ISSN:1984-2295

Revista Brasileira de Geografia Física

Homepage: www.ufpe.br/rbgfe

Heavy metal concentrations in the water of a dam by an open dump in Teofilândia, state of Bahia, Brazil

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Artigo recebido em 04/01/2018 e aceito em 14/02/2018

ABSTRACT

The objective of this work was to evaluate the concentrations of heavy metals (Cd, Pb, Cu, Cr, Mn, Ni, and Zn) in the water of a dam that is located by an open dump in the municipality of Teofilândia, Bahia, Brazil. Water samples were collected in six sampling points in the pre-rainy (May), post-rainy (June) and dry (November) periods in 2016 to assess the effects of the seasons on the heavy metal concentrations in the water body. The analyses of heavy metals were carried out using flame atomic absorption spectrometry and compared with the maximum concentrations established by the Resolution 357/2005 of the Brazilian National Environmental Council. The collection, conservation, and analysis of the water samples followed the methods described by the Standard Methods for Examination of Water and Wastewater. According to the heavy metal concentrations found, the water of the evaluated dam is compromised.

Keywords: semiarid, solid waste, heavy metals, water quality

Avaliação da contaminação por metais pesados na água do açude público na área de influência do lixão no município de Teofilândia-BA

RESUMO

O presente trabalho tem como objetivo avaliar as concentrações de metais pesados (Cd, Pb, Cu, Cr, Mn, Ni e Zn), na água do açude público, localizado em área de influência do lixão no município de Teofilândia-BA. Foram determinados 6 pontos amostrais e realizada a coleta de água nos períodos pré-chuva (maio), pós-chuva (junho) e seco (novembro) de 2016, para identificar as influências sazonais no corpo hídrico. As análises de metais pesados foram realizadas por espectrometria de absorção atômica por chama (GBC-Avanta) e comparados com os valores máximos permitidos pela Resolução nº 357/2005 do Conselho Nacional do Meio Ambiente (CONAMA). Os métodos adotados para as coletas, preservação, e análise das amostras seguem a padronizações descritas no *Standard Methods for Water and Wastewater Examination* (APHA, 2005). Os resultados obtidos nesse estudo mostram que a água do açude no entorno do lixão municipal, estão comprometidas quanto a sua qualidade.

Palavras-chave: semiárido, resíduos sólidos, metais pesados, qualidade da água

Introduction

Construction of dams is an alternative for increasing water availability in the Brazilian semiarid, since this region has prolonged droughts; however, little is known about these water bodies

(Freitas et al., 2011; Araújo et al., 2014). These water resources are very valuable to local communities due to their culture, and economic activities; however, they can negatively affect people and the environment, mainly due to human

actions—land use, pollution of springs, inadequate use of water for irrigation—that are responsible for the contamination of these water bodies and, consequently, for their unsuitability for use (Barreto and Garcia 2010; Araújo et al., 2014).

The disordered urbanization of most Brazilian cities has been causing changes in the environment, altering biological, physical, and chemical processes of natural systems, thus affecting directly or indirectly the quality of life of people (Nascimento et al., 2015).

According to Cavallete et al. (2013), several authors found heavy metal contamination of waters adjacent to solid waste disposal sites (Hypolito and Ezaki, 2006; Xiaoli et al., 2007; Aniceto et al., 2012). Solid waste by domestic, industrial, and agricultural activities is a serious environmental problem in large urban centers (Aniceto et al., 2012). Excess concentration of heavy metals in these materials in open dumps can favor their leaching.

Leaching is the physical process in which the liquids of solid wastes released during the decomposition process percolates through the soil profile (Cavallete et al., 2013). These liquids can also be carried by surface runoff to nearby springs, favoring the entering of heavy metals into the food chain and consequent accumulation and contamination of the biota (Oliveira and Jucá, 2004; Pradeep et al., 2005; Korf et al., 2008).

Impacts caused by urban waste extend to the general population through direct or indirect pollution and contamination of water bodies and water tables, depending on the water use, and absorption of toxic or contaminated materials (Batista and Freire, 2010). Potentially toxic metals are non-biodegradable chemical contaminants and tend to accumulate in living organisms, causing disorders and diverse diseases; however, they have been systematically released into the environment, affecting the quality of soils and waters (Oliveira

and Silva, 2013). The lack of access to good quality water is a risk to human health; it increases the occurrence of acute infectious diseases and cause or increase chronic diseases. (Razzolini and Günther, 2008)

Researches on physical and chemical characteristics of soils of irrigated areas and sediments deposited in water sources focused on heavy metals are still scarce in Brazil, especially in the Northeast region, mainly due to the high costs and complexity of the analyses (Brito et al., 2004).

