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PEAT AS SORBENT FOR THE REMOVAL OF PHOSPHATE IONS FROM AQUEOUS SOLUTION

Artis Robalds, Liga Dreijalte, Maris Klavins, Department of Environmental Science, University of Latvia, Raina blvd. 19, LV-1586, Riga, Latvia; +371 26769597;
E-mail: artis.robalds@inbox.lv

SUMMARY

Phosphorus pollution from point and nonpoint sources is a serious problem in many European countries and is causing eutrophication in freshwater and marine ecosystems. In this study, peat modified with iron compounds has been used as sorbent for the removal of phosphate ions from water. The maximum sorption capacity of modified peat reached 9.92 mg/g at initial phosphate concentration of 500 mg/l. Sorption capacity was found to be pH dependent, and maximum uptake occurred at pH 2. Kinetic data revealed that sorption was relatively rapid – 57 % of phosphate had been sorbed in the first 15 minutes. Results indicate that modified peat could be used as an effective sorbent to bind phosphate ions from aqueous solutions.

KEYWORDS: modification, peat, phosphate, removal, sorption

INTRODUCTION

It is well known that excessive amounts of phosphorous compounds in surface waters can lead to eutrophication, which is as a serious environmental problem in many countries around the world. Eutrophication causes fish kills, extraordinary growth of algae and the deterioration of water quality (Song *et al.*, 2011; Zeng *et al.*, 2004). The main causes of eutrophication are discharges of raw or treated wastewater and agricultural runoff (De-Bashan and Bashan, 2004), therefore adequate wastewater treatment methods must be used. When traditional wastewater treatment methods, such as biological treatment or chemical precipitation, cannot be used because of the high costs or other drawbacks, the use of sorbents is one of the alternative options (Khadhraoui *et al.*, 2002).

Research by Xiong and Mahmood (2010) shows, that peat is a suitable biosorbent for the removal of phosphate ions from aqueous solution. However, it is presumed that the sorption capacity of peat can be significantly increased by its modification with iron compounds. Iron rich material, such as furnace slag, clays and sands, ferric sludge and iron oxides have been used as sorbents/filtering material for the removal of phosphorus compounds from different types of wastewater (Moelants *et al.*, 2011).

The aim of the present study was to test the phosphate removal potential of peat modified with iron compounds and to study the effect of initial phosphate ion concentration, contact time and pH.

MATERIALS AND METHODS

The *Sphagnum fuscum* peat was collected from industrially mined raised peat bog in Latvia. Peat was characterized by its botanical origin and major physical and chemical properties, such as element analysis, ash content and degree of decomposition. Peat sample was homogenized and sieved through a 2 mm sieve to remove large particles and then dried at 105 °C for 24 h. Peat was mixed with iron compounds, then heated for several hours.

Quantities of 1 g modified peat were shaken on a rotary shaker with a constant speed of 140 rpm for 24 hours with different concentrations (0.1–500 mg/l) of phosphate ions (as KH_2PO_4 in deionized water). After the filtration, the concentration of phosphate ions in the filtrates as well as in the initial solutions was determined by molybdenum blue spectrophotometric method at λ_{max} of 880 nm (Murphy and Riley, 1962). Sorption capacity (expressed by mass of phosphate sorbed/mass of sorbent) was calculated from the decrease of phosphate concentration in the solutions. For the pH studies, the pH was adjusted in range 2-10 with diluted HCl or NaOH using pH meter, before the addition of the peat and during the sorption process. For the kinetic experiments, peat was contacted with the phosphate solution and shaken from 1 minute up to 24 hours. The initial phosphate concentration in kinetic and pH studies was 25 mg/l. The effect of initial phosphate concentration has been studied at 15 °C. The effect of pH and contact time has been studied at room temperature (20 °C).

RESULTS AND DISCUSSION

Effect of initial phosphate concentration

Sorption isotherms, derived from equilibrium batch sorption experiments, were used to evaluate the removal of phosphate ions from aqueous solution by raw and modified peat. As seen from Fig. 1, raw peat did not bind phosphate ions. The sorption capacity of modified peat increased with the increase of the initial phosphate concentration. The steep rise of the isotherm curve close to its origin indicates high uptake values at low concentrations. 99 % of phosphate ions had been sorbed at initial concentration range 0.1 - 25 mg/l, which is a range typical for wastewaters. The maximum sorption capacity of modified peat reached 9.92 mg/g at 15°C and initial phosphate concentration of 500 mg/l.

