Removal of phosphate using fly ash and chemically modified zeolite

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Abstract:

High phosphorus concentration levels in water cause eutrophication, while its sustainable recovery can overcome the future lack of P resulting from the exhaustion of natural phosphate mineral resources. Phosphorus removal through adsorption from wastewater treatment is an efficient treatment process. Therefore, it can be applied in wastewater treatment plants as an advanced treatment stage, and therefore, accomplish the new strict nutrient discharge regulations prevailing in several countries. The application of low-cost materials with good adsorption proprieties can increase the economic sustainability of the process and increase its attractiveness to the water industry. This study investigates the feasibility of P recovery from aqueous solution by applying Fly Ash (FA) and natural zeolite (Z-N). The P removal capacity of FA and Z-N was identified by testing the effect of adsorbent quantity (5 and 10 g/L), the solution pH (4, 7 and 9) and the initial phosphorus concentration for fly ash (10, 50, 75 and 100 mg/l P), and the initial phosphorus concentration for modified zeolite (5, 10, 20, 50, 100 and 200 mg/l P)at room temperature (20℃ ± 2).

Fly Ash (FA) obtained from CEMEX company (UK) and was complies for categorisation conforming to BS EN450-1, with a classification of S. And also a natural zeolite (Z-N) obtained from Greece with a grain size ranges of 05 to 1.0mm was used was washed and dried at 120℃ for 24hr. The experiments were performed in batch configurations. The dried material were used for the modification process and batch experiments. A Z-N sample of 10 g was submerged under agitation in a $FeCl_3$ (14%w/w) solution with initial concentration 96,5gr Fe/L, and diluted (1/500) to reach a final concentration of 193 mg Fe/L. The mixture was shaken for two days. By the third day, the solution with the adsorbent was filtrated to separate the solid part (iron modified zeolite). Then, the modified material was washed with deionized water and filtered three times. Finally, the iron-modified zeolite was dried at 40°C for four days.

Additionally, adsorption isotherms and kinetic models were tested in order to explain the experimental results. The results showed that high phosphate removal rates were achieved for Z-N when the initial or adjusted pH of the aqueous solution was between the 4 and 7. The adsorption isotherms and kinetics for Z-Fe followed the Freundlich model and the Pseudo Second-Order model respectively. The maximum adsorption capacity obtained by the Langmuir isotherm equation was 4.27 and 6.32 mg/g respectively 5 and 10g/L of Z-Fe were applied in the solution. Moreover, it was possible to identify a balance point between the adsorption capacity at equilibrium (qe) and the adsorption rate (K') of Z-Fe when the P concentration- adsorbent concentration ratio (C0/AC) is equal to 2.0mg/g.

Table 1. Adsorption experiments by adsorbent material

Adsorbent material	Phosphate concentration (mg/L)	Temperature	PH
Natural Zeolite (Z-N)	10	20℃ ± 2	7
	10	20℃ ± 2	Variable (Table 2)
	10	20℃ ± 2	Variable (Table)
Modified Zeolite (Z-Fe, $FeCl_3$)	10	20℃ ± 2	7
	Variable (Table 2)	20℃ ± 2	7
		20℃ ± 2	7

Fly ash (FA)	10	20℃ ± 2	7
	50	20℃ ± 2	7
	75	20℃ ± 2	7
	100	20℃ ± 2	7

Table 2. Variable parameters for the batch experiments

Parameter	Range	Adsorbent material
Adsorbent concentration (g/L)	0.5 – 10.0	Z-N, Z-Fe and FA
Initial Phosphate concentration (mg/L)	5.0 – 100.0	Z-Fe
Initial/Adjusted pH	4.0 – 9.0	Z-N