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Analysis Of Physicochemical Parameters From The Waters Of The Hydrographic Basin From District Of Caraparu In Santa Isabel Of Pará (Brazil)

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Abstract
Justification: *The unplanned growth of cities has caused several impacts on water resources due to population growth, the presence of cemeteries, fairs and markets, the destruction of primary forests for food production, landfills, the construction of canals and barriers in water resources altering the natural flow, industrialisation, clandestine mining of sand, rocks and clay for construction, the introduction of exotic plant and animal species, the deforestation of ciliary forests for the construction of highways, streets, housing complexes and leisure areas, placing water resources at biophysiochemical risk, among others, and consequently causing impacts on the health of the population and environmental spaces, in this context, there is a need to identify the impacts and consequent risks to the local population, the environment and limnological resources of the Caraparu river basin in the Caraparu District in Santa Isabel do Pará, as to inform the population involved about the risks, causes and ways of mitigation so that they can establish participatory public policies to ensure the environmental and human health.*
Objectives: *the general objective was to identify the impacts of urban development on the limnological resources of the Caraparu district in the city of Santa Isabel do Pará, in the state of Pará (Brazil) and the consequences for human and environmental health; Specific objectives were to identify possible risk agents for local environmental degradation; analyse health and environmental impacts caused by human activities; present data to support control measures to contain the harmful impacts on water resources; identify risks and vulnerabilities impacts on human health due to the degradation of limnological resources.*
Methodology: *Water samples were collected from the Caraparu and Maguari rivers at different times and tidal situations (high and low), always in the morning and with in-locus analysis. The samples were collected between July 2023 and September 2024, with in locus physiochemical analysis of pH, electrical conductivity values of the water samples, sample and environmental temperature; Total Dissolved Solids; the samples were subjected to multiparameter test strips with 3 tests for each sample to identify: alkalinity, lead, bromine, nitrate, nitrite, iron, chromium (VI), copper, Mercury, fluoride, among others; was evaluated turbidity, colour, visibility, odour of the samples. The qualitative observational method was used to obtain information regarding anthropogenic environmental pollution in the studied river and its surroundings and the presence of wild flora and fauna.*
Conclusion: *the analyses performed on the samples were of physiochemical factors, in this sense it is suggested that bromine and chromium (VI) be monitored for a longer period, given their presence in the first two samples in the Caraparu River, even though they were not identified in the last two samples. Also, a study of biological parameters in the rivers studied in Caraparu in Santa Isabel do Pará (Brazil) is suggested, since at that time these parameters were not the objectives of this research. However, in the interviews there were interviewees who related some health signs and symptoms related to bathing in the Caraparu River, which also indicates the need for research into biological factors.*
Keywords: *Environmental chemistry, Chemophysical analysis, Limnology, Maguari River, Caraparu River.*

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I. Introduction

The municipality of Santa Isabel of Pará is located at latitude: 01º 17' 55" S, longitude: 48º 09' 38" W, with altitude: 24m[1]. Has an area: 720.9 Km^2, with a population of 73,019 inhabitants, with a diarrhea rate of 0.2% per 1000 persons. It presents only 10.7% of homes with adequate sewage, 19.9% of urban homes on public roads with trees and 6.3% of urban homes on public roads with adequate urbanisation (presence of manhole, sidewalks, paving, etc.)[2]

The main river in the Caraparu district in the municipality of Santa Isabel do Pará, is the Caraparu River, which begins in the city of Santa Isabel and flows into the Guamá River, with great importance for agriculture, tourism and, in some cases, consumption. However, its tributaries are also of great importance, with the Maguari River standing out.

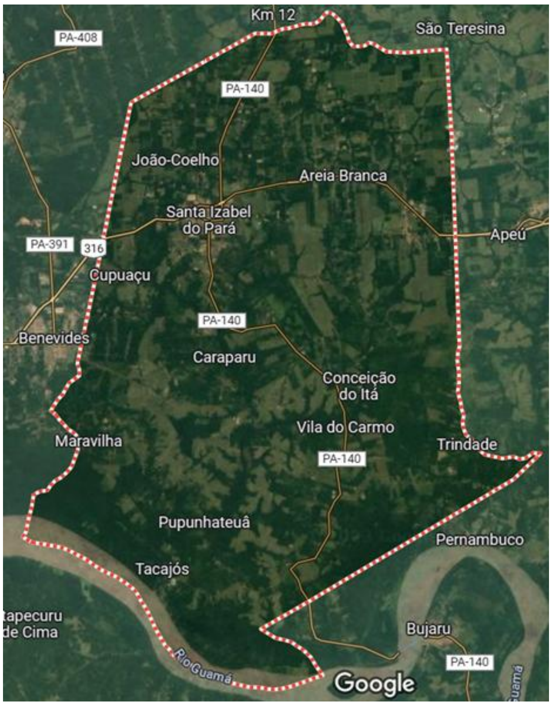
Large rivers have enormous economic, ecological and social importance. They are highly biodiverse ecosystems and sources of food for millions of people. In addition, they provide transportation through navigation and stimulate local and regional economies. The great rivers of South America are also enormously important from an economic point of view. In addition to meeting the protein needs of local and regional populations, they are used for navigation, irrigation, recreation, and sport fishing[3].

