

## Adsorption of arsenic by natural pozzolan in a fixed bed: Determination of operating conditions and modeling



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### ABSTRACT

The presence of arsenic at relatively high concentrations in water as a result of natural and human activity discharges requires proper treatment before use. Arsenic was analyzed using a spectrophotometric method. Experiments were carried out in a column packed with natural pozzolan (black, red) from Djoungo (Cameroon) at different pH (5, 7, 9), initial arsenic concentration (100 µg/L, 200 µg/L, 400 µg/L) and flow velocity (0.39 cm/min, 0.79 cm/min, 1.57 cm/min). Results showed that the bed saturation time (outlet concentration from the bed  $\geq 10$  µg/L) is longer for a lower pH, flow velocity and initial arsenic concentration. Two kinetics models; Adams-Bohart and Thomas were applied to the experimental data to predict the breakthrough curves using linear regression and to determine the characteristic parameters of the column. The Thomas model was found appropriate for the description of the whole breakthrough curves, whereas the Adams-Bohart model could only predict the initial part of the breakthrough curves. Using water with low arsenic concentration, pozzolan demonstrated its effectiveness in arsenic removal below the acceptable level (10 µg/L).

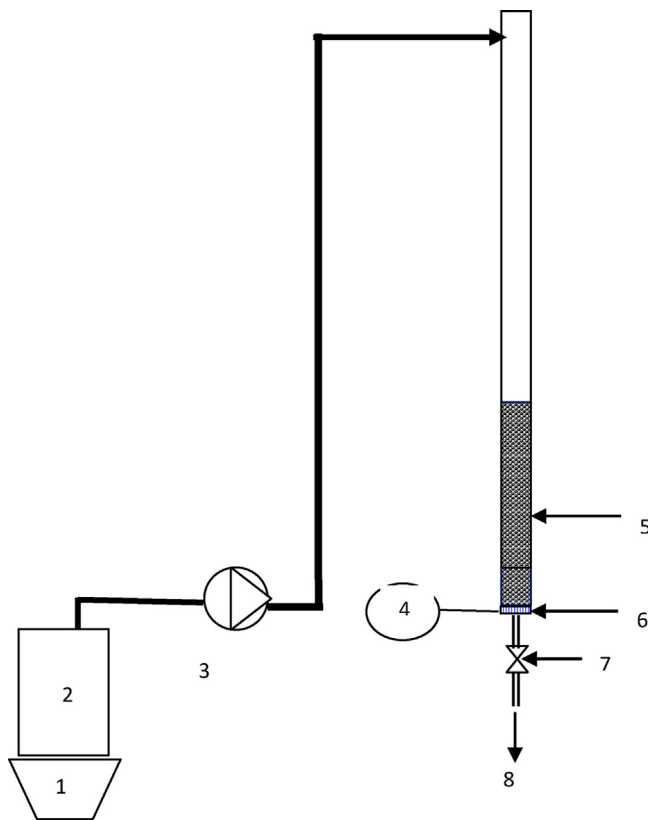
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### 1. Introduction

Contamination of drinking water by arsenic has become a key environmental problem of the 21st century [1]. Arsenic is an ubiquitous element and its presence in water originates from arsenic-containing rocks and soil, and from some anthropogenic sources including mining activities, glass processing, insecticides, pesticides and landfill leaching [2,3,4]. Arsenic is transported to water through erosion and dissolution [5] and it occurs in natural water mainly as inorganic arsenite [As(III)] and arsenate [As(V)]. Dominant arsenic species are functions of pH and redox potential. Arsenate is thermodynamically more stable than arsenite and predominates in surface water, while arsenite is favored under reducing conditions such as in anaerobic groundwater. Besides, [As(III)] is easily converted to [As(V)] by oxidizing agents such as oxygen, ozone, hypochlorite, permanganate [6,7]. Thus it is more convenient to give priority to the removal of [As(V)] from

water in the process of treating water to be used for drinking. Long-term exposure to inorganic arsenic in drinking water leads to gastrointestinal, cardiovascular, dermal and respiratory disorders and hyper-pigmentation [8,9,10]. Considering its health effects and toxicity, the World Health Organization (WHO) has recommended the maximum concentration of 10 µg/L in drinking water [11]. Conventional treatment for arsenic removal from water involves coagulation with ferric chloride or aluminum sulphate, followed by separation of the produced insoluble material by settling or direct filtration through sand beds [12,13]. Other treatment techniques for arsenic removal are reverse osmosis, ion exchange and lime softening [14,15]. However these techniques present some disadvantages amongst others: incomplete metal removal, high cost of reagent and energy requirements [15,16]. Adsorption has emerged as an alternative to these traditional methods with several advantages. For example, it is technically easy to use, cheap, highly efficient and flexible [1]. Presently, the applicability of the adsorption process using granular adsorbent as a fixed bed is being explored. Results from several investigators [17,18,19] indicate that some of these adsorbents such as iron oxide and aluminum oxide are very promising. However most of these adsorbents are synthetic and are relatively expensive. Pozzolan is a natural material of volcanic origin which contains oxides like

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**Fig. 1.** Schematic representation of experimental setup for arsenic removal. 1. Magnetic stirrer; 2. influent solution (distilled water spiked with arsenic); 3. peristaltic pump; 4. manometer; 5. pozzolan; 6. porous disk; 7. flow controller and 8. effluent solution.

iron and aluminum in its matrix. The presence of those oxides may increase the efficiency of pozzolan for the removal of arsenic. Pozzolan is available in Cameroon and in many regions around the world. It was used successfully for the removal of laterite from water [20] and as a coagulant aid for the removal of dissolved organic matter [21]. The present work investigates the possible use of natural black and red pozzolan as a fixed bed for arsenic adsorption from aqueous solution. The effects of various factors such as pH, initial arsenic concentration and flow velocity were systematically examined. The Adams–Bohart model and the Thomas model were applied to the experimental data to simulate breakthrough curves.

