variation of the concentration in the synthetic solutions depends on the waste roof tile dosage and the contact time.

The value of phosphate concentration significantly decreases by increasing both, the quantity of the adsorbent and its contact time with the synthetic solution.

For instance, the concentration of PO _4^(3-)decreases from 50 mg/L at the beginning of the experiment to 41,67 mg/L after 1 hour of contact with 2 g of waste roof tile and remains almost constant during the contact time. This corresponds to an phosphate removal efficiency from the synthetic solution of 17,11%.

By increasing the waste roof tile dosage up to 4 g /500 mL solution, the PO _4^(3-) concentration decreases to 38,02 mg/L in the first 1 hour of contact with this sorbent and attains a value of 13,40 mg/L after 24 hours, corresponding to a removal efficiency value of 73,34%.

Conclusions

The present paper aimed to test the efficiency of phosphate removal from wastewater using various materials from the demolition of constructions: artisanal brick, burnt brick and roof tile.

Under the investigated experimental conditions, the tested materials proved a high ability to remove phosphates from wastewater. The removal efficiency depends on the dose of coagulant and contact time.

Thus, the use of homemade brick at a dose of 4g/500 mL solution resulted in a decrease in concentration from 50 mg/L to 15.89 mg/L achieving a removal efficiency of 68.39% after 24 hours of contact.

Using a dose of 4g burnt brick, the phosphate concentration after 24 hours, reaches 15.5 mg/l, representing an efficiency of 69.16%.

The maximum phosphate removal efficiency

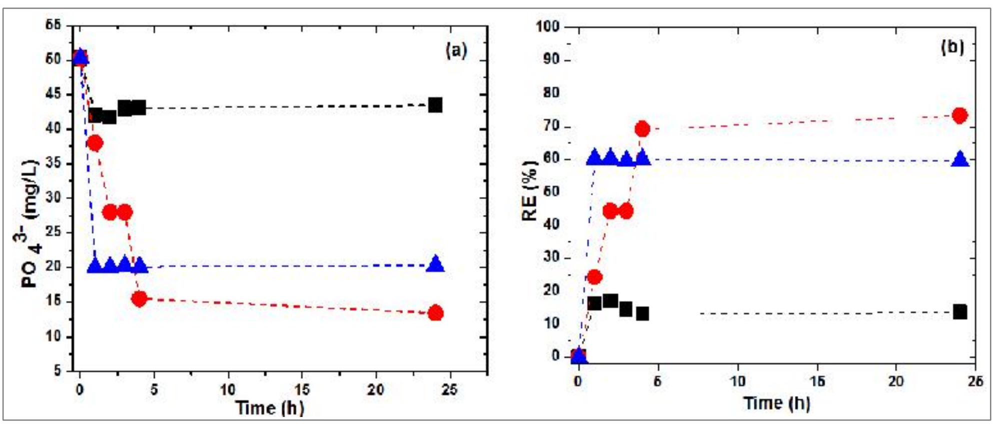

Fig. 3. Variation of concentration (a) and removal efficiency (b) of phosphate in the synthetic solution during its contact time with different doses of dry roof tile (g):(■)2;(●)4; (ó)6.

using roof tiles was obtained at a dose of 4g/500mL, the value being 73.34% after 24 hours of contact. The experimental results obtained in this paper have shown that building materials have a high ability to remove phosphorus compounds from wastewater, but this significantly depends on the dosage and chemical composition of the material.

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