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Land use impact on potentially toxic metals concentration on surface water and resistant microorganisms in watersheds

Luciana Maria Saran[a,*,1], Teresa Cristina Tarlé Pissarra[b,1], Géssica Aparecida Silveira[a,c], Milena Tavares Lima Constancio[a,c], Wanderley José de Melo[a,d], Lúcia Maria Carareto Alves[a,c]

[a] São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Department of Technology, Jaboticabal, Brazil
[b] São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Department of Rural Engineering, Jaboticabal, Brazil
[c] Agricultural and Livestock Graduation Program, School of Agricultural and Veterinarian Sciences, São Paulo State University (UNESP), Brazil
[d] Brazil University, Descalvado, Brazil

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ABSTRACT

Soil and water resources must be conserved and protected. However, the management of production activities causes a change in the quality of these natural resources due to accumulation in soil of potentially toxic metals. The objective of the present study was to identify the variety and paths of potentially toxic metals (PTMs), such as cadmium, lead, copper, chromium, nickel and zinc, which are associated spatially and temporally to soil and water. We also intended to isolate bacteria resistant to PTMs with important characteristics to be used in bioremediation processes. Water samples were collected every two months for one year (February–December/2014) at eight sites (P1–P8) and the soil samples were collected twice (February and August/2014) from twelve sites (S1–S12). Results indicated that agricultural land use impacts the environment, increasing the concentration of potentially toxic metals, mainly copper, zinc and chromium, in soil and water due to crop management. Ten bacteria resistant to all the metals studied were isolated, which could be used as tools for bioremediation of contaminated soils and water with those metals. The results would positively contribute to land use policy, and for the development of enhanced agricultural practices.

1. Introduction

Land impacts associated with agricultural and urban development can intensify runoff and increase erosion that can pollute areas downstream, and stream banks in river basins (Pacheco et al., 2014; Paul, 2017; Valle Junior et al., 2014, 2015). Due to anthropogenic inputs, the concentration of potentially toxic metals (Duffus, 2002) has increased in the environment, and a thorough understanding on the inputs will enhance our capability to predict land contamination. Singh and Kumar (2017) and Zhang et al. (2017a) related that potentially toxic metals have a wide distribution in the environment, mainly in rural and urban areas (Zhang et al., 2017b).

There are reports in the literature emphasizing that, mainly due to multiple agricultural, medical, industrial, domestic and technological applications, the concentration of a potentially toxic metals may exceed the regulatory standards and lead to harmful toxicity and bioaccumulation (Acosta et al., 2011; Ali et al., 2016; Chapman et al., 2016; Kadhum et al., 2015; Liu et al., 2016; Mokhtar et al., 2015). Therefore, it is important to know the actual concentration of PTMs in soil and water, the agricultural soil managements and other anthropic actions that contributed for the pollution in other to take providence for the depollution or to avoid other areas also be contaminated.

Potentially toxic metals like cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni) and zinc (Zn), and are of high concern due to their direct impact on human health and aquatic ecosystem (Marrugo-Negrete et al., 2017). Thus, land use and agricultural management practices, which are a source of additional degradation in watersheds, are particularly distressing. These metals need to be monitored carefully because their toxicity depends on several contributing factors and concentrations, and special consideration should be given to PTMs, which are of particular concern while implementing land usage policies. According to the U.S. Environmental Protection Agency (U. S. EPA, 1996) and the International Agency for Research on Cancer, an analysis of their environmental occurrence must be done to determine the human exposure due to their carcinogenicity risk (Tchounwou et al., 2012).

* Corresponding author.
E-mail address: lm.saran@unesp.br (L.M. Saran).
[1] Shared authorship.

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The land uses impact on soil and water and must be studied on subbasins to show if the anthropogenic management affect the aspects of water, geology, geomorphology and soil (Ali et al., 2016; Kelepertzis, 2014; Liu et al., 2016; Valle Junior et al., 2015). Studies have yet to produce a comprehensive assessment of PTMs pollution associated with agricultural activities to better understand the contamination sources of hydrogeology environments.

The ecosystems within watershed streams may be contaminated by PTMs concentration above their tolerance limits (Tóth et al., 2016; Singh and Kumar, 2017), compromising the environment (Valle Junior et al., 2015; Pacheco et al., 2015). In the present study the focus was on the potential impact of PTMs on natural resources, and the modification and conversion of land cover in agricultural lands and urban areas by the interaction of the variables in space and time. Therefore, spatial assessment of these PTMs should be investigated to evaluate the impacts of those pollutants. How these changes potentially affect the decisions of agribusiness and the consumer was also analyzed.

The objectives of this study were to determine and to understand how the concentrations of Cd, Pb, Cu, Cr, Ni and Zn linked spatially and temporally to water by modification of the land uses in watersheds, and analyze the concentrations of these metals in soil and water. In addition, a microbiological evaluation of water was performed to determine the percentage of bacterial isolates resistant to these metals. The new view on soil and water management is to develop strategies for water security in relation to PTMs, their toxicity to humans, and their potential to spread pollution. Furthermore, the possibility of using isolated bacteria is being studied in assisting bioremediation processes.

