HEAVY METAL CONTAMINATION IN THE JANDIÁ CANAL, MUNICIPALITY OF MACAPÁ-AP, BRAZILIAN AMAZON

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ABSTRACT

Objective: Evaluate contamination by heavy metals: Cadmium (Cd), Lead (Pb), Chromium (Cr), Manganese (Mn), Copper (Cu) and Nickel (Ni), from Canal do Jandiá, Macapá-AP.

Theoretical framework: This study based on theoretical reflections on environmental issues, the relationship between society and nature. The problems of heavy metals in the environment, environmental toxicity, and the uses of water.

Method: Techniques such as bibliographic and documentary research; information inventories; collection and analysis of bottom sediment samples. Collections were at 3 (three) points at the mouth of the channel, one on the channel bed and one on the Sérgio Arruda Bridge. An Atomic Absorption Spectrophotometer from the Atomic Absorption and Bioprospecting Laboratory (LAAB).

Results and conclusion: Observed that Cd, Pb, Cr and Ni presented values above those stipulated by legislation. And that seasonal variation contributes to the increase in the concentration of the metals Cd, Cr, Cu, Mn and Ni in the bottom sediment.

Implications of the research: This study will contribute to public policy measures, helping decision-making for environmental improvement in the municipality of Macapá-AP.

Originality/value: This research is of socio-environmental and scientific importance, as it evaluates the concentration of heavy metals and associates it with the lack of environmental sanitation and rainfall in the region.

Keywords: Bottom Sediment, Seasonal Variation, Environmental Legislation, Environmental Toxicity, Environmental Impacts.

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CONTAMINAÇÃO POR METAIS PESADOS NO CANAL DO JANDIÁ, MUNICÍPIO DE MACAPÁ-AP, AMAZÔNIA BRASILEIRA

RESUMO

Objetivo: Buscou-se avaliar a contaminação por metais pesados: Cádmio (Cd), Chumbo (Pb), Cromo (Cr), Manganês (Mn), Cobre (Cu) e Níquel (Ni), do Canal do Jandiá, Macapá-AP.

Referencial teórico: Esse estudo foi conduzido com base nas reflexões teóricas acerca das questões ambientais, da relação sociedade e natureza. Foram abordadas as problemáticas dos metais pesados no meio ambiente, toxidade ambiental, e os usos que se faz das águas.

Método: Utilizou-se de técnicas como levantamento bibliográfico e documental; inventários de informações; coleta e análise de amostras de sedimentos de fundo. Foram realizadas coletas em 3 (três) pontos na foz do canal, um no leito do canal e um na Ponte Sérgio Arruda. Utilizou-se Espectrofotômetro de Absorção Atômica do Laboratório de Absorção Atômica e Bioprospecção (LAAB).

Resultados e conclusão: Observou-se que o Cd, o Pb, o Cr e o Ni, apresentaram valores acima dos estipulados pela legislação. E que a variação sazonal contribui para o aumento da concentração dos metais Cd, Cr, Cu, Mn e Ni no sedimento de fundo.

Implicações da pesquisa: Este estudo contribuirá para medidas em políticas públicas, auxiliando a tomadas de decisão para melhoria ambiental do município de Macapá-AP.

Originalidade/valor: Esta pesquisa é de importância socioambiental e científico, por avaliar a concentração de metais pesados e associar a falta de saneamento ambiental e índices pluviométricos da região.


1 INTRODUCTION

Pollution of soil and aquatic systems by heavy metals is a factor affecting the quality of the environment and poses an imminent risk of human poisoning. The carrying out of research with the purpose of assessing the possible environmental impacts related to the increase in the concentration of heavy metals in the environment, is fundamental for quantifying and qualifying possible contaminations. Metals are distributed in the most diverse compartments, such as soil, water, air, sediments, living organisms and in the most varied chemical forms and properties (QUINÁGLIA, 2012).

