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JOURNAL OF ENVIRONMENTAL SCIENCES
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Characterization of soil fauna under the influence of mercury atmospheric deposition in Atlantic Forest, Rio de Janeiro, Brazil

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ARTICLE INFO

Article history:
Received 3 September 2014
Revised 20 December 2014
Accepted 26 December 2014
Available online 24 April 2015

Keywords:
Biodiversity
Litter
Microarthropods
Soil
Trace-element

ABSTRACT

The increasing levels of mercury (Hg) found in the atmosphere arising from anthropogenic sources, have been the object of great concern in the past two decades in industrialized countries. Brazil is the seventh country with the highest rate of mercury in the atmosphere. The major input of Hg to ecosystems is through atmospheric deposition (wet and dry), being transported in the atmosphere over large distances. The forest biomes are of strong importance in the atmosphere/soil cycling of elemental Hg through foliar uptake and subsequent transference to the soil through litter, playing an important role as sink of this element. Soil microarthropods are keys to understanding the soil ecosystem, and for such purpose were characterized by the soil fauna of two Units of Forest Conservation of the state of the Rio de Janeiro, inwhich one of the areas suffer quite interference from petrochemicals and industrial anthropogenic activities and other area almost exempts of these perturbations. The results showed that soil and litter of the Atlantic Forest in Brazil tend to stock high mercury concentrations, which could affect the abundance and richness of soil fauna, endangering its biodiversity and thereby the functioning of ecosystems.

Introduction

Currently, seventeen countries are considered megadiverse, by containing 70% of the world's biodiversity. Brazil is the first for harboring between 15% and 20% of the biological diversity of the planet and the largest number of endemic species, the largest tropical forest (the Amazon) and two of the nineteen hotspots worldwide (the Atlantic Forest and the Cerrado). The Atlantic Forest Biome extending through fifteen Brazilian states (totalling approximately 1,105,000 km^2 of continental extension) is the fifth most endangered forest area of the planet. In the state of Rio de Janeiro, only 20% is preserved (INPE, 2013), although in a fragmented and localized way. The biodiversity of these biomes has been degraded due to anthropogenic activities such as industry, which emit pollutants, compromising the quality of atmospheric, aquatic and terrestrial ecosystems, leading to an accelerated loss of species. The mercury (Hg) stands out among the global pollutants due its ease of dispersion and toxicity, since it can stay in the atmosphere for about 0.5–2 years (Liang et al., 2014). Approximately 4070 tonnes of mercury is introduced in the Earth's atmosphere every year (Mason et al., 1994; UNEP, 2013). Environmental variables such as rainfall, temperature, wind and solar radiation can influence in the Hg enrichment in forest soils. According to Sigler and Lee (2006) the increase of soil and air temperature were directly associated to promote greater Hg deposition, while factors as solar

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http://dx.doi.org/10.1016/j.jes.2015.01.009

radiation and water vapor did not influence the deposition. Teixeira (2008, 2012) showed negative correlation between the wind speed and rainfall. Fire (Dicosty et al., 2006; Melendez-Perez et al., 2014) and CO_2 concentration (Natali et al., 2008) have been also reported to collaborate with the high Hg deposition in forests. Most of the Hg input to ecosystems is through atmospheric deposition (Niu et al., 2011) coming from anthropogenic and natural sources and may be deposited into a forest canopy in gaseous and aerosol forms (Lindberg et al., 2007). Forest canopies can uptake atmospheric Hg more rapidly than other landscapes due to their large leaf areas and rough surfaces (Risch et al., 2012). The dry deposition velocity to forests for the Hg species (in order of relative abundance—gaseous elemental, oxidized or reactive, and particulate of Hg) can be 2–5 times larger than in other vegetated or non-vegetated surfaces (Zhang et al., 2009). This trace element has been found in litter, in Brazil in Atlantic Forest (Silva-Filho et al., 2006; Teixeira et al., 2012), and in China in Subtropical Mixed Forest (Wang et al., 2009) in the largest concentrations reported worldwide.