For recreational water users, risks associated with chemical hazards will depend on the type and concentration of the chemical contaminants, and the characteristics of the area. River flows, and tidal and wave action can dilute and disperse chemical discharges. In contrast, slow-flowing lowland rivers and lowland lakes may be more susceptible to contamination and provide low levels of dilution or dispersal. Water bodies subject to continuous or intermittent discharges could accumulate contaminated sediments. Potential sources of chemical hazards include onshore and offshore industrial discharges and spills; wastewater discharges; discharges from contaminated sites; local use of motorised crafts; petroleum receiving stations; pesticides; mining wastes; naturally occurring chemicals, including algal toxins[4].

The unplanned growth of cities has caused several impacts on water resources due to population growth, the presence of cemeteries, fairs and markets, the destruction of primary forests for food production, landfills, the construction of canals and barriers in water resources altering the natural flow, industrialisation, clandestine mining of sand, rocks and clay for construction, the introduction of exotic plant and animal species, the deforestation of ciliary forests for the construction of highways, streets, housing complexes and leisure areas, placing water resources at biophysiochemical risk, among others, and consequently causing impacts on the health of the population and environmental spaces.

Given this context, there is a need to identify the impacts and consequent risks to the local population, the environment and limnological resources of the Caraparu river basin in the Caraparu District in Santa Isabel do Pará, as well as to inform the population involved about the risks, causes and ways of mitigation so that they can demand participatory public policies that contain the scenario of impacts on water resources and ensure the quality of environmental and human health.

The general objective of this research was to identify the impacts of urban development on the limnological resources of the Caraparu district in the city of Santa Isabel do Pará, in the state of Pará (Brazil) and the consequences for human and environmental health. The specific objectives were to identify possible risk agents for local environmental degradation; analyse health and environmental impacts caused by human activities; present data to support control measures to contain the harmful impacts on water resources; predict possible impacts on human health due to the degradation of limnological resources.



Municipality Of Santa Isabel Of Pará. Source: Google Maps[5]

Caraparu River. Source: Google Maps[6]

II. Methodology

Water samples were collected from the Caraparu and Maguari rivers at different times and tidal situations (high and low), always in the morning and with *in-locus* analysis. The samples were collected between July 2023 and September 2024.

The pH was measured in the samples using a portable electronic pH meter and compared with test strips as a control. The electrical conductivity values of the water samples were measured using a portable electronic conductivity meter, expressed in µS/cm-1 (micronSiemes per centimetre), as well as the sample temperature and Total Dissolved Solids. For environmental temperature, an environmental thermometer was used.

The samples were subjected to multiparameter test strips with 3 tests for each sample to identify: alkalinity, lead, bromine, nitrate, nitrite, iron, chromium (VI), copper, Mercury, fluoride, among others. The Secchi disk was used to evaluate turbidity and visibility in centimetres, among others.

The qualitative observational method was used to obtain information regarding anthropogenic environmental pollution in the studied river and its surroundings and the presence of wild flora and fauna.

It is worth mentioning that: The climate in most Amazon areas is hot and humid, with a predominance of rain for six months and occasional rain for the rest of the other months. As it is largely located in the equatorial region, the high temperature and vapours from lakes, rivers, the ocean, etc., will contribute to the great Amazon humidity, which, in addition to the evapotranspiration of the plants that extract moisture from the soil that makes up the forest, will result in high atmospheric humidity and a significant level of annual rainfall[7]. Logically, this humidity, mainly due to rainfall aspects, will influence the analysis of the samples, in this sense, some data such as winds, environmental visibility, local temperature, tide, among others, were considered in the sample collections.

Several variables must be considered when collecting material for limnologic research, including: temperature; odour; pH; colour; transparency; turbidity; dissolved oxygen; electrical conductivity; chlorophyll; deep current; surface current; total suspended solids; total dissolved solids; current speed; wind speed, among others. For example, in a water column at a certain depth there are certain species of plankton, at another depth this can change due to the luminosity, speed of the current, among other specific aspects[7].

