

Ecotoxicological assessment of arsenic contaminated soil and freshwater from Paracatu, Minas Gerais, Brazil

S. Egler, R. Zacaron, B. Pinheiro & Z.C. Castilhos
Centre of Mineral Technology, Rio de Janeiro, Brazil

E.D. Bidone
Fluminense Federal University, Niteroi, Brazil

ABSTRACT: Samples of freshwater and soils were submitted to ecotoxicological tests to estimate the arsenic bioavailability and its toxic effects on aquatic and terrestrial biota. Aquatic organism bioassays indicated no acute but chronic toxicity in tested freshwater from Paracatu. Although the As bioaccumulation factor in soil at Corrego Rico resulted lower than in controls, the actual bioavailability of As is high because As levels resulted 30 times higher than in controls. This indicates that As from soils at Corrego Rico is bioavailable, but the earthworms can mitigate As toxicity by biological saturation controls. Despite of this fact, bioassays with earthworms suggested no acute toxic effects.

1 INTRODUCTION

Toxicity of metals to soil organisms has been related to total metal activity in pore water and to bounded-organic matter digested in guts. The two major routes of metal accumulation in aquatic organisms are dissolved uptake and dietary assimilation, whereas excretion played a dominant role in arsenic elimination, maybe as arsenosugars. Evaluation of the degree of contamination of aquatic environments must not take in account only its chemical characterization but it should be complemented with biological assays, which assess potential toxic effects to aquatic biota as a results of synergic, antagonistic, or additive effects of substances (Palma *et al.*, 2010). These methods allow the characterization of water quality in a shorter period and the assessment of multicomponent long-term effects of water contamination. The objective of this work was to evaluate the bioavailability and ecotoxicity of arsenic in waters and soils from Paracatu on aquatic and terrestrial biota.

2 METHODS/EXPERIMENTAL

Six stream surface water and two soil samples were collected from a gold mining area. The surface water were collected from 4 streams: Córrego Rico (points 2 and 9), Santo Antônio (3 and 20) and Neto river (Y) and Santa Isabel river (22). Soils were sampled from point 2 (Córrego Rico area)

and 22 (Santa Isabel area). Points 2 and 3 are close to the gold mining and tailings dam, respectively, whereas point 22 is almost 50 km far from gold mining and it is the Paracatu water supply. After collected, the water sample was frozen, and the soil was air-dried and sieved to < 2.0 mm prior to total arsenic measurement by ICP-OES at CETEM.

In order to evaluate the ecotoxicity of surface water, the cladoceran species was chosen as indicated by the Brazilian legislation. Ecotoxicity of soils was assessed by acute assay by using the earthworm species *Eisenia andrei*.

Daphnia similis (Cladocera, Crustacea) were housed in 2-L glass beakers at environmental chamber with constant temperature ($20 \pm 2^\circ\text{C}$) and photoperiod (16:8 h light:dark). Organisms were maintained in dilute MS medium and fed daily *Pseudokirchneriella subcapitata* at a rate of 3.3×10^6 cells/mL per organisms. Toxicity tests employed 100% stream water samples and a control (MS medium) group per test. Five neonates (24 h old) were randomly placed into a 25-mL glass exposure chamber containing 20 mL of sample or MS medium. Four replicate exposure chambers were employed per sample or control group. Daphnids were not fed during tests, and all tests were conducted at the same condition of culture. Mortality or immobilization was assessed for individuals in each container after 48-h exposure. The algal growth inhibition test with *P. subcapitata* was performed based on monospecific algal cells growth in test flasks incubated on a shaker (130 rpm) with continuous illumination of

4500 lux at $20 \pm 3^\circ\text{C}$. The inocula came from exponential phase of cell growth in LC Oligo medium at 24°C and continuous lighting. During the tests, the algae are incubated with 100 mL sample and LC Oligo medium as control group. Three replicate exposure chambers were employed per point or control group. Algal biomass was assessed for each replicates after 96 h.

Samples were monitored at the start and conclusion of each test for pH and dissolved oxygen. Percentage of inhibition is: $I = (\text{mean control biomass} - \text{mean sample biomass}) / (\text{mean control biomass} * 100)$.

Eisenia andrei (Lumbricidae, Annelida) were kept in plastic boxes in a bedding of cow manure, held under continuous lighting at $20 \pm 2^\circ\text{C}$. The artificial soil used as control soil was prepared by mixing 70% quartz sand, 20% kaolin clay and 10% coconut shell powder. Moisture content of samples and control soils were brought to 55% (w/w) by adding demineralized water. Test soils (500 g dw) were placed in 1 L glass test containers and 10 adult earthworms were added at each of the three replicates. The total weight of earthworms added to each replicate was recorded. The survival earthworms were placed on moist filter paper for 24 h to allow them to void its gut contents. The earthworms were rinsed with distilled water, and then they were killed at -20°C . After they were freeze-dried for 24 h and then ground to a fine powder with an agate pestle and mortar for metal chemical analysis.