The Hg stock in litter to the horizon O (organic) in the soil is directly proportional to the quantity of produced litter (Silva-Filho et al., 2006), and this deposition is mainly related to weather, deposition in cold regions are weaker than in warm regions. Litter is one of the biggest sources of Hg accumulation in forest soils, affecting the terrestrial and aquatic trophic chain (Tabatchnick et al., 2012). The forest biome has a huge relevance in the elemental (Hg^0) atmosphere/soil cycling through leaf capture and posterior transference to soil by the litter (Grigal, 2002). The atmospheric deposition in forest areas can represent an important local sink in the biogeochemical cycle of this element (Lyman and Jaffe, 2012). Moreover, because it is a global pollutant, the effect of this sequestration could affect regional and even global background values.

Through litter decomposition the Hg is incorporated to the soil, which is considered as the environment that has the major biodiversity of the planet. Hundreds of thousands of species of invertebrates live in this environment, which have been playing important functions in the terrestrial ecosystems, fundamental for decomposition and mineralization processes of the organic matter and providing a series of environmental services for humans, with value estimated in hundreds of billions of dollars per year (Van Der Putten et al., 2004). Those services are being threatened by the ignorance of such animals and their importance, and by the progressive alteration of their natural habitats caused, among other factors, by soil contamination. Thus the soil edaphic fauna is a key tool to understanding the anthropogenic impacts in the environment. In this context, the qualitative and quantitative variations of the fauna can reflect the loss or diminishing of determined groups of the fauna, as well as, of the population and of specific species.

Due to the scarcity of studies assessing the ecological risk of atmospheric Hg deposition for edaphic fauna in tropical forest biomes, this work is based and focuses on the quantification of Hg levels in litter and soils, coming from atmospheric deposition, and the characterization of the fauna of two Units of Conservation of Atlantic Forest in the Rio de Janeiro state, Brazil.

1. Material and methods

1.1. Characterization of the forest areas

The study was performed in two Units of Forest Conservation (UFCs) of the state of Rio de Janeiro in Brazil, Três Picos State Park (Latitude: 22°35′52.24″S, Longitude: 43°14′21.15″O, altitude: 74 m) and Taquara Municipal Natural Park (Latitude: 22°30′ 8,76″S, Longitude: 42°51′21.95″O, altitude: 72 m). The first park is considered an urban forest and is located in an industrial zone at 12.4 km from a big petroleum refinery, which was activated fifty-two years ago and still works. The second park is inserted in a rural zone, away from industrial activities and at 18.2 km from the largest petrochemical complex in Brazil, which is under construction, beginning its functioning in 2016. The choice of these areas was based on the following factors: (1) the distance lower than 40 km of the possible Hg emission sources, since the largest rate of deposition occurs in these perimeter (Schroeder and Munthe, 1998); (2) the wind direction from the emitting source to the forests, South to North; (3) the similarity in the phytophysiognomy of the vegetation in the chosen altitudes, being both Lowland Rain Forest Dense; (4) the soils of the sampling of fauna and total mercury to the UFCs are of the same category, classified as Dystrophic Haplic Cambisol (Ta), according to EMBRAPA (2013); and (5) same geologic formation, being Santo Aleixo Unit, composed of garnet–hornblende–biotite granodioritic, rich in xenolits of paragneisse partially molten. This geology has no mercury in its composition (Guimarães, 1999).

According to the Köppen classification (1936), the climate in the region, for the two UFCs is Aw, hot and humid, with an average annual temperature of 24°C, and an average annual precipitation of 1299 mm in Taquara Municipal Natural Park (T), and 1473 mm in Três Picos State Park (P).

1.2. Physico-chemical analysis of the soil

For each UFC 20 sub-samples of soil of 20 cm depth were collected, with the aid of a Dutch auger, forming a composite sample of 500 g of soil. The analysis was performed in the Brazilian Agricultural Research Corporation — EMBRAPA — Agrobiologia, following the methods of physico-chemical analysis of the soil described in Nogueira and Souza (2005).

1.3. Characterization and quantification of accumulated litter

For quantification and characterization of accumulated litter, eight litter samples were collected using a square mold of 0.5 m^2, randomly placed in forest areas. The samples were dried in the lab oven at 65°C, and posteriorly separated and classified according to their stages of fragmentation: (1) layer of leaves non-fragmented (L portion); (2) layer of leaves fragmented (F portion); and (3) layer of humus, advanced stage of decomposition (H portion).

1.4. Analysis of mercury

For the determination of total Hg concentration in litter and soil, the samples were prepared by mechanical grinding.