According to Kawai et al. (2012), there are three classes of metals, the ones known as essential elements, i.e., the maintenance of life depends on them, represented by sodium, potassium, calcium, iron, zinc, copper, nickel and magnesium, the micro-contaminants, have a degree of need in our society but as the nomenclature suggests, they contaminate, represented by arsenic, lead, cadmium, mercury, aluminum, titanium, tin and tungsten and the essential and simultaneously micro-contaminants, has both characteristics, so conscious use is necessary, represented by the elements chromium, zinc, iron, cobalt, copper, manganese and nickel (2)

These metals are present in the environment, and their concentration can occur naturally or be enhanced by human activities. Several authors (NRIAGU; PACYNA, 1988; TEIXEIRA
et al., 2000; ALLEONI et al., 2005; GUILHERME et al., 2005) attribute to anthropic action the responsibility for the accumulation of these metals in nature, either by their indiscriminate dumping or by incorrect management.

In this context, the Jandiá Canal is included, which, historically, presents serious socio-environmental problems, such as infrastructure insecurity, lack of basic sanitation and low habitability conditions, which is linked to the socioeconomic condition of the local population, which shares situations of unhealthiness, mainly due to the inadequate dumping of waste in the region and the lack of sanitation.

In this way, this research sought to answer the following question: do the concentration levels of heavy metals found in the water and sediment samples taken from the Jandiá Canal, exceed the reference values defined by the relevant legislation, as far as contamination is concerned? If they extrapolate, is it possible to infer that the anthropic action potentiates this contamination in the study area?

To guide the response to the problem of this research, it was considered that the forms of local use and occupation, as well as the absence of effective public policies of sanitation, greatly potentize the contamination and pollution by heavy metals in the Jandiá Canal, as discussed by local scholars, such as: Cunha (2012), Cardoso et al. (2015), Ribeiro (2016), Santos (2018), Rodrigues (2018), Carvalho (2020).

2 THEORETICAL FRAME

Heavy metals are found naturally in the environment, due to weathering of the rocks, leaching and transport of the resulting disaggregated material by the fluvial and wind pathways (LOUREIRO et al, 2012). According to Passagli (2013), many metals are essential for the growth of all types of organisms, from bacteria to even human beings, but they are required in low concentrations and can damage biological systems.

However, the problems generated by high concentrations of metals are countless. In addition to harming the environment, these elements have a negative influence on human life. Human beings often interfere as a potentiator of the concentration of these materials in nature, which causes significant changes in the environment, mainly due to the degradation of natural resources.

For Muniz; Oliveira-Filho (2006), the metals originate from lithogenic processes and/or anthropic activities, such as the use of fertilizers in agricultural areas and in mining activity. Santi, Sevá Filho (2004) and Milanez (2007), cite that the main anthropogenic sources of heavy metals in the environment come from fertilizers, pesticides, urban and industrial waste, contaminated irrigation water, mining, smelting and refining of metals and in the urban environment; that is, industrial activities can be considered the main sources of heavy metal contamination. Still, Gonçalves et al. (2016), points out that the increase in metals in the environment is caused mainly by industrial dumping, household effluent dumping, use of fertilizers and pesticides, areas of dumping and disposal of solid waste, presence of cemeteries and natural composition of soils.

Metals such as manganese, cadmium, nickel, chromium (III), chromium (IV) have different characteristics and toxicity. The presence of these metals in water is mainly associated with effluent discharge and fertilizer leaching (PEREIRA; NASCENTES; COSTA, 2011). However, soil weathering and leaching are also examples of natural processes that generate the appearance of these heavy metals in water and soil (NRIAGU; PACYNA, 1988; TEIXEIRA et al., 2000; ALLEONI et al., 2005; GUILHERME et al., 2005; GAMBOA, 2019).

Heavy metals can enter the human body through inhalation, skin absorption and ingestion, the latter being the most common (ROCHA, 2009). For Oliveira; Schlünzen Junior;
Schlünzen (2013), the risk to human health occurs when metals accumulate on a large scale, causing adverse effects, when consumed in excess.

