Arsenic retention on technosols prepared with nanoparticles for treatment of mine drainage water

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ABSTRACT: Arsenic (As) concentrations of 4.8 to 27.5 $\mu\text{g L}^{-1}$ have been detected in wastewater of gold mines in southern Ecuador (Portovelo) thus there is a need of applying remediation techniques to avoid superficial and groundwater contamination. In this study we have prepared a technosol composed by a ferric soil collected in the mining area and multicomponent nanoparticles synthesized using sodium borohydride and orange peel extract as co-reductants. The sorption capacity of the technosol was experimentally characterized using sorption isotherms. Langmuir model fits the experimental results and its parameters such as maximum sorption capacity and adsorption bond energy are 71185 mg kg^{-1} 7.50 kg mg^{-1} , respectively. Based on these preliminary results, it seems that the as-prepared technosol will be a cheap cost solution for capturing arsenic from the mine drainage water.

1 INTRODUCTION

Mine drainage water usually contains high concentrations of heavy metals and other compounds. Due to poor handling, this contaminated water may leach and migrate to ground and spring water, becoming a potential contaminant of drinking water sources (Bolaños, 2015; Polizzotto *et al.*, 2006). There are many available technologies to cleanup As-contaminated water, whose efficiency and applicability will mainly depend on the chemical form of As in water (Cumbal, 2004). Adsorption of As in specific sorbents has been widely used due to its high versatility, easy operation and handling, and low costs. The application of specifically “tailored” technosols, composed of soil components and non-harmful residues with sorption capacities for specific contaminants, has shown successful results on the restoration of degraded mining areas contaminated with a wide variety of trace metals and metalloids (Macías, 2012). On the other hand, nanosorbents has emerged as a promising alternative for the cleanup of As-contaminated water (zero valent iron and iron oxide nanoparticles), because of their distinctive and advantageous properties, such as the small size, high surface area, and high reactivity due to the large number of sorption active sites (Pérez-Esteban *et al.*, 2016).

The objective of the present study was to find out the arsenic sorption capacity of a tailored technosol composed of a ferralsol, with 25,531 mg kg^{-1} of Fe (2% w/w, associated to Fe and Mn oxides) and multicomponent nanoparticles.

2 METHODS

Water samples were collected at three discharges of artesian gold-processing plants located in the border of the Amarillo River (Portovelo, Ecuador), the main collector of liquid wastes from the gold-processing artesian plants. pH, Eh, electric conductivity were measured on site and heavy metals and As were analyzed with an atomic absorption spectrometer using standardized methods. For the fabrication of multicomponent nanoparticles (MCPNs) $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ and Na_2SO_4 solutions were mixed and purged with nitrogen. Then, NaBH_4 and orange peel extract were added as co-reductants. The technosol was prepared mixing 12.5 mg of MCPNs and 4,987.5 mg of soil. Arsenic sorption was performed in batch tests mixing 5 g of technosol with 100 mL of arsenic contaminated water at neutral pH.

Mine drainage water was doped with six different concentrations of arsenic (25, 50, 100, 200, 400, 600 $\mu\text{g L}^{-1}$). The amount of arsenic sorbed on the technosol was determined by mass balance using the equation (Vanderborght & Van Grieken, 1977):

$$q = V/m (C_i - C_f) \quad \dots\dots\dots (1)$$

where q = concentration of As in the soil, V = volume of water contaminated with As, m = mass of soil and C_i and C_f initial and final As concentrations.

Table 1. Metal concentration in soil, used for preparing of technosol.

Soil Fraction	Cu mg kg ⁻¹	Cd	Zn	Cr	Pb	Fe	As
Exchangeable	0.37	0.56	0.78	1.65	2.26	0.8	0.00
Sorbed-carbonate	1.23	0.50	2.11	0.96	5.70	3.43	0.00
Oxidizable (Fe/Mn oxides)	1.89	0.00	154.32	1.12	6.42	432.88	0.09
Reducible	3.54	0.15	5.27	2.78	1.67	190.09	0.00
Residual	4.5	0.00	6.94	0.75	3.21	24904	0.02
Total	11.53	1.21	169.42	7.26	19.26	25521.24	0.11

Figure 1. Sorption of arsenic on technosol.

3 RESULTS AND DISCUSSION

Water samples collected from the mine drainage had pH of 8.56 and Eh -107.50 mV. Under these conditions, arsenic is probably precipitating into the sediments basin. However, the variation of these parameters can easily lead to the release and mobilization of arsenic into the water (Polizzoto *et al.*, 2006) what is evidenced by the variation of arsenic concentrations from 4.8, 8.6 and $27.5 \mu\text{g L}^{-1}$. Concentrations of metals in soil are given in Table 1. Soil with concentration of 25,531 mg of total iron kg^{-1} (432.9 mg kg^{-1} of Fe associated to oxides) was selected for preparing the technosol. The As-prepared MCNPs showed sizes in the range of 5 to 20 nm containing zero valent iron in the core and iron sulfide in the coverage similar to those reported by Cumbal *et al.* (2015). With the As-prepared technosol, we run adsorption tests for arsenic. In Figure 1, it is observed that experimental data fit very well the Langmuir isotherm model:

$$q = (Q_{\max} b C)/(1+bC). \dots\dots\dots (2)$$

The maximum adsorption capacity and adsorption bond energy (Langmuir, 1918) ($Q_{\max}$) and b are $71,185 \text{ mg kg}^{-1}$ and 7.50 kg mg^{-1} , respectively. The high sorption capacity of the technosol for arsenic could be associated to iron oxides (Cumbal, 2004) contained in soil and the zero valent iron and the iron sulfide of the nanoparticles (Cumbal *et al.*, 2015).

4 CONCLUSIONS

Technosol prepared with iron-rich soil mixed with multicomponent nanoparticles shows a good sorption capacity for arsenic dissolved in the mine drainage water. Adsorption results fit very well a Langmuir isotherm. Approximately 95% of arsenic is captured from the aqueous phase contaminated with 4.5 mg L^{-1} .

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4.4 Arsenic solidification and immobilization for contaminated soils

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