It is important to note that lotic systems, due to their flow and permanent interaction with their tributaries, their waters can present significant variables between the collection of one sample and another, given their transport capacity, decomposition of organic and inorganic matter, difference in water temperature by area and depth, among others.

III. Results And Discussions

Caraparu River					
Parameters	**Sample 1 22/112023**	**Sample 2 19/03/2024**	**Sample 3 25/06/2024**	**Sample 4 10/09/2024**	**Tolerability In Recreational Waters/Source**
Environmental Visibility	Normal	Normal	Cloudy	Normal	-
Environment Temperature Cº	35.1	31.4	31.5	33.1	-
Wind	No	No	No	Low	-
Ciliary Forest	Yes	Yes	Yes	Yes	Varies Depending On The Type And Width Of The River
Tide	Low	High	High	Low	-
Aquatic Macrophyte Presence	Yes	Yes High	Yes High	Yes High	Must Not Present Eutrophication
Ph	6,2	6,2	6,2	6,2	6-9
Temp Cº - Sample	27.9	26	25.5	27.2	-
Secchi Disc Depth	95cm	78cm	Not Applied	Not Applied	-
Colour	Dark Brown	Dark Brown	Dark Brow	Dark Brow	True Colour: Natural Colour Level Of The Water Body In Mg Pt/L – Conama[8]
Turbidity	Normal	Normal	Normal	Normal	≤ 40 Nephelometric Turbidity Units (Ntu) – Conama[8]
Odour	Normal	Normal	Normal	Normal	Absent Odour
Electrical Conductivity- (Ms/Cm).	0.046	0.024	0.042	0.040	Depends On Ions, Geological Aspects, Ph And Others
TDS (Total Dissolved Solids)	0.023	0.012	0.021	0.020	< 500 Mg/Litre – Conama[8]
Carbonate	0	0	0	0	Observe Ph, Presence Of Macrophytes And Other Factors.
Water Hardness	25	100	50	50	500mg/L Review
Lead	20	10	20	0	0,01mg/L – Conama[8]
Bromine	1	0	0	0	0,5mg/L (500 µg/L) Who[9]
Nitrate	0	0	0	0	10,0 Mg/L – Conama[8]
Nitrite	0	0	0	0	1,0 Mg/L – Conama[8]
Iron	5	0	0	0	0,3 Mg/L – Conama[8]
Chromium (Vi)	1	1	0	0	0,1 Mg/L
Copper	0	0	0	0	0,009 Mg/L – Conama[8]
Mercury	0	0	0	0	0,0002 Mg/L – Conama[8]
Fluoride	0	0	0	0	1,4 Mg/L – Conama[8]

Based On Determination For Fresh Water Salinity ≥ 0.5 ‰ Conama[8]

Caraparu River. Photo by Aureliano Guedes II.

Maguarí River (1)					
Parameters	**Samples 1 22/11/2023**	**Samples 2 19/03/2024**	**Samples 3 25/06/2024**	**Samples 4 10/09/2024**	**Tolerability In Recreational Waters/Source**
Environmental Visibility	Normal	Normal	Cloudy	Normal	-
Environment Temperature Cº	23.3	30.8	30.0	28.9	-
Wind	No	No	No	Low	-

Ciliary Forest	Yes	Yes	Yes	Yes	Varies Depending On The Type And Width Of The River
Tide	Low	High	High	Low	-
Aquatic Macrophyte Presence	Yes	Yes	Yes High	Yes High	Must Not Present Eutrophication
Ph	6.2	6.2	6.2	6.2	6-9
Temp C° - Sample	26.6	26.2	25.7	27.7	-
Secchi Disc Depth	Not Applied	Not Applied	Not Applied	Not Applied	-
Colour	Dark Brown	Dark Brown	Dark Brown	Dark Brown	True Colour: Natural Colour Level Of The Water Body In Mg Pt/L
Turbidity	Normal	Normal	Normal	Normal	≤ 40 Nephelometric Turbidity Units (Ntu) – Conama[8]
Odour	Normal	Normal	Normal	Normal	Absent Odour
Electrical Conductivity-(Ms/Cm).	0.104	0.038	0.048	0.074	Depends On Ions, Geological Aspects, Ph And Others
TDS (Total Dissolved Solids)	0.052	0.019	0.024	0.037	< 500 Mg/Litre – Conama[8]
Carbonate	0	0	0	0	Observe Ph, Presence Of Macrophytes And Other Factors
Water Hardness	25	100	200	50	500mg/L
Lead	20	10	20	0	0,01mg/L Conama[8]
Bromine	1	0	0	0	0,5 µg/L Who[9]
Nitrate	0	0	0	0	10,0 Mg/L – Conama[8]
Nitrite	0	0	0	0	1,0 Mg/L – Conama[8]
Iron	0	0	5	0	0,3 Mg/L – Conama[8]
Chromium (Vi)	0	0	0	0	0,05 Mg/L – Who[9] 0,05 Mg/L Conama[8]
Copper	0	0	0	0	0,009 Mg/L – Conama[8]
Mercury	0	0	0	0	0,0002 Mg/L – Conama[8]
Fluoride	20	25	25	0	1,4 Mg/L – Conama[8]

Based On Determination For Fresh Water Salinity ≥ 0.5 ‰ Conama[8]

Maguari River In 2024. Photo by Aureliano Guedes II.