The sorption capacity of modified peat obtained in this study could be compared with other materials reported in the literature (Table 1). However, the maximum sorption capacity is not the only parameter determining whether the chosen material could be used as suitable sorbent in field scale systems. Parameters, such as availability, content of heavy metals, hydraulic conductivity, and the recyclability of material as fertilizer should be taken into consideration (Vohla *et al.*, 2011).

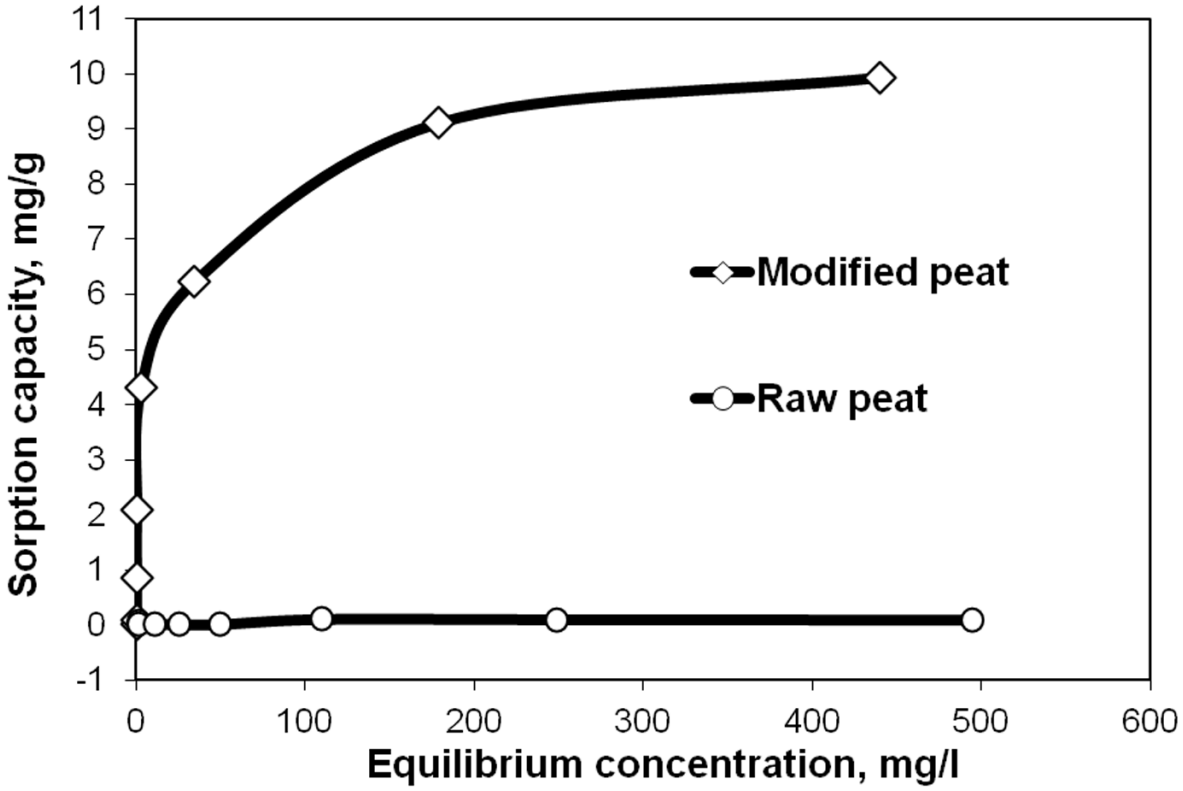

Fig. 1. Sorption isotherms of phosphate ions by raw and modified peat.

Table 1. Comparison of phosphate sorption capacity of iron modified peat with some literature values.

Material	Sorption capacity, mg/g	Reference
Iron modified peat	9.92	This study
Ferric and alum water treatment residuals (FARs)	28.4	Wang *et al.*, 2011
Activated FARs	53.2	Wang *et al.*, 2011
Different types of sands	0.13 - 0.29	Xu *et al.*, 2006
Furnace slag	8.89	Xu *et al.*, 2006
Mineral apatite	~0.3	Bellier *et al.*, 2006
Shale	0.5	Cyrus and Reddy, 2010

Effect of contact time

The effect of contact time at initial phosphate concentration of 25 mg/l is presented in Fig. 2. The kinetics of the sorption process could be described as a two stage process. At the first stage, the removal of phosphate ions is very rapid – in the first 15 minutes 57 % of phosphates had been sorbed. The first stage is followed by a gradual increase of sorbed amount of phosphate ions. Equilibrium is reached in 8 hours with 99.5 % (2.07 mg/g) sorbed.