Thus, wastewater, which covers domestic effluents and industrial discharges, represents the largest artificial source of point pollution of water bodies, including pollution by heavy metals. These sources are considered to be point sources as the pollutants reach a given body of water in a concentrated form in space, with defined location and often with continuous production regime (LIMA et al., 2016).

3 METHOD

3.1 Field of Study

The municipality of Macapá, capital of the state of Amapá, is located in the southern mesoregion of Amapá and is limited to the north with the municipalities of Cutias and Amapá, to the east with the municipality of Itaubal and the Amazon River, to the south with the municipality of Santana and to the west with the municipalities of Ferreira Gomes and Porto Grande (Figure 1). It consists of five districts: Bailique, Carapanantuba, Fazendinha, Macapá (headquarters) and São Joaquim do Pacuí (IBGE, 2009). It has a land area of 6,563,849 km² and a population of 442,933 inhabitants, indicating a population density of 67.48 inhabitants/km² (IBGE, 2022).

The Jandiá Channel has its source located within the area of the Brazilian Agricultural Research Corporation-EMBRAPA, in an area of special interest, since it characterizes a spillway of rainfall runoff to the drainage bed. It has an approximate length of 4.2 km, covering the neighborhoods Pacoval, Jesus of Nazaré, São Lázaro and New Town, and draining part of the neighborhoods Santa Rita and Laguinho. It comprises the Hangover of Jandiá, with total
area of 2,380,156.25 m². It flows directly into the Amazon River, in the Cidade Nova neighborhood (CUNHA, 2012; CARDOSO et al., 2015; SANTOS, 2018).

It is one of the mooring points of vessels on the coast of Macapá, which depend on the tide regime to access it, since this condition determines the hours of entry and exit. The vessels that sail the Canal are small and serve for the distribution and disposal of wood from the resorts located there, as well as other goods that supply the local trade. At its mouth is a small port, where the boats dock (SANTOS, 2018).

The section surveyed is located between the Sergio Arruda Bridge (PSA) and the mouth of the Amazon River and has a length of 2160 km. The Canal is inserted in a peripheral region, far from the municipality's sewage network, without any sanitation infrastructure. It is lacking in land use planning measures, and is heavily polluted by the heavy occupation of the banks of this drainage. The waste and pollutants generated come from the activities of: trade and food industry, wood, trade in construction material, locksmith's shops, rubber shops, mechanical workshops, rubber shops, open markets, butchers’ shops, residences, gasoline station, among others.

### 3.2 Sampling Points

This is research of an applied nature, with a qualitative and quantitative approach and a descriptive and exploratory analysis. To do so, research techniques such as a bibliographical and documentary survey were used; information inventory; geographical location of the municipality; collection of sediment samples in the field; and analysis of the samples.

The spatial cut-off considers the Jandiá Canal, where it was possible to observe the level of criticality of the impacts in that place, arising from anthropic interventions and, on a smaller scale, from the influence of the Amazon River. The flowchart below illustrates the development of research (Figure 2).

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**Figure 2 - Research Development Flowchart**

**Source:** Adaptado de Cunha (2012)

The sediment samples were collected at five (5) strategic points along the Jandiá Canal (Table 1), three (3) at the mouth of the canal, one (1) at the canal bed and one (1) at Ponte Sérgio Arruda, over six (6) campaigns. The collection cycle was based on the tidal board, when the low tide times were used for its realization.
Table 1 - Geographical location of sediment collection points