These effects may be aggravated in areas with presence of open dumps, or sanitary landfills with structural defects or without an adequate drainage system. Therefore, urban solid waste is a source of environmental pollution when it is irregularly disposed in open dumps, as occurs in several places.

Similarly, the semiarid part of the Northeast region of Brazil lacks scientific studies on heavy metals in areas affected by open dumps, including the municipality of Teofilândia, in the Território de Identidade do Sisal. Thus, the objective of this work was to evaluate the concentration of heavy metals in the water of a dam that is located by an open dump in the municipality of Teofilândia BA, Brazil.

Methodology

Study area

The study was carried out in the municipality of Teofilândia, (8717676 to 8743471 N; 492732 to 520002 E UTM / WGS 84), in the Território de Identidade do Sisal, state of Bahia (BA), Northeast region of Brazil. Teofilândia is limited by the municipalities of Araci (north), Serrinha (south), Biritinga (east), and Barrocas (west) (Figure 1).

Figure 1. Location of the municipality of Teofilândia, state of Bahia, Brazil. Source: SIG-BA (2015) and LandSat 8 Image (2014).

The dam (BR dam) evaluated is alongside the BR116 Highway (8728073 N and 500468 E), at 2 km from Teofilândia, by an open dump (Figure 2).

Figure 2. Image of the highway, open dump, BR dam, and water collection points (P1 to P6). Source: Google Earth (2016).

Sampling and analysis

Six points along the dam were chosen for water collection and identified using a GPS device

(Etrex; Garmin) to assess the water quality, especially regarding concentrations of heavy metals (Table 1).

Table 1. Location and description of the water collection points in the BR dam, Teofilândia BA, Brazil.

Points	Coordinates		Description
P1	500469 E	8728007 N	Downstream from the open dump, near a channel that drains the waters to the other side of the highway.
P2	500384 E	8728081 N	Downstream from the open dump, approximately 100 meters from P1.
P3	500296 E	8728239 N	Downstream from the open dump, approximately 170 meters from P2.
P4	500238 E	8728370 N	Right bank of the dam, near a pig farm.
P5	500341 E	8728260 N	Approximately 150 meters from P4.
P6	500445 E	8728148 N	Near a fence by the Highway.

Water samples were collected in the pre-rainy (May), post-rainy (June) and dry (November) periods in 2016. These different sampling periods allowed the evaluation of seasonal effects on the heavy metal concentrations, due to their climatic differences, especially considering the leaching of materials from the open dump to the water of the dam due to precipitation events.

Water samples were collected at 30 cm from the surface water to avoid anthropogenic contamination and put into 1-L amber glass bottles containing 5 ml of HNO₃ (65%). Then, these bottles were labeled and kept under refrigeration in a polystyrene box for 24 hours until sent to the Laboratory of Technology and Sanitation (LABOTEC) of the State University of Feira de Santana (UEFS), Brazil.

The analyses of heavy metals—Cadmium (Cd), Lead (Pb), Copper (Cu), Chromium (Cr), Manganese (Mn), Zinc (Zn) and Nickel (Ni)—were performed in triplicates; 125 mL of each sample was added to 2.5 mL of hydrochloric acid (50%) and 0.5 mL of nitric acid (50%) and placed on a heating plate (80°C) until reaching 25 mL. The samples were then filtered through a 0.47-μm GFC membrane and read in a flame atomic absorption spectrophotometer (HG-3000; Avanta-GBC); the results were expressed in mg L⁻¹.

The water sample collection, conservation, and analysis followed the methods described in the Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

The results of the analyses of heavy metals were processed using descriptive statistics assisted by the Action tool of the Microsoft Excel 2013

program. Then, they were compared with the standards established by the Resolution 357/2005 of the Brazilian National Environmental Council (Conama) for freshwater of Class 2 (Brasil, 2005).

Results and discussion

The mean concentrations of heavy metals in the evaluated water samples are presented in Figures 3 to 8.