The chemical quality of water is measured by identifying the component in the water, using specific laboratory methods. Such chemical components must not be present in water above certain concentrations determined with assistance of epidemiological and toxicological studies. Tolerable limit concentrations mean that the substance, if ingested by an individual with an average physical constitution, in a certain daily amount, during a certain period of life, added to the expected exposure of the same substance through other means (food, air, etc.), subjects this individual to an unacceptable risk of developing a resulting chronic illness. Two important groups of chemical substances, each with specific origins and effects on human health, are inorganic chemicals, such as heavy metals, and organic chemicals, such as solvents[10].

Turbidity is important to check for suspended particles that, in excess, can hinder the passage of light, damaging phytoplankton, some types of important bacteria, photosynthesis of macrophytes, among others. In the case of the Caraparu and Maguari rivers, at the sample collection site in different periods, it presented ≤ 40 nephelometric turbidity units (NTU), as normal, without harming photosynthesis and other important actions.

Secchi disc depth is a qualitative value because it depends on the observer's vision and the solar radiation in the probed environment, in addition to the influence of organic and inorganic materials that make up the water. In the case of this research, when for some reason, for example, the riverbed is visible, due to low tide or other reason, the use of the Secchi disc is not applicable.

In the Caraparu River, when possible, the use of the Secchi disk allowed visibility between 78cm and 95cm, always presenting the water colour dark brown, both in normal river visibility and in environmental visibility, being normal or cloudy, with normal turbidity. In the Maguari River, in the district of Caraparu in Santa Isabel, the Secchi disk was not applied, due to the good visibility of the riverbed, even presenting the colour dark brown, both in normal river visibility and in environmental visibility, being normal or cloudy, with normal turbidity.

The predominant dark colour in the waters of the Santa Isabel hydrographic basin in the State of Pará is due to the large contribution of organic compounds from trees that fall and decay, flowers, fruits, leaves and roots of the ciliary forest, in addition to aquatic macrophytes, influencing the turbidity, colour and pH of the waters of rivers, streams, among others[11].

Chemically pure water does not conduct electricity; however, if acids, bases or salts are dissolved in it, the solution will conduct an electric current, and chemical transformations will also occur [12]. In the case of waters of a limnological nature, they will be chemically influenced by sediments, substances transported by leaching, rainwater, aquatic and terrestrial biota, anthropogenic and natural pollution, among others, therefore, presenting in their chemical composition substances that have a greater or lesser degree of electrical conductivity.

The electrical conductivity of water constitutes one of the most important variables in Limnology, as it can provide information both about the metabolism of the aquatic ecosystem and about important phaenomena that occur in its drainage basin. Among the information that can be provided by electrical conductivity values includes information on the magnitude of ionic concentration. The ions most directly responsible for electrical conductivity values in inland waters are the so-called macronutrients (calcium, magnesium, potassium, sodium, carbonate, sulphate, chloride, etc.), while nitrate, nitrite and especially reactive soluble phosphorus have little influence. The ammonium ion can only have an influence at high concentrations; the daily assessment of the electrical conductivity of water provides information about important processes in aquatic ecosystems, such as primary production (reduction in values) and decomposition (increase in values); electrical conductivity can help detect sources of pollution in aquatic ecosystems; geochemical differences in the tributaries of the main river or a lake can be easily evaluated with the help of electrical conductivity measurements[13]. It is important to know that the electrical conductivity of water can also be related to the presence of salts, tide and elements leached into the river by rain.

The electrical conductivity of the Caraparu River varied from 0.024 to 0.046 and that of the Maguari River in the Caraparu district in the city of Santa Isabel varied between 0.038 and 0.104, both influenced by the Total Dissolved Solids, which were between 0.012 and 0.023 in the Caraparu River and 0.19 and 0.052 in the Maguari River, also influenced, among others, by the rainiest period in the region and the tide, where the data were higher at high tide.

