Geoderma Regional 14 (2018) e00173

Contents lists available at ScienceDirect

Geoderma Regional

journal homepage: www.elsevier.com/locate/geodrs

Microbial community and heavy metals content in soils along the Curu River in Ceará, Brazil

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A R T I C L E I N F O

Article history:
Received 22 January 2018
Received in revised form 4 May 2018
Accepted 7 May 2018
Available online xxxx

Keywords:
Contaminants
Heavy metals
Microbial community composition
PLFA
Entisols
Watershed

A B S T R A C T

This study aimed to survey the soils surrounding the Curu River with respect to the content of heavy metals and microbial community, besides evaluating the effects of heavy metals on the microbial community. Soil samples were collected from the layers of 0–5 cm and 5–30 cm at 22 sites, close to areas possibly contaminated by heavy metals. The samples were analyzed for granulometry, pH, electrical conductivity, organic matter (OM) and the contents of arsenic, cadmium, cobalt, chromium, copper, molybdenum, nickel, lead and selenium. The responses of microbial structures to the different soil uses were evaluated using phospholipid fatty acid PLFA analysis. Canonical correlation was used to verify possible relations between groups of variables (soil physical-chemical characteristics, heavy metals and soil microbiological attributes). The soil chemical and physical characteristics (clay, OM, silt, pH and sand) contributed to explain the contents of heavy metals in this soil, but the behavior of the microbiological attributes cannot be explained by the heavy metals in this soil. According to the national standards of the Environmental Company of São Paulo State (CETESB), some sites in the studied area are contaminated by heavy metals.

1. Introduction

The Curu River watershed extends for 198 km, located in the North center of Ceará – Brazil, with an area of 11,719,392 km^2 exposed to the effects of the irregular rainfalls of the semiarid region and low water balance indices throughout the entire year (Brasil, 2010). Distinct environmental units are found along the Curu River, which are explored according to their natural potentials and particular conditions of use or exploration. These units are eventually used by city supply systems, big landowners, farmers and the small subsistence farmers who cultivate in the humid soil left by a river when its water level recedes. These users ultimately interfere with the environmental processes and conditions, due to intensive and, in many cases, inadequate use of these areas.

The drainage systems of the Curu River watershed permeate many sites of concentrated and diluted pollution, such as municipal headquarters and areas of farming and industry (Gorayeb et al., 2006). These potential pollution sources cause damages to the environment, such as pollution of surface waters and contamination of soils with heavy metals (HM) (Erdem et al., 2004).

Among the main anthropogenic sources of soil contamination are the HM, which are elements found in low contents in the agroecosystems (He et al., 2005). Some elements, including copper (Cu) and molybdenum (Mo), are essential to plant growth and are referred to as micronutrients (He et al., 2005). Some HM, such as cobalt (Co) and selenium (Se), are not essential to plant growth, but are necessary for animals and humans. Others, like cadmium (Cd), lead (Pb), chromium (Cr), nickel (Ni) and arsenic (As), have toxic effects on living organisms and are frequently considered as contaminants (Wan ngah and Hanafiah, 2008). HM can enter agroecosystems through the inheritance from the parent material of the soil or through human activities (Kimberly and William, 1999; Li et al., 2001; Wan ngah and Hanafiah, 2008). Soil contamination with HM and toxic elements, due to parent material or point sources, often occurs in a limited area and is easily identified. The repetitive use of chemical products rich in metals, fertilizers and organic correctives, such as sewage sludge, as well as wastewaters, can cause large-scale contamination (He et al., 2005).

Abbreviations: EC, electrical conductivity; OM and the contents of arsenic As, organic matter; Cd, cadmium; Co, cobalt; Cr, chromium; Cu, copper; Mo, molybdenum; Ni, nickel; Pb, lead; Se, selenium; CETESB, Environmental Company of São Paulo State.

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https://doi.org/10.1016/j.geodrs.2018.e00173

Irrigation constitutes a significant source of soil contamination by HM, especially when the water used comes from rivers that have received high pollutant loads (Arora et al., 2008; Liu et al., 2005).

Environmental and microbiological factors can influence the toxicity of HM, through degradation, biosorption and bioaccumulation processes in organelles or linked to proteins of the cellular interior of the microorganisms (Mapanda et al., 2015; Pereira and de Freitas, 2012). However, not all microorganisms have the same resistance to HM. Therefore, when a soil is contaminated with HM, a large part of soil microorganisms are the first living organisms to suffer the impacts. The HM can decrease the microbial biomass by directly killing or biochemically deactivating soil organisms (He et al., 2005; Wang et al., 2007).

Soil microorganisms help in the regulation of environmental processes, such as soil aggregation, nutrient cycling, degradation of xenobiotic compounds and gas balance (Fernandes and Chaer, 2010; Viana et al., 2011). According to the observations, the management of these processes occurs through complex interactions between different microbial groups, and currently there is the understanding on the necessity of adopting the microbial communities (MC) as basic units in the ecology studies (Drenovsky et al., 2010; Fernandes and Chaer, 2010).