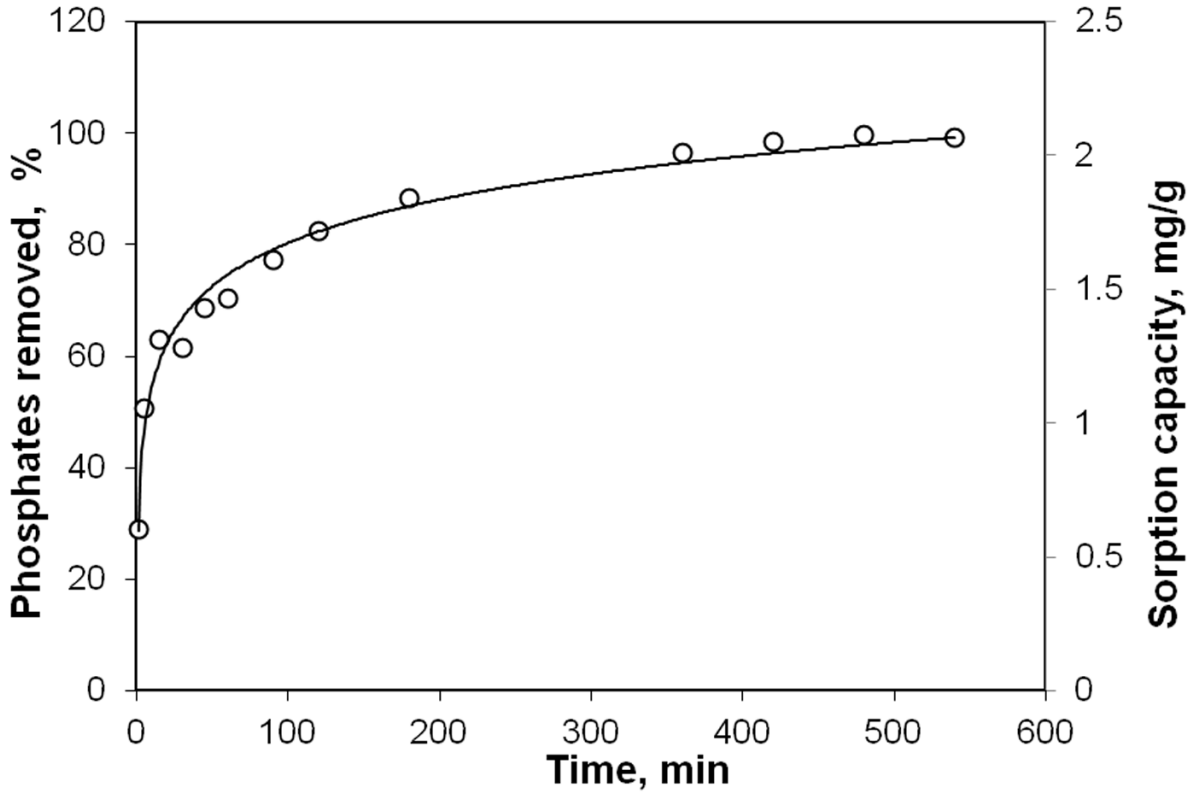

Fig. 2. Effect of contact time on the uptake of phosphate ions by modified peat.

Effect of initial pH on phosphate uptake

Previous studies showed that the removal capacity of phosphate ions by different materials was dependent on the pH of the aqueous solution. As shown in Fig. 3., phosphate uptake by modified peat was just slightly affected by the solution pH. The uptake of phosphate decreased as pH was increased from 2.0 to 10.0. The maximum sorption capacity occurred at pH 2 with sorption capacity of 1.99 mg/g. pH was adjusted during the sorption process, however, some of pH values changed significantly after the last correction step (22 hours after the beginning of sorption or 2 hours before the end of the process). When the initial pH values were 2.0; 3.0; 4.0; 5.0; 6.0; 7.0; 8.0; 9.0; 10.0, pH values after the sorption were 2.01; 2.99; 4.55; 5.50; 6.07; 6.51; 6.92; 7.56; 9.22, respectively.