The water temperature in lotic systems varies daily and seasonally, due to factors such as climate, altitude, type and extent of ciliary forest and contribution of groundwater. This temperature sets limits to the geographic distribution and physiology of organisms, influencing reproduction, survival and the life cycle of organisms[3]. At water temperature in tropical regions, conductivity values in aquatic environments are more related to the geochemical characteristics of the region where they are located and the climatic conditions (dry and rainy season), but can also be influenced by the trophic state, mainly in environments under anthropogenic influence[13].

Temperatures, both environmental and water, are important related to water density, preservation of microfauna and microflora, mainly nitrifying bacteria, among others, and are important in measuring pH. In this sense, the variation in the temperature of the water samples and the environment shows the characteristics of the hot humid climate of the studied region, therefore with a strong influence on the characteristics of the flora, fauna, hardness and pH of the samples[14].

The temperatures of the samples of water in Caraparu River varied, in the different collection periods, between 25.5ºC and 27.9ºC, while the environmental temperature varied between 31.4ºC and 35.1ºC. in the various measurement periods. The samples of water in Maguarí River temperatures of the varied between 25.7ºC and 27.7ºC, in the different collection periods, while the environmental temperature varied between 23.3ºC and 30.8ºC. in the various measurement periods. These temperatures, among other factors, influence the increase in water acidity by breaking down some water molecules, generating carbonic acid (H_2CO_3) that mix with water.

The pH and plant and animal communities in aquatic ecosystems exhibit close interdependence. aquatic communities and interfere with pH, just as pH interferes in different ways with the metabolism of these communities. In communities, pH acts directly on cell membrane permeability processes, therefore interfering with intra and extracellular ionic transport and between organisms, for example, through the assimilation of CO_2.[15]

The presence or absence of carbonate ions defines hard water rivers or acidic water rivers with low concentration of carbonate ions[3]. Carbonate (CO_3^{-2}), considered an inorganic carbon ion, related to the pH of the water, it may be related to minerals leached from the banks of rivers, type of sediment, among others, making the water even more acidic due to carbonic acid; however, the processes of decomposition of plant and animal remains by microorganisms, eutrophication of plants, organic components of domestic sewage, respiration of fish and other shellfish, animal and plant decomposition, among others, in these rivers and their banks will generate organic carbon, also making the water more acidic. Acid rain, resulting, among others, from the burning of fossil fuels, fires, industrial chimneys, among others, also contributes to the acidity of limnic waters.

In the rivers researched in the Caraparu district, the identified carbonate rate was 0.00. The presence of carbonates in the Maguarí and Caraparu rivers at the sample collection sites in the Caraparu district in the city of Santa Isabel do Pará was insignificant in terms of risks to human and environmental health. However, lotic waters should always be monitored, especially because there are small and medium-sized industries nearby and agricultural activities, in addition to the urbanisation of the district studied.

The pH is also related to the hardness of the water, in the case of the Caraparu, on the perimeter of Caraparu district in the municipality of Santa Isabel, in all sample collections were 6.2 and water hardness from 25 to 100, which is classified in hardness as soft water, in addition to showing homeostasis, even with changes in tide, rainy season, sample collection period, among others, which can also be proven by the absence of carbonates in water samples collected at different period. Therefore, the water hardness in Caraparu river presenting no environmental risks and/or risks to human and livestock health.

In Maguari river, on the perimeter of Caraparu district in the municipality of Santa Isabel, in all sample collections, the pH was 6.2 and water hardness from 25 to 200, with an average of 85, which is classified in hardness as soft water, in addition to showing homeostasis, even with changes in tide, rainy season, sample collection period, among others. Which can also be proven by the absence of carbonates in water samples collected at different period. Taking that in account the water hardness, the Maguari river presents no environmental risks and/or risks to human and livestock health.

In limnic waters (rivers, lakes, lagoons, wells, etc.) it may contain barium, bicarbonate, calcium, chlorides, strontium, fluorides, phosphates, magnesium, nitrates, potassium, sodium, sulphates, among others of soil origin through leaching, atmospheric, tributary rivers, anthropogenic influences, among others[7].

The main natural sources of trace elements for the continental aquatic environment are the weathering of rocks and the erosion of soils rich in these materials. Recently other sources of trace elements have assumed great importance: industrial activities, through solid tributaries that are released directly into the atmosphere and liquids that are released into small streams or directly into rivers and lakes; Hg in mining activities; domestic effluents and surface water from areas cultivated with chemical fertilisers and mainly from those where agricultural pesticides are used (these contain the most varied trace elements such as: Cd, Hg, Pb, Cu, etc.). The atmosphere is also an important source of trace elements for aquatic ecosystems. There are several sources that enrich the atmosphere with trace elements, which through wet and dry precipitation can reach the aquatic environment. Among these sources, marine and biogenic aerosol stand out, resulting from the disintegration and dispersion of plants and animals, natural fires, particles of volcanic origin, and others carried by the wind (dust) and mainly industrial emissions directly into the atmosphere (anthropogenic source)[16].