<table>
<thead>
<tr>
<th>POINT NAME</th>
<th>COLLECTION LOCATION</th>
<th>GEOGRAPHICAL COORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEC</td>
<td>Left side of channel mouth</td>
<td>00°03'25.12&quot;N 51°02'20.59&quot;O</td>
</tr>
<tr>
<td>LDC</td>
<td>Right side of the mouth of the canal</td>
<td>00°03'20.29&quot;N 51°02'25.44&quot;O</td>
</tr>
<tr>
<td>FC</td>
<td>Mouth of canal</td>
<td>00°03'23.35&quot;N 51°02'23.68&quot;O</td>
</tr>
<tr>
<td>LC</td>
<td>Channel bed</td>
<td>00°03'35.82&quot;N 51°02'49.50&quot;O</td>
</tr>
<tr>
<td>PSA</td>
<td>Sérgio Arruda Bridge</td>
<td>00°03'49.80&quot;N 51°03'25.30&quot;O</td>
</tr>
</tbody>
</table>

Source: Prepared by the Authors (2023)

Sampling was sought in places that notably receive the highest intake of solid waste, water served and other effluents, as is the case of Ponte Sergio Arruda, the Canal Bed, the Mouth of the Canal and the right side of the Mouth of the Canal (Figure 3). The left side of the mouth of the Canal has less anthropic influence, as it still preserves native vegetation.

Figure 3 - Research Development Flowchart

3.3 Sample Collection and Analysis

The sediment collection was carried out at the low seas moments of the Amazon River (Figure 4), in places that, during the flood, remain submerged. For the collection of sediments, a handmade sample collector was used, given by the Atomic Absorption and Bioprospecting Laboratory (LAAB), of the Federal University of Amapá (UNIFAP). They were stored in plastic pots with a lid, capable of storing up to 200g of material, sterilized and identified with the name of the sample, the date and time of collection.

Once in the LAAB, the sediment samples were submitted to drying in the Drying and Sterilization Oven, model SL-100/A, SOLAB brand, at a temperature of 40°C, according to the technique described by Carter (1993). After drying, the samples were crushed with the use of crucible and pistil of porcelain, sieved, bagged, by the author, with identification and weighed in electronic scale, model FA2104N, Bioprecise brand.
After these initial processes, the heavy metal analysis consisted of the following phases: digestion, filtration and reading of the concentrations of the elements in these diluted samples, which was determined by the Flame Atomic Absorption Spectrophotometer (F-AAS), model AA-6300, brand SHIMADZU. This is one of the most widely used equipment for heavy metal analysis at part-per-million levels. The working principle is to raise the solution to high temperature, this situation will cause the elements to suffer a stress, which will allow each of the elements to absorb the specific radiation generated by the hollow cathode lamp, in a way directly proportional to the concentration of the metal in the sample.

4 RESULTS AND DISCUSSIONS

The results, in triplicate, of these analyzes were carried out on dry sediment samples. The levels identified for each of the heavy metals considered will be discussed below.

4.1 Cadmium concentration

The levels of cadmium found in the sediment samples collected along the Jandiá Canal showed variations in each of the samples, especially the first, which had the highest values.

Generally speaking, considering the six samples taken in the five points analyzed, the cadmium showed values above the acceptable value in the legislation. The highest levels analyzed were found in the 1st and 2nd samples. Considering the 1st collection, carried out on December 10, 2019, the cadmium levels showed variations and values above those admitted by the legislation used as reference, mainly in the CRL and LC, with concentrations of 3.0064 mg.kg\(^{-1}\) and 6.6667 mg.kg\(^{-1}\), respectively.

In the second collection, on 27 January 2020, it was found that the highest concentration of cadmium in sediment samples was at Ponte Sérgio Arruda (PSA), with a content of 1.5606 mg.kg\(^{-1}\), although all others had levels above the maximum acceptable reference values. Figure 5 illustrates the variation in the levels found in each of the points.
In this sense, the results of each collection point can be analyzed as follows:

- **LEC** - in the 2nd, 4th and 6th collections values were found above those established by the reference legislation, being the value of the 6th collection the most expressive, of 1.1254 mg.kg-1; as well as, in the 3rd collection, where the value found, of 0.8340 mg.kg-1, also exceeded the acceptable limit. This demonstrates the significant temporal variation where during the rainy season the cadmium concentration is higher than during the dry season;