One of the potential techniques to detect the toxic effects caused by HM on soil microorganisms is the analysis of profiles of phospholipid fatty acids, or soil PLFA (Frostegård et al., 2011). PLFA analysis is a technique very sensitive to variations in soil MC and has been used in studies on microbial ecology. In addition, it is widely used to observe variations that indicate physiological changes in the MC in response to an environmental stress factor (Fernandes and Chaer, 2010). Despite not allowing differentiation of microorganisms at the level of species, PLFA analysis provides a quantitative evaluation of the many groups inside the MC of the soil (Viana et al., 2011). PLFA analysis provides most of the information required for the characterization of MC in the environment, including biomass, composition, nutritional status and metabolic activity (White, 1983).

Despite the economic, social and environmental importance of the Curu River watershed for a significant part of the population inhabiting its surroundings and as a source of agricultural products for the supply of the metropolitan area of Fortaleza-CE, little information is found on the current conditions of the environmental quality of the Curu River watershed. Given the above, this study aimed to survey the soils surrounding the Curu River with respect to the contents of HM and MC biomass and structure, besides evaluating the effects of the heavy metals contents on the MC, through soil PLFA analysis.

2. Material and methods

The survey was performed in the Curu River watershed, which extends for 198 km and has its source located in the Serra do Machado (42°47′73 W; 94°97′519 S) and the mouth of the river in the Atlantic Ocean, between the cities of Paraipaba and Paracuru-CE, Brazil (49°38′ 0.87 W; 96°22′884 S). The area has average annual temperature of 26.3 °C, with maximum of 35 °C and minimum of 18 °C, and average annual rainfall of 800 mm, exposed to the effects of the irregular rainfalls of the semiarid region. The Curu River watershed has a predominant moderate to strong relief. This watershed was chosen because it was the first one to be created in the state of Ceará and because of the little information on the current conditions of the environmental quality of the Curu River.

For the survey of the contents of HM and the MC, 22 sites were georeferenced close to the main roads with intense traffic of vehicles and to urban, industrial and agricultural areas (Table 1). According to Kimberly and William (1999), Li et al. (2001) and Wan ngah and Hanafiah (2008), areas with these characteristics are considered as potential sources of heavy metals. The geographic coordinates of the 22 sampling sites along the Curu River are shown in Fig. 1.

Samples were collected in July 2013, using a hand riverside auger in the layers of 0–5 cm and 5–30 cm, close to the river shore. The collected samples were preserved in ice until arrival at the laboratory, where they were separated into two fractions. One fraction was air-dried, its clods were broken and it was sieved (2-mm grid) for the analyses of soil physical and chemical characteristics. The other fraction was used for soil microbiological analysis and was carefully packed in plastic recipients with capacity for 40 g, cooled at 4 °C and sent to the Water Management Research Laboratory of the USDA, Parlier-CA, USA.

Table 1
Soil classification, characteristics and land use types of sample collection sites along the Curu River – Ceará, Brazil.

SiBCS[a]	Soil taxonomy[b]	Site	Characteristics of site
Neossolos Litólicos	Entisols Lithic	1	It is located at the source of the river, has natural vegetation and does not human action
		2	Has a source of water for animals that are created close and does not human action
Luvissolos Crômicos	Aridisols	3	There is a weir, region of leisure for people, with intense antropic action, no vegetation and visible appearance of being a compacted area
		4	Area there is an animal leather processing factory and has no vegetation
		5	Area under a site of intense traffic of vehicles and realization of agriculture
Argissolos Vermelho-Amarelos Eutróficos	Oxisols	6	Recreation area, the population washes clothes and receives some of the city's sewage
		7	Area used in agriculture
		8	There is a dam for water storage for human use and it is an area of agriculture
		9	It is an area of intense urbanization and the neighboring areas are used with intensive agriculture that receive heavy loads of fertilizers and chemical defenses
		10	Area used with agriculture receiving large loads of fertilizers and chemical pesticides
		11	Area used with agriculture that receive heavy loads of fertilizers and chemical pesticides.
		12	Area used with intensive agriculture, receives great amount of fertilizers and chemical defenses and easy visualization of the contamination of the river water by eutrophication
Argissolos Vermelho-Amarelos Distróficos	Ultisols	13	Area under a site of intense traffic of vehicles and realization of agriculture
		14	Area close to the city, but with soil covered by secondary vegetation
		15	Area close to the city and receives part of the sewage of the city
		16	Area used for storing water to be used in agriculture and receiving large amounts of fertilizers and chemical pesticides
		17	Area used with intensive agriculture, receives great amount of fertilizers and chemical defenses
		18	Area of intense anthropic use, used for recreation and extraction of river area
Neossolos Quartzarênicos Órticos	Entisols Quartzipsamments	19	Deforested areas, without human use and used for grazing animals
		20	Areas with characteristics of dunes near a shrimp farm
		21	Area of wetland and has little human intervention
		22	The mouth of the Curu River

[a] Brazilian System of Soil Classification.
[b] Soil Taxonomy Classification System from USDA-NRCS.

Please cite this article as: Anjos, D.C., et al., Microbial community and heavy metals content in soils along the Curu River in Ceará, Brazil, (2018), https://doi.org/10.1016/j.geodrs.2018.e00173