The simple change in metal valence transforms the slightly toxic trivalent chromium into the aggressive and carcinogenic hexavalent chromium[17]. Hexavalent chromium Cr(VI), among the various ionic forms of Cr, is the most toxic. This is generally industrial, by products widely used for pigment production, leather tanning, wood processing, chrome plating, metallurgical and chemical industries, stainless steel manufacturing, welding, cement production, ceramics, glass, etc. Cr(VI) levels have increased in soil, water and air, mainly due to increased use by industries and inadequate disposal of these residues in the environment[18].

In the Maguarí River in the Caraparu district of Santa Isabel, the transition metal Hexavalent Chromium was not detected in any sample during the different periods. However, in the Caraparu River it was identified in the first samples. In nature, Hexavalent Chromium is rare, and some bacteria can process it in small quantities; in large quantities, the processing bacteria will not be able to perform their task, and the origin is suspected to be industrial or agricultural processes. The presence of Hexavalent Chromium appeared in the first two sample collections in the Caraparu River, and was not repeated in sample collections at other times. However, there is a need for monitoring to identify whether it is related to the rainy season in the region, where it could originate from residues from agricultural processes, contaminating the soil and reaching the river through leaching due to rain during the period and/or through possible contamination from industrial processes. In any case, monitoring is necessary given the toxicity of Hexavalent Chromium, which causes dermatitis, contact allergy, kidney disease, intoxications, cancer and other diseases. However, also there is a need to treat domestic sewage to ensure better quality of water in the aforementioned river and industries must always be monitored and recommended to carry out efficient and effective maintenance of heavy metal residue filtration processes. The same applies to automotive paint shops.

In general, inorganic lead salts have low solubility in water, except for nitrate, chlorate and, to a lesser extent, lead chloride. Lead forms stable organic compounds, that is, when its atom is bonded to a carbon atom, such as tetraethyl lead and tetramethyl lead. These compounds, both colourless liquids, have low solubility in water and are volatile[19]. However, a water source that is in contact with minerals containing lead sulphide, or through natural, industrial or anthropogenic contamination of this metal, where penetration via the gastrointestinal, dermal and/or respiratory tract may have cumulative effects on individuals, which, when reaching a level above the tolerability threshold, may cause pathologies related to the transport of calcium in the body, in the gastrointestinal tract and problems in the central nervous system (CNS) and peripheral nervous system (PNS) in a diffuse manner[7].

In the first three sample collections, both in the Maguarí River and in the Caraparu River, in the Caraparu District in Santa Isabel in the State of Pará, trace elements of lead were identified, only testing negative in the last sample, requiring tracking to identify the origin and whether this could happen again, given the risk to environmental and human health.

Lotic systems, as they present flow and permanent interaction with their tributaries, their waters can present significant variables between the collection of one sample and another, given their transport capacity, decomposition of organic and inorganic materials, difference in water temperature per area and depth, among others[11].

As for mercury, the ability of organomercurial compounds to efficiently cross cell membranes significantly increase its retention in organisms (high biological half-life) and results in its bioaccumulation and biomagnification throughout trophic chains. Thus, most of the mercury present in the tissues of aquatic organisms is in the form of methylmercury, although the levels of inorganic mercury are much higher than the organomercurial forms. It is believed that the formation of methylmercury in the aquatic environment occurs mainly through a reaction mediated by microorganisms (e.g. sulphate-reducing bacteria). However, other abiotic mechanisms (photochemical methylation, transalkylation, etc.) are also capable of producing methylmercury in the environment[19].

Mercury toxicity in the body can result in various pathologies, both, acute and chronic, mainly in the central nervous system, respiratory tract, urinary tract, gastrointestinal tract, and haematopoietic system, resulting in dementia, depression, stomatitis, insomnia, among others[7]. However, in the samples collected and analysed in the Caraparu and Maguari rivers in the Caraparu District area in the city of Santa Isabel, the presence of mercury was not identified.

The nitrite concentration is always very low (< 60 mg $N\text{-}NO_{-2}.\ \ell^{-1}$), as this chemical substance can be reduced chemically and/or through the activity of bacteria that reduce nitrate or oxidise ammonium. Especially in tropical waters, this concentration is very low and is often below the method's detection limit. Nitrite may occasionally accumulate in pockets with oxygen tensions below 1mg $O_2.\ell^{-1}$ and in conditions of low stratification[3]. Inorganic nitrate is highly soluble and abundant in waters that receive high concentrations of nitrogen, resulting from the discharge of domestic sewage or agricultural activities[3].