In general, peat is a material rich in humic acids, which has a large buffer capacity in a wide pH range (Pertusatti and Prado, 2007). Xu *et al.* (2006) observed that the addition of peat (from 0% to 20%) to the studied material both increased and decreased pH of the solutions. For example, the pH of the solutions with furnace slag decreased from 12.12 to 9.11. The pH of solution with soil increased from 4.17 to 5.62.

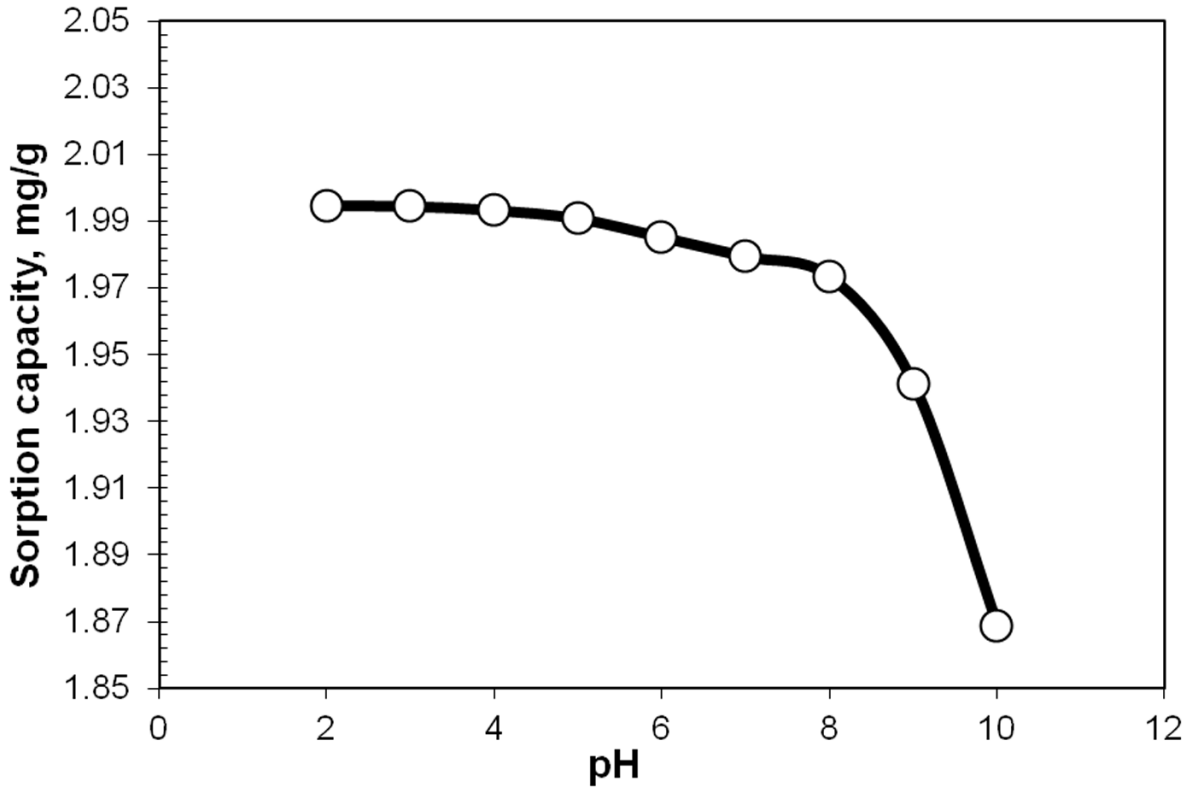

Fig. 3. Effect of pH on the uptake of phosphate ions by modified peat.

CONCLUSION

The phosphate sorption capacity of peat can be significantly increased by its modification with iron compounds. The phosphate removal by modified peat depends on initial phosphate concentration, pH and contact time between solution and modified peat. High uptake values were observed, especially in the concentration range typical for wastewaters. Taking into account the low cost and availability, the use of peat based sorbents may be considered as alternative to conventional wastewater treatment methods. However, supplementary experiments should be carried out to evaluate the performance of developed sorbent in field scale systems – in constructed wetlands or in bed systems.

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