The cadmium concentrations were below the limit of detection of the device used (0.009 mg L⁻¹) in all sampling points and evaluation periods. Thus, these concentrations were lower than the maximum concentration (0.001 mg L⁻¹) established by the Conama in the Resolution 357/2005 for freshwater of Class 2 (Brasil, 2005).

Lead

The lead (Pb) concentrations in the evaluated water samples was higher than that established by the Conama (0.01 mg L⁻¹), except in P1 at the pre-rainy and dry periods (Figure 3). Pb concentrations ranged from 0.01 to 0.03 mg L⁻¹ in samples collected in the pre-rainy period, 0.01 to 0.02 mg L⁻¹ in the dry period, and had low variation in the post-rainy period, with average of 0.03 mg L⁻¹.

Figure 3. Mean concentrations (mg L^{-1}) of Lead in water samples collected from different points (P1, P2, P3, P4, P5, and P6) of the BR dam in Teofilândia BA, Brazil in May, June, and November 2016.

According to Paoliello and Chasin (2001), most Pb found in air, food, water, and dust is from emissions by automobiles—in places where this metal is still used in gasoline—and industrial activities. The Pb found in water is, in general, from effluent discharges from industries, and inadequate use of paints, and pipes and accessories based on lead (CETESB, 2009).

Silva et al. (2014) and Batista and Freire (2010), evaluated water of dams in the state of Paraíba, Brazil, and found Pb concentrations lower than the maximum concentration established by the Conama. Machado (2003) found higher Pb concentrations—0.002 to 0.16 mg L^{-1} —in water samples from the Gramame/Mamuaba dam, in Paraíba, Brazil, exceeding the maximum concentrations established by the Conama.

Copper

The copper (Cu) concentrations in the samples were above that established by the Conama (0.009 mg L^{-1}), except in P5 in the pre-rainy period, and P6 in the dry period (Figure 4). The maximum Cu concentration in P5 was 0.21 mg L^{-1} . This metal was not found in any samples collected in the post-rainy period.

Figure 4. Mean concentrations (mg L^{-1}) of Copper in water samples collected from different points (P1, P2, P3, P4, P5, and P6) of the BR dam in Teofilândia BA, Brazil in May, June, and November 2016.

Significant contents of Cu are found in ferrous metals, electronics, cans, bottle caps, and electrical wires. The high Cu concentrations found in the analysis indicate that the leachate from the decomposition of urban residues is reaching the dam water. Discharge of domestic effluents, with no processing for minimizing contamination of these wastewaters, and accumulation of solid waste on the dam banks were observed in the research period.

Batista and Freire (2010) found Cu concentrations exceeding the limit established by the Conama. It was attributed to the discharges of domestic and industrial effluents, and possible presence of submerged solid waste, or residues dragged through the dam galleries.

Chromium

Chromium (Cr) can be found in waters, air, rocks, soils, and is present in all biological organisms; however, natural occurrence of high Cr concentrations in water is uncommon. The mean concentrations of Cr found in all collection points and periods were lower than the maximum concentration established by the Conama (0.05 mg L^{-1}), except those of P5 (0.10 mg L^{-1}) in the pre-rainy period (Figure 5).

According to Barros et al. (2001), the Cr concentrations in freshwater are, in general, very low (less than 0.001 mg L^{-1}).

Figure 5. Mean concentrations (mg L^{-1}) of Chromium in water samples collected from different points (P1, P2, P3, P4, P5, and P6) of the BR dam in Teofilândia BA, Brazil in May, June, and November 2016.

The Cr concentrations found were different from those found by Silva et al. (2014), who reported Cr concentrations ranging from 0.00 to 0.06 mg L^{-1} . Batista and Freire (2010) found Cr concentrations lower than the maximum concentration established by the Conama in all evaluated points.

Manganese

Manganese (Mn) is found in waters mainly due to soil biogeochemical processes. According to Ayres and Westcot (1991), Mn rarely reaches concentrations of 0.1 mg L^{-1} in natural surface waters, presenting, in general, amounts below 0.2 mg L^{-1} .

The Mn concentrations ranged from 0.02 to 0.17 mg L^{-1} (Figure 6). P1 (0.11 mg L^{-1}), P5 (0.14 mg L^{-1}) and P6 (0.17 mg L^{-1}) presented concentrations exceeding the limits established by the Conama (0.1 mg L^{-1}) in the post-rainy period.