Nitrogen, when oxidised, will result in nitrites and nitrates which, as a nutrient for plants, can cause eutrophication of aquatic plants, resulting in increased oxygen consumption, causing competition with aquatic fauna, resulting in migrations or extinction of certain species of fish, crustaceans, etc., and attracting other species that are tolerant to low amount of dissolved oxygen in the water, for example: *Arapaima gigas*, *Colossoma macropomum*, *Electrophorus electricus*, *Geophagus brasiliensis*, *Hoplosternum littorale* and others.

In the rivers surveyed, no significant quantities of nitrites and nitrates were detected at the time of sample collection.

In addition to water levels and rainfall, biomass, primary productivity and, consequently, the population dynamics of aquatic macrophytes are affected by several other abiotic factors, among which physical factors (e.g. ecosystem morphometry, water velocity, temperature and underwater radiation), chemical factors (e.g. water and sediment nutrients, and inorganic carbon) and physicochemical factors (e.g. pH) can be highlighted. However, these factors affect each biological type of aquatic macrophyte differently. In addition to the effects of abiotic variables, aquatic macrophyte populations are also affected by biological interactions, especially competition (intra and interspecific), herbivory and facilitation[20].

A large quantity of free floating macrophytes of the species *Pristia stratiotes* can be observed in the Caraparu River, characterising eutrophication. It is worth noting that during some of the team's incursions into that river, city hall workers were observed removing large quantities of these macrophytes from the water to promote the tourist use of the area. This mechanical removal of the large excess of this species reduces shading for other species and the silting of certain areas of the river, exodus of local aquatic biota and its effluents in the

Caraparu district such as the Maguari River, contributing to better oxygenation of the Caraparu River and its effluents. The main negative point is the reduction in shelter for some fish species and the availability of food and nutrients for other species, for example, macro-invertebrates and micro-invertebrates, among others.

There is a need to identify whether eutrophication is natural or artificial, if artificial, to track the source, diagnose the causes and develop projects to minimise or contain the harmful impacts on the Caraparu River and its tributaries and effluents, such as the Maguarí River, which is already beginning to show eutrophication by *Pristia stratiotes* in the areas influenced by the Caraparu River.

Pristia stratiotes. Photo by Aureliano Guedes II.

Several species of fauna were observed during the collection of water samples, among which stand out: *Ardea alba*, *Bradypus tridactylus*, *Boa constrictor*, *Bothrops atrox*, *Cebus apella*, *Cichla ocellaris*, *Columbina passerina, Electrophorus electricus*, *Eunectes murinus, Gampsonyx swainsonii, Guerlinguetus sp., Pitangus sulphuratus, Saimiri sciureus, Tamandua tetradactyla, Turdus fumigatus*, *Vanellus chilensis*, among others; As for flora, several species were observed, including: *Astrocaryum vulgare*, *Bertholletia excelsa*, *Caladium bicolor*, *Dinizia excelsa*, *Endopleura uchi*, *Euterpe oleracea*, *Fittonia albivenis*, *Hevea brasiliensis*, *Oenocarpus bacaba*, *Oenocarpus mapora*, *Spondias mombin*, *Symphonia globulifera, Theobroma grandiflorum*, among others.

Riparian and ciliary forest in Caraparu with emphasis on *Ardea alba*. Photo by Aureliano da Silva Guedes, PhD.

Euterpe oleracea. Photo by Aureliano da Silva Guedes, PhD

Lotic systems are affected by the following modifications: pumping water for irrigation or public or private supply (farms), which alters the flow and structure of rivers; organic and inorganic pollution from industrial and agricultural sources (point and diffuse sources). Pesticides, herbicides, heavy metals and discharge of untreated sewage are some of the threats to the integrity of rivers; intensive land use, which leads to an increase in suspended material and the discharge of substances and elements in large quantities into lotic systems; introduction of exotic species, which alter the food web and the natural process of community interaction; removal of ciliary vegetation, which is extremely important in maintaining buffer conditions for rivers. This removal, in addition to reducing the organic matter available to fish and invertebrates, no longer protects the banks and slopes of rivers, altering their morphometry; construction of dams for hydroelectricity and public supply; alteration of floodplains and flooded areas associated with dams for agriculture, construction of canals or urbanisation; construction of canals, bridges and passages, which interferes with the functioning of rivers, alters the substrate (physical and chemical compositions) and removes and affects organisms; construction of large areas for irrigation, with considerable withdrawals of water for this activity, contaminated by domestic (sewage) and industrial waste, are the two biggest threats to lotic systems[3].