## 2. Materials and methods

### 2.1. Adsorbents

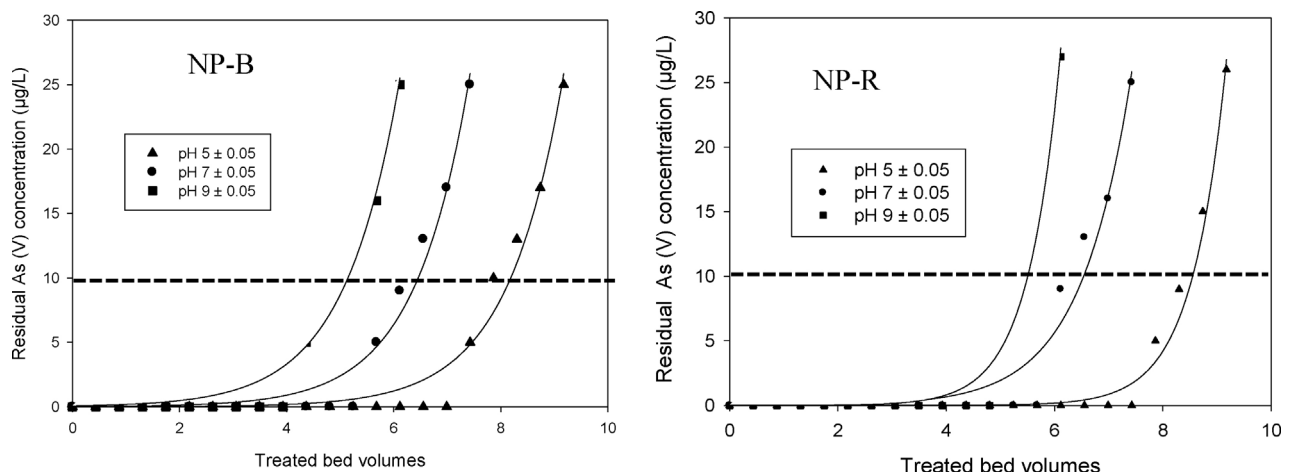
In this study, natural pozzolan from Djoungo quarry, Cameroon were used as adsorbents. Two types of pozzolan designated hereafter as NP-B for black pozzolan and NP-R for red pozzolan were sampled, crushed using a jaw crusher (RETSCH, Germany), reduced to powder by grinding in a CDE 532 ROCKLABS (New Zealand) hammer mill, and sieved to produce granular particles size of 100–125  $\mu\text{m}$ . Before it was used in adsorption studies, pozzolan adsorbent was prepared in order to remove soluble alkali and alkali earth material. In order to do this, 100 g of pozzolan was added to distilled water (500 mL) under agitation, and the resulting suspension was maintained at  $\text{pH } 3 \pm 0.05$  by adding drops of HCl (0.1 M) or NaOH (0.1 M). The suspension was then allowed to settle for 20 min and the supernatant was discarded. Several steps of washing and settling operations on the resulting sediment were carried out until constant conductance was obtained. The recovered sediments were dried at  $105 \pm 5^\circ\text{C}$  for 24 h, allowed to cool in a desiccator and kept in a capped polyethylene bottle.

### 2.2. Column packing

A glass column of 18 mm internal diameter and 90 cm height was used. At the bottom of the column, a 45 micron porous plastic disk was fixed to retain the particle media. The loading of the column with pozzolan involved initial charging with distilled water. This was done to wet pozzolan bed completely and to prevent air bubbles being trapped in the column which might have subsequently affected the adsorption performance. To maintain a water head above the top of the bed in the column, the overflow was set at a constant level.

### 2.3. Adsorption experiments

Experiments were carried out at different pH values (5, 7, 9), arsenic concentrations (100, 200, 400  $\mu\text{g/L}$ ) and flow velocity (0.39, 0.79, 1.57 cm/min). The bed height taken was 10 cm (30 g). The arsenic solution was pumped into the column using peristaltic pump (Gilson, France) in a down-flow direction. The outlet solution was taken at preset time intervals and the concentration of arsenic was analyzed, as described in the following section. All the adsorption experiments were carried out at a temperature of  $24 \pm 2^\circ\text{C}$ . The schematic representation of experimental setup is shown in Fig. 1.



**Fig. 2.** Effect of pH on As (V) adsorption by pozzolan (inlet arsenic concentration = 400  $\mu\text{g/L}$ , flow velocity = 0.79 cm/min).

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