2. Materials and methods

2.1. Studied area

The studied area is located in the Northeast region of the State of São Paulo, Brazil (see location map in Fig. 1). The central geographical coordinates are latitude 21°15'22"S and longitude 48°18'58" W Gr and the specific boundaries were defined as the external limits of the watershed mapping units at Jaboticabal watershed (extent of 76 km^2) of the Córrego Rico Watershed, a watershed of the Mogi-Guaçu River, located in the 7th Hydrographic Zone of the State of São Paulo and corresponds to the 9th Water Resources Management Unit (CBH-Mogi-UGRHI-09, 1999; IBGE, 1971; Pissarra et al., 2004).

The climate, according to Köeppen classification is Aw (Melo et al., 2017), which is defined as a humid subtropical climate with a dry winter. The average temperature of the coldest month is below 18 °C and that of the hottest month above 22 °C. The average annual rainfall ranges between 1200 and 1500 mm, and the elevation of the Jaboticabal watershed ranges from altitudes of 450 and 650 m.

A dominant geologic feature is formed from the calcareous sandstones and sandy limestones of the Bauru Group (Suguio and Barcelos, 1983) and basaltic slopes that border this plateau with the Peripheral Depression of the Paraná Basin (Penteado and Ranzani, 1971). Mainly, in the higher and flatter portions of these hills are the Red Oxisols, whose material was originally basalt and the transition to the lower part of the hillside (near the bottom of the valleys) to eutrophic Latosols with clayey texture, originated from the products of the Sandstones' alteration to Basaltic (Andrioli and Centurion, 1999; Cunha et al., 2005). The watershed is described on general appearance of the entire area as undulating landscape. The subbasin hills are gentle topography, the state of the highest and lowest parts of the area is occupied by agricultural land uses and the valleys are occupied by rivers. It presents particular erosion surfaces and this erosive condition and distribution of soils are highly common in the State (Lepsch, 2010; Pissarra et al., 2010).

2.2. Water sampling

The water samples were taken from 8 locations that were representative of the Jaboticabal Watershed Streams Sites' water source. In selecting sampling points (P1 to P8) each locality was considered individually, particularly points uniformly that were proportional to the

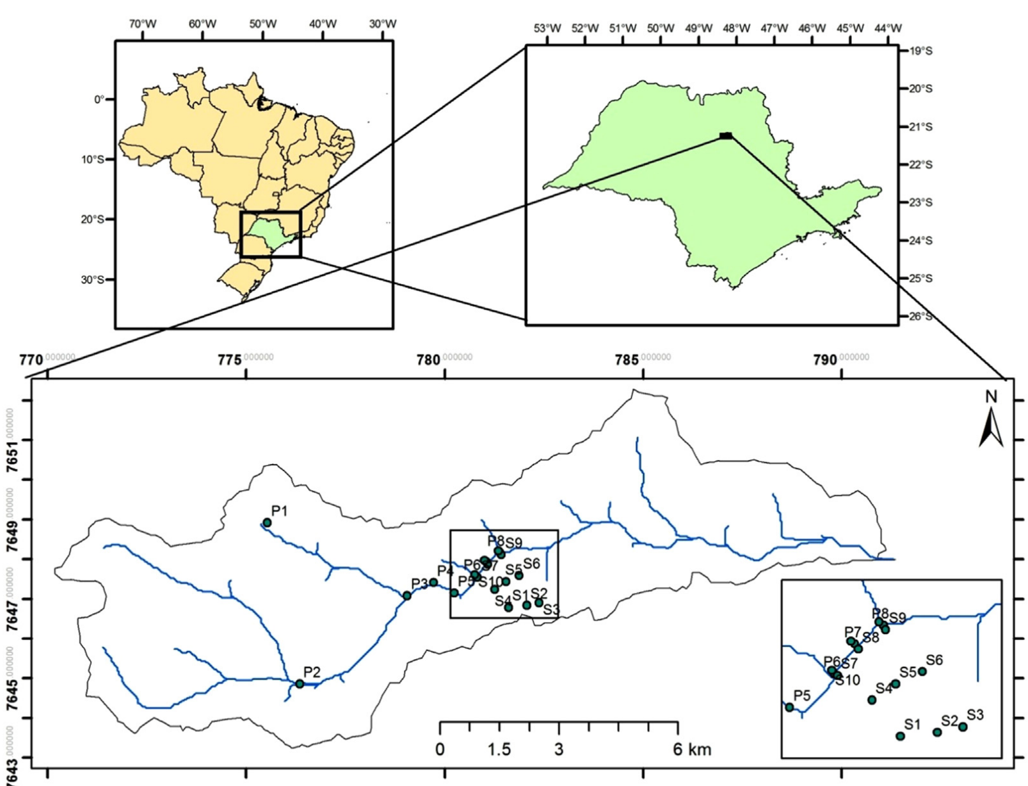

Fig. 1. Geographic watershed unit on the São Paulo State, Brazil (Jaboticabal Watershed) and the samples points (soil and water).