

# Influence of earthworms (*Nicodrilus giardi*, S., *Oligochaeta*, Lumbricidae) on arsenic of geogenic origin in the Swiss Jura.

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Arsenic occurs naturally in the environment, but rarely in dangerous levels. However, industry and agriculture have greatly increased concentrations in certain areas. Arsenic may be released to water by natural weathering of arsenic bearing rocks, by discharge from industrial facilities, by leaching from landfills or soil, or by urban runoff. Most arsenic, about 80%, generated by man is released to the soil. Industrial processes, solid waste from fossil fuel combustion and the use of pesticides constitute the major sources. Once in the soil, arsenic can be transported again by wind erosion as dust. Under aerobic conditions inorganic arsenic is present predominantly in a high (+5) oxidation state, mainly as arsenate,  $[\text{AsO}_4]^{3-}$ ; however arsenite,  $[\text{AsO}_3]^{3-}$ , the more reduced form of arsenic (+3), which is significantly more toxic than arsenate, predominates in anoxic soils. Usually, it is assumed that arsenic in soil above 20 parts per million (ppm) is higher than normal, and is a public health concern. Earthworms are widely used as indicators of soil contamination (Stafford and MacGrath, 1986; Edwards and Bohlen, 1996) and the "OECD-Earthworm Toxicity Test" (ISO 11268-1/2) is a widely used terrestrial ecotoxicological test which is applied both in prospective as well as increasingly in retrospective ecotoxicological research. Only a few studies have focused on earthworm survival in soils artificially or historically enriched in arsenic (Meharg *et al.*, 1998; Langdon *et al.*, 1999). In addition, all studies used epigeic worms that live mostly in organic layers (Bouché, 1972). Populations of the epigeic earthworm

*Lumbricus rubellus* resistant to very high concentrations of arsenate have colonised abandoned copper/arsenic mine and tungsten mine spoils that contain up to 50,000 ppm As on a soil dry weight basis (Langdon *et al.*, 1999, 2001). This level of arsenic would be fatal for most earthworms), therefore the physiological capability of these earthworms to become established on arsenic-contaminated soil must involve a mechanism for detoxifying accumulated arsenic in their tissues. However, the mode of arsenic detoxification in earthworm tissues is not clear (Langdon *et al.*, 2002). With their major role in the incorporation and decomposition of dead organic matter in the soil, and in the development and maintenance of soil structure, earthworms are valuable indicators of soil health. Earthworm bioturbation, *i.e.* casting and burrowing activities, may also have consequences for the speciation, solubility and toxicity of soil contaminants. Ireland (1983) stated that total cadmium in earthworm casts from contaminated soils was sometimes higher than in the surrounding soils for some species, whereas concentrations ratios of zinc, lead and copper in casts were more variable. In contrast, Hartenstein *et al.* (1980) reported that passage of sludge through the gut of the epigeic *Eisenia fetida* did not increase cadmium, nor copper, nickel, lead and never been made on arsenic. That's the reason why we have focused in our study on the influence of earthworms on arsenic dynamics. The originalities of our work are the following: i) the soil was naturally enriched in arsenic, *i.e.* a geogenic origin of the contaminant, ii) the earthworms

belonged to the anecic category, i.e. worms that mix thoroughly organic matter and mineral particles and build sub-vertical burrows, iii), arsenic was measured both in surface-casts and in burrows to estimate a potential concentration of arsenic in these microsites and its relative redistribution and availability compared to non-ingested soil. We worked in laboratory controlled conditions for a 2-months period, the soil (53% clay, 35% silt and 0.3% sand) was collected in the field, air-dried, sieved and remoistened prior to fill microcosms. The distribution and availability of arsenic were determined in the surface-casts and the burrows-linings of the anecic earthworm *Nicodrilus giardi* and were compared with non-ingested soil.

Our results showed that the total concentration of arsenic did not differ between soil and biogenic structures (casts and burrows). In contrast with the literature, granulometry was the same both in casts and soil, probably due to the initial low amount of sand in the soil. Sequential extractions demonstrated no significant variations in the redistribution of arsenic in casts despite their particular physico-chemical and biological processes (Schrader *et al.*, 1997; Le Bayon and Binet, 2005). Using a rising pattern of phosphates enriched solutions, we showed a concomitant increase of arsenic mobilization. However, the solubilization of arsenic was lower in casts than in non-ingested soil. The same tendency was observed using rainwater as an extractant instead of phosphates enriched solutions. These variations were strongly correlated with concentrations of solubilized iron, indicating that arsenic was probably desorbed from iron complexes. Looking at arsenic bio-accumulation by earthworms, we found a bio-concentration factor of 0.01 compared to 0.06 in earthworms extracted from a industrial polluted soil (Langdon, 2005).

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