- **FC** - the results found in the samples of the 2nd, 3rd, 5th and 6th samples, presented values above acceptable by CONAMA 344 (2004) and CETESB (2005), being the value of the 2nd collection, of 0.8843 mg.kg-1, the most relevant. The 3rd collection, referring to the period of drought, also showed a value higher than those of the benchmarks, of 0.7385 mg.kg-1. Therefore, the temporal variation of cadmium in CF during the rainy period was greater than in the dry period, although the difference between them is not significant;

- **LDC** - the results found in the samples of the 1st, 2nd and 6th samples, presented values above acceptable by CONAMA 344 (2004) and CETESB (2005), being the value of the 1st collection, of 3.0064 mg.kg-1, the most relevant. The 3rd collection, presented value within the benchmarks, of 0.4375 mg.kg-1. Therefore, the temporal variation of cadmium in LDC during the rainy period was greater than during the dry period;

- **LC** - in the majority of the collections values were found above those established by the reference legislation, the highest value being the 1st collection, of 6.6667 mg.kg-1. In the 3rd collection, the result found was 0.6315 mg.kg-1, that is, if we compare the values of the rainy period and of drought, there was a significant increase;

- **PSA** - in all the samples, the results found in the samples presented values above the acceptable by CONAMA 344 (2004) and CETESB (2005), being the value of the 2nd collection, of 1.5606 mg.kg-1, the most relevant. The 3rd collection, referring to the period of drought, also showed a value higher than those of the benchmarks, of 0.7631 mg.kg-1. Thus, the temporal variation of cadmium in PSA during the rainy period was greater than in the dry period, showing a significant increase between periods.

On the right bank of the Canal, repair and maintenance workshops are located for boats, resorts and petrol stations, as well as residences, which also dump domestic sewage, without
treatment, and solid waste. This scenario includes several sources of contamination, potentialized by anthropic action and with little attention from the public authorities.

4.2 Lead concentration

The lead values analyzed refer only to the 1st collection, held on December 10, 2019, since it was not possible to read the other collections. The reference parameter for lead in Resolution CONAMA 344 (2004) is 35 mg.kg⁻¹, and in CETESB (2005) it is 17 mg.kg⁻¹. The Sergio Arruda Bridge (PSA) was the highest result of 40.0278 mg.kg⁻¹ (Figure 6).

Lead is the heavy metal that is most closely related to petroleum and its derivatives, such as fuels and lubricating oils. Around and along the Channel, petrol stations and other fuels are located that are needed for inland and river transport.

![Figure 6 - Change in Lead concentration results in sediment samples background](Source: Prepared by the Authors (2023))

4.3 Chromium concentration

The levels of chromium analyzed in the sediment samples collected along the Jandiá Canal showed significant variations in each of the samples, especially the 2nd collection, which showed the highest values, all above the standards accepted by Resolution CONAMA 344 (2004) and by CETESB (2005).

The highest levels analyzed were found in the samples of the 2nd collection, held on January 27, 2020, when the chromium levels showed variations and values above those admitted by the legislation used as reference, mainly in PSA, with a concentration of 115.8238 mg.kg⁻¹. Figure 7 shows the chromium variations in the samples collected.
Thus, the results of each collection point can be analyzed as follows:

- **LEC** — in the 2nd collection, during the rainy period, the value found, of 44.8208 mg.kg$^{-1}$, exceeded the limits established by the legislation of reference. Comparing it with the value of the 3rd collection, of 9.8714 mg.kg$^{-1}$, referring to the period of drought, it is possible to observe a significant variation between them;

- **FC** - the highest value found during the rainy period, was recorded in the 1st collection, which contains 47.3182 mg.kg$^{-1}$ of chromium. In the 3rd collection, this metal presented a content of 8,9810 mg.kg$^{-1}$, revealing a sudden drop of chromium in the period of drought;