The endpoints were lethality (%L) and weight loss (%WL). The bioaccumulation factor (BAF) is the metal levels ratio between tissue and soil.

3 RESULTS AND DISCUSSION

The water samples were chosen according to their As levels: four samples are higher than the Brazilian legislation limit ($10 \mu\text{g L}^{-1}$) while two samples are lowest than the limit. Total As levels in artificial soil were lower than the prevention value (15 mg kg^{-1}); sample 22 was slightly higher and soil sample 2 was 10 times higher than industrial (150 mg kg^{-1}) intervention criterion (Table 1).

No water acute toxic effect was observed in daphnids bioassays, but chronic effect was observed in algal bioassays. Fikirdeşici *et al.* (2012) found $\text{LC}_{50, 24\text{h}} = 0.509 \text{ mg L}^{-1}$ to As concentration for *D. magna* bioassays. Other authors found higher $\text{LC}_{50, 24\text{h}}$ (from 2.6 to 2.9 mg L^{-1}). At the present study, As levels were lower than those LC_{50} and not toxic to the daphnids tested. Algal bioassays may be a good indicator, as all points tested (2, 3, 9, 20, 22 and Y) were significantly different from the

Table 1. Total As levels in surface water and soils of Paracatu.

Samples and control	Total As	
	Surface water ($\mu\text{g L}^{-1}$)	Soil (mg kg^{-1})
2	23.6	1752.9
3	5.0	-
9	40.1	-
20	18.9	-
22	0.5	16
Y	22.1	-
Artificial soils	-	0.8

Table 2. Earthworms As contamination and bioassays results.

Soil samples	L (%)	WL (%)	As (mg kg^{-1})		
			Earthworms	Soil	BAF
Control	0	16.2	1.6	0.8	2
2	0	18.0	69	1752.9	0.04
22	20	18.2	2.1	16	0.1

L—Lethality; WL—Weight Loss.

control ($p < 0.05$) and showed $I = 37, 40, 37, 48, 19$ and 21 for points studied, respectively. Duester *et al.* (2011), testing As species (III and V) toxicity for *P. subcapitata*, found that both $\text{EC}_{50, 72\text{h}}$ were $>100 \text{ mg L}^{-1}$. Although the total As concentrations of surface water (Table 1) were lower, they showed chronic effects on the algal species tested.

Earthworms bioassay showed no acute and sub-lethal (weight loss) toxic effect by exposure to soils from Paracatu. The results in Table 2 showed higher BAF values for artificial soil and sample 22 (where soil arsenic is relatively low) than for sample 2, which has As levels two orders of magnitude higher. It has been reported by Watts *et al.* (2008), suggesting that elimination rates of arsenic may be increased at higher concentrations of arsenic. On the other hand, earthworm exposed to high levels of As in soils (Corrego Rico, point 2) showed As levels close to 30 times higher than the control (and Santa Isabel—point 22). This indicates that As from soils at Corrego Rico is bioavailable but the earthworms can mitigate As toxicity by biological saturation controls.

4 CONCLUSIONS

Aquatic organism bioassays indicated no acute but chronic toxicity in tested freshwater from Paracatu. This indicates that strong contamination

in the streams studied may occur but continuous inputs of contaminants may not cause acute toxicity. Although As BAF result at Corrego Rico was lower than in control, the actual bioavailability of As is high because the result of earthworms As level was 30 times higher than in control. This indicates that As from soils at Corrego Rico is bioavailable but the earthworms can mitigate As toxicity by biological saturation controls. Despite of this fact, bioassays with earthworms suggested no acute toxic effects.

REFERENCES

Dueter, L., van der Geest, H.G., Moellenken, S., Hirner, A.V. & Kueppers, K. 2011. Comparative phytotoxicity of methylated and inorganic arsenic- and antimony

species to *L. minor*, *W. arrhiza* and *S. capricornutum*. *Microchem J.* 97: 30-37.

Fikirdeşici, S., Altındağ, A. & Ozdemir, E. 2012. Investigation of acute toxicity of cadmium-arsenic mixtures to *D. magna* with toxic units approach. *Turk. J. Zool.* 36(4): 543-550.

Palma, P., Alvarenga, P., Palma, V., Matos, V., Fernandes, R., Soares, A. & Barbosa, I. 2010. Evaluation of surface water quality using an ecotoxicological approach: a case study of the Alqueva Reservoir (Portugal). *Environ. Sci. Pollut. Res.* 17(3): 703-716.