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UNPLANNED OCCUPATIONS AND THEIR DAMAGE TO SURROUNDING WATER BODIES - A CASE STUDY IN THE MUNICIPALITY OF PERUÍBE

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Abstract: Unplanned occupations have been a growing concern in urban areas, causing negative impacts on the environment and public health. The aim of this study was to investigate the damage caused by the occupation of allotments located near water bodies in an area of the municipality of Peruíbe without sewage systems. A review of the literature and applicable legislation covered concepts related to unplanned occupations and their environmental impacts, as well as a case study on monitoring water bodies. The research methodology included field data collection and qualitative and quantitative analysis of the data obtained. The contributions of this study include the identification of the main impacts of these occupations, an analysis of the legislation on the classification of water bodies, as well as proposing possible mitigation measures and good practices for the proper management of these occupations. The results indicate that the water bodies in the region studied present critical problems in terms of physical, chemical and biological aspects compared to the standards established in current legislation. This discussion could help formulate more effective public policies to protect water bodies and promote sustainable urban development in the municipality of Peruíbe.
Keywords: Environmental Impacts, Environmental Monitoring and Sustainability

INTRODUCTION

Disordered urbanization and unplanned occupations have become increasingly common in many Brazilian cities. This lack of planning leads to serious environmental, economic and social impacts, especially on the surrounding water bodies, which are affected by pollution and degradation resulting from human activities (BRASIL, 2015).

The municipality of Peruíbe, located on the south coast of São Paulo, has faced this problem. Disorderly urbanization and the lack of effective public policies for environmental control and management have affected the municipality's water bodies, which are fundamental for maintaining biodiversity and the local population's quality of life.

In view of this, it is essential to carry out a study that analyzes damage to the surrounding water bodies due to unplanned occupations, in order to better understand the magnitude of the problem and propose solutions to minimize its negative impacts. This case study in the municipality of Peruíbe is therefore of great importance and relevance for understanding the problem in question and for developing more effective and sustainable public policies in the Brazilian urban context.

Unplanned occupations are characterized by a lack of proper urban planning and the absence of effective public land management policies. These occupations usually occur in areas of environmental preservation, such as riverbanks, hillsides and mangroves, as well as other risk areas, such as regions subject to floods, landslides and other natural disasters (SANTOS, 2017).

The negative impacts of unplanned occupations on the environment are many and include: deforestation, soil erosion, air pollution, soil and water contamination, among others. In addition, the lack of basic infrastructure in these areas, such as basic sanitation and waste collection, can further aggravate the situation, increasing the risk of diseases and epidemics (FARIAS, et al., 2018).

In the specific case of water bodies, unplanned occupation can cause a range of environmental impacts, such as reducing water quality, degrading aquatic habitat and reducing biodiversity. Disordered urbanization can also increase the occurrence of flooding and other problems associated with the inadequate occupation of river banks and other bodies of water.

Understanding the importance of the surrounding water bodies is fundamental to understanding the relevance of research into unplanned occupations and their damage to these natural resources. In the specific case of the municipality of Peruíbe, it is important to note that the region is known for its wealth of water bodies, such as rivers and streams, which play a fundamental role in maintaining biodiversity and promoting human well-being.

The surrounding water bodies are important for regulating the climate, as they act as a source of humidity and help to reduce the ambient temperature. They are also fundamental for maintaining soil quality, as they are responsible for recharging aquifers and promoting the circulation of nutrients. Unfortunately, these bodies of water have faced many challenges in recent years. Disorderly urbanization and unbridled population growth have led to the inadequate occupation of river banks and other bodies of water, which generates a series of negative environmental impacts, such as water pollution, degradation of aquatic habitat and a decrease in biodiversity (SANTOS, 2017).

The research aims to provide an in-depth understanding of the impacts of unplanned occupations on water bodies in the municipality of Peruíbe, contributing to scientific knowledge on the subject. The results obtained can provide input for the formulation of more effective public policies for the management of water bodies and the control of unplanned occupations, with a view to preserving the environment and protecting public health.

OBJECTIVES

To evaluate the water quality of the water bodies affected by unplanned occupations, using physical-chemical and microbiological indicators; to identify the main challenges and consequences of unplanned occupations for the preservation of the water bodies under study.

THEORETICAL BACKGROUND

IRREGULAR OCCUPATIONS

Unplanned occupations refer to human settlements established in urban or rural areas without proper planning in terms of infrastructure, regulation and land use management. These occupations usually take place illegally or informally, without following the urban planning and environmental guidelines established by government agencies and without considering the socio-environmental impacts.

Unplanned occupations often lack basic infrastructure, such as water supply, basic sanitation, electricity, public transportation, paved roads, among others. This lack of adequate infrastructure can result in precarious living conditions for residents, contributing to health, safety and quality of life problems.

The disorderly urban expansion resulting from unplanned occupations can cause a number of negative socio-environmental impacts. These include soil degradation, soil sealing, water pollution and loss of biodiversity, among others. Lack of proper planning can also lead to inappropriate construction, deforestation, solid waste dumping and air pollution, affecting environmental quality and the health of the local population (BRASIL, 2015).

The main problems associated with unplanned occupations are disorderly urban expansion, water pollution where unplanned occupations often do not have adequate sewage treatment and solid waste management systems, which can result in the pollution of water bodies such as rivers, lakes and groundwater, social problems where the lack of land regularization in these areas can result in legal uncertainties, insecurity in land tenure and difficulties in obtaining credit and financing for housing improvements (FARIAS, et al., 2018).

ENVIRONMENTAL IMPACTS

Unplanned occupations can have significant environmental impacts, especially in relation to water bodies. Lack of proper planning can lead to water contamination from solid waste, domestic and industrial effluents, as well as inappropriate use of water resources, deforestation and siltation, among other problems. They can often have solid waste management problems, which can lead to garbage accumulating in unsuitable areas, such as riverbanks, streams and lakes