Figure 6. Mean concentrations (mg L^{-1}) of Manganese in water samples collected from different points (P1, P2, P3, P4, P5, and P6) of the

BR dam in Teofilândia BA, Brazil in May, June, and November 2016.

Nickel

Nickel (Ni) concentrations ranged from 0.019 mg L^{-1} (P3) to 0.077 mg L^{-1} (P5) in the pre-rainy period; from 0.013 mg L^{-1} (P1, P2, and P3) to 0.022 mg L^{-1} (P4) in the post-rainy period; and 0.021 mg L^{-1} (P5) to 0.064 mg L^{-1} (P4) in the dry period (Figure 7).

Figure 7. Mean concentrations (mg L^{-1}) of Nickel in water samples collected from different points (P1, P2, P3, P4, P5, and P6) of the BR dam in Teofilândia BA, Brazil in May, June, and November 2016.

P1 and P4 in the pre-rainy and dry periods, P5 in the pre-rainy period, and P2, P3 and P6 in the dry period presented Ni concentrations exceeding the limits established by the Conama (0.025 mg L^{-1}).

Ni and compounds with Ni are used in electroplating, and manufacture of stainless steel, Ni-Cd batteries, coins, and pigments. Ni concentrations in natural surface waters can reach 0.1 mg L^{-1} ; high concentrations can be found in mining areas (CETESB, 2009). The Ni concentrations found are probably associated with contamination from materials containing this element, since this metal reached maximum concentrations of 0.77 mg L^{-1} during the pre-rainy period. The main sources of Ni in garbage are alkaline batteries and fluorescent lamps; the presence of these residues in the open dump probably contributed to the increased Ni concentrations found.

Contrastingly, Silva et al. (2014) found Ni concentrations around 0.03 mg L^{-1} in a preliminary evaluation of waters of the Mussurú, and Mumbaba streams in João Pessoa, Paraíba, Brazil.

Zinc

The concentrations of Zinc (Zn) (Figure 8) were lower than the maximum concentration established by the Conama (0.18 mg L⁻¹) in all points and periods evaluated. The Zn concentrations found were around 0.01 mg L⁻¹. They ranged from 0.01 to 0.02 mg L⁻¹ in the pre-rainy period; from 0.03 to 0.04 mg L⁻¹ in the post-rainy; and from 0.02 to 0.13 mg L⁻¹ in the dry period.

Figure 8. Mean concentrations (mg L⁻¹) of Zinc in water samples collected from different points (P1, P2, P3, P4, P5, and P6) of the BR dam in Teofilândia BA, Brazil in May, June, and November 2016.

The Zn concentrations found in the present work confirm the reports of Philippi et al. (2004); they reported that the concentrations of Zn in surface waters are normal in the range of 0.001 to 0.10 mg L⁻¹.

Conclusions

According to the analyses of heavy metals in the water from the BR dam, alongside the BR 116, in Teofilândia BA, Brazil, Zn concentrations were lower than the maximum concentration established by the Brazilian legislation in the Resolution 357/05 of the Brazilian National Environmental Council for freshwater of Class 2; and high concentrations of Pb, followed by Ni, Cr, Cu, and Mn.

Higher concentrations of heavy metals are found in this dam in months with more precipitation, probably due to the waste disposed in the open dump next to the dam that is carried by runoff to this water body, and the percolation of the leachate generated by this open dump that reaches the water body after rainfall events. The heavy metals contaminating the water body were, in decreasing order Ni>Pb>Cr>M

n in the pre-rainy period; Pb>Ni>Mn>Zn in the post-rainy period; and Ni>Cu>Zn>Pb>Mn>Cr in the dry period.

Continuous studies for mitigating the contamination of this dam and informing the local population regarding its water quality is necessary, since the concentrations of these heavy metals are exceeding the limits allowed by the Brazilian legislation and endangering the of the people that use this resource.

Acknowledgements

The authors thank the Bahia State Agency for Research and Development (FAPESB) for the financial support for the development of this research; the Laboratory of Technology and Sanitation (LABOTEC) and the Laboratory of Geochemistry and Environmental Catalysis (LGCA) of the State University of Feira de Santana (UEFS) for assisting in the analyses of heavy metals.

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