- **LDC** - in the 2nd collection, during the rainy period, the value found, of 39.0254 mg.kg$^{-1}$, is not within the standards of Resolution CONAMA 344 (2004), but is acceptable by CETESB (2005). When compared with the value of the 3rd collection, of 8.8011 mg.kg$^{-1}$, carried out at the end of the dry period, a significant increase in chromium concentrations is noted;

- **LC** - the highest chromium content found in the analyzes of the Canal Bed, was recorded in the 2nd collection, during the rainy period, with a value of 44.8798 mg.kg$^{-1}$. When compared with the value found in the 3rd collection, of 36.9634 mg.kg$^{-1}$, it is noted that there was a small variation between the rainy and dry periods;

- **PSA** — the highest value analyzed was found in the 2nd collection, during the rainy period, and corresponded to a content of 115.8238 mg.kg$^{-1}$ of chromium. This value, compared to the value of the 3rd collection, of 27.2426 mg.kg$^{-1}$, demonstrates an extremely significant variation from the rainy period to the dry period.

Along the road that gives access to the Jandiá Canal, some repair and refurbishment workshops of vessels and engines were identified, which use welding machines, paints and oils to carry them out, as well as, petrol station. Figure 16 (A) depicts a vessel and (B) an engine undergoing maintenance, and (C) a locksmith. These activities contribute to the dispersion of heavy metals on site.
4.4 Manganese concentration

The analysis of the levels of manganese obtained in the collections did not count upon reference values in the legislations used in this research. Its variation can be observed below, from the exposure of the analytical results of this metal at each of the sampling points visited (Figure 8).

![Graph](image)

**Figure 8** - Variation of Manganese concentration results in sediment samples background
**Source:** Prepared by the Authors (2023)

4.5 Copper concentration

All copper levels analyzed in the sediment samples collected along the Jandiá Canal, were within the standards allowed by Resolution CONAMA 344 (2004) and by CETESB (2005) (Figure 9).

![Graph](image)

**Figure 9** - Variation of Copper concentration results in sediment samples background
**Source:** Prepared by the Authors (2023)

In summary, the results of each point show:
- **LEC** - in the 6th collection, held on March 26, 2021, the highest copper content found, presented the value of 7.7222 mg.kg⁻¹; while in the 3rd collection, referring to the
drought period, the copper content was quantified at 6.6125 mg.kg⁻¹. The variation between them is not considered significant;

• FC - in the 1st collection, held on October 10, 2019, the highest copper content found, presented the value of 6.9091 mg.kg⁻¹; while in the 3rd collection, referring to the period of drought, the copper content was quantified at 3.9255 mg.kg⁻¹. The variation between them is considered significant, since, during the dry period, the quantity of copper found represented half the quantity of the rainy period;

• LDC - in the 6th collection, held on March 26, 2021, the highest copper content found, presented the value of 8.1189 mg.kg⁻¹; while in the 3rd collection, referring to the period of drought, the copper content was quantified at 3.6354 mg.kg⁻¹. The variation between them is considered significant;

• LC - considering the highest value found during the rainy period, of 10.0413 mg.kg⁻¹, referring to the 6th collection, it can be considered that there was a marked variation in relation to the value found in the 3rd collection, of 22.1662 mg.kg⁻¹. Unlike the other copper analyzes, in the Canal Bed, its concentration was higher in the dry period than in the rainy period;

• PSA - the highest value found during the rainy period was 21.7707 mg.kg⁻¹, recorded in the 6th collection. When compared with the value obtained in the period of drought, of 8.6725 mg.kg⁻¹, referring to the 3rd collection, it is considered that the variation between them was significant. In this sense, it is understood that the rainy period presented higher concentrations of copper.

Considering the surroundings of the Jandiá Canal, it is noted that part of the dwellings occupy the place irregularly, without drainage infrastructure. It is also possible to observe the practices of accumulation of solid waste and clandestine sewage pipes, which discharge effluents into the Canal and its mouth.