In an interview with residents, some referred to the Caraparu River as polluted. One resident reported that, “The increase in 'mururé' (*Pristia stratiotes*) has been occurring for two years, and that it may be related to pollution”; another interviewee said that he “didn't like to bathe in the Caraparu River, because it made my skin feel as if there was mud on top of it and it itched afterwards”; another interviewee reported that, “I thought that a nearby factory was causing pollution”. The fact is that some seasonal or perennial substances were present in collected samples, requiring tracking of the polluting source, since there are some factories and small agricultural areas very close to the Caraparu and Maguari rivers.

Modelling the eutrophication process is very important as a mechanism for solving this problem (recovery of the lake, dam or river, minimisation of effects). Defining the process for the purposes of introducing the model implies identifying the boundaries of the systems, time scales and subsystems. The definition of the spatial and temporal scales and of the subsystems obviously depends on in-depth limnological and ecological knowledge of the system[3].

Caraparu river eutrophication by *Pristia stratiote*s. Photo by Aureliano Guedes II.

Maguari river eutrophication by *Pristia stratiotes*. Photo by Aureliano Guedes II.

In the case of anthropogenic pollution, the main sources are caused by population growth, in many cases, with disorderly urban growth, therefore, without planning, with the main consequences being: changes in river flows, cemeteries, deforestation of ciliary forests, industrialisation, among others. The growing need for food production will reflect an increase in pollution risks in rural areas, through extensive agricultural activities, where chemical products for soil correction, if misused, will generate nutrients that, when falling down the gradient in lakes, rivers, Amazonian wells, among others, causing eutrophication, as well as deforestation and the introduction of exotic species, etc. To generate energy for the consumption of these populations and their industries, there is a need for large-scale energy production, whether through charcoal and/or mineral coal, burning fossil fuels, construction of hydroelectric plants, among others, resulting in damage to surface and underground water resources; another factor is clandestine mining that, without production criteria, silts up rivers, streams and lakes, as well as contaminating them with heavy metals; among many others[7].

The establishment of the practice of the four Rs, where the waste management philosophy would be aimed at decreasing the volume of waste through: reducing the amount of materials used (source reduction); reusing materials once formulated; recycling materials to recover components that can be manufactured again; and recovering the energy content of materials if they cannot be used in any other way[21].

An important technique used in pollution prevention is life cycle analysis (or assessment), which consists of accounting for all inputs and outputs at the different stages of a product's life, from the extraction of raw materials to final disposal. This type of analysis from start to finish of a product (or process) can be used to identify the types of environmental impact and their magnitudes, both the natural resources used, and the pollution produced. The results of a life cycle analysis can be used in two ways: to identify opportunities to minimise the overall environmental burden of a product over its life cycle, and; compare two or more alternative products, with the aim of determining which is more beneficial to the environment[21].

It is increasingly clear that human health is closely linked to the conditions of the natural environment. Chemicals released into an environment far from inhabited areas can pose a health hazard by accumulating in the food chain. Other chemicals can have adverse effects on crop growth and kill birds or fish of great economic value. Neither a cloud of dangerous gases nor contaminants in river or ocean waters know natural boundaries. The adverse effects of a chemical on wildlife may be the first indication of an early danger to the human organism. The disappearance of non-target species such as bees, birds and butterflies may be the first sign of deteriorating conditions[22].

IV. Conclusion

The analyses performed on the samples were of physiochemical factors, in this sense it is suggested that bromine and chromium (VI) be monitored for a longer period, given their presence in the first two samples in the Caraparu River, even though they were not identified in the last two samples. Also, a study of biological parameters in the rivers studied in Caraparu in Santa Isabel do Pará (Brazil) is suggested, since at that time these parameters were not the objectives of this research. However, in the interviews there were interviewees who related some health signs and symptoms related to bathing in the Caraparu River, which also indicates the need for research into biological factors.

The aquatic compartmental environment is the one that suffers the most impacts from pollution, since what is in the air and soil can somehow directly or indirectly reach rivers, streams, lakes, lagoons, seas, oceans, reservoirs, among others, and can even reach aquifers. In this sense, there is a need for investments in biorefineries and biofuels, sustainability projects, solid waste management, use of agricultural waste, incentives for industrial recycling and reuse of materials, biopolymers and biomonomers and other biodegradable materials, improvement of urban sanitation technologies, education for conscious consumption, efficient and effective environmental management programs, production of renewable energy, adequate treatment of wastewater, public policies to guide the conscious use of water, replacement of chemical fertilisers with organic fertilisers among others, in addition to controversial measures such as combating consumerism and reproductive education, among other actions.

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