4.6 Nickel concentration

The most expressive results of nickel in the sediment were identified in the 1st collection, especially in LDC, LC and PSA, which correspond to 19.5170 mg.kg⁻¹, 24.8783 mg.kg⁻¹ and 20.7950 mg.kg⁻¹, respectively. In the 2nd collection, the values found in the LEC, FC, LC and PSA, exceeded those established by both Resolution CONAMA 344 (2004) and CETESB (2005) (Figure 10).
In this sense, the results of each collection point can be analyzed as follows:

- **LEC** - the highest levels of nickel found, presented the value of 17.9792 mg.kg⁻¹, in the 1st collection, and of 15.2349 mg.kg⁻¹, in the 2nd collection; while in the 3rd collection, referring to the period of drought, the nickel content was quantified at 8.1722 mg.kg⁻¹. The variation between them is considered significant;

- **FC** - the highest value of nickel concentrations found at the Mouth of the Canal was 15.3082 mg.kg⁻¹, during the 2nd collection. In the 3rd collection, carried out in the period of drought, the value identified was 7.0196 mg.kg⁻¹. This indicates that during the rainy season the concentration of nickel in the mouth doubles;

- **LDC** - the highest nickel content found, presented the value of 19,517 mg.kg⁻¹, recorded in the 1st collection; while in the 3rd collection, referring to the period of drought, the nickel content detected was 6,8054 mg.kg⁻¹. The variation between them is considered significant;

- **LC** - the highest nickel content found in the Canal Bed, was 24.8783 mg.kg⁻¹, during the 1st collection, in the rainy period. In the dry period, represented by the 3rd collection, the level of Ni totaled 15.8605 mg.kg⁻¹. The variation between the two levels can be considered significant, although both have values higher than those considered by the legislation;

- **PSA** — during the 1st collection, in the rainy period, the highest level of nickel was identified at Ponte Sérgio Arruda, corresponding to 20.7950 mg.kg⁻¹. In the 3rd collection, during the dry period, the level of Ni totaled 3.2870 mg.kg⁻¹. The variation between them proved to be significant, which reveals the intense concentration of the metal during the rainy season and its decrease during the dry season.

Around the Jandiá Canal, there are industrial, manufacturing, maintenance, electroplating and painting activities of aluminum vessels, which release Ni in the environment.

### 5 FINAL CONSIDERATIONS

The Jandiá Canal Basin is inserted into an urbanized and disorderly area, which has socio-environmental impacts, mainly due to the lack of basic sanitation structures and the disorganized use and occupation of the land.
Throughout the studied stretch, several potential sources of contamination were identified, which directly influence the concentrations of heavy metals found in the analyzed samples, posing a risk to the population and the local ecosystem.

Anthropic activity is the main driver of these risks, as downstream and along the Channel, sewage and household solid waste can be seen, as well as shipbuilding, small resorts, engine repair shops, petrol stations, etc.

The concentrations of heavy metals in the background sediment samples showed high values of cadmium, with emphasis on the 1st and 2nd collections on the Right Side of the Channel (LDC) and on the Channel Bed (LC); lead for the 1st collection, carried out at the LDC and at the Ponte Sérgio Arruda (PSA); chromium, being the highest levels analyzed in the sample of the 2nd collection, in the PSA; nickel, being the most expressive result identified in the 1st collection, in the LC.

Considering the analyzes and measurements carried out, it is concluded that all the sections studied in the Jandiá Canal are contaminated with heavy metals in the background sediment, except for copper, which showed concentration values below the detection limit of the apparatus.

The Canal do Jandiá is a water body of fundamental importance for the municipality of Macapá, since it determines the flow of vessels that carry cargo and people. In addition, in its mouth, there is a recreational area, which is used for sports, with football tournament, for seaside and even for artisanal fishing.

In this sense, this work could serve as a parameter for the competent bodies, in order to improve the surroundings, avoiding the increase of social vulnerability of residents, from interventions such as: cleaning and depollution of the Jandiá Canal, removal of clandestine sewage connections and urbanization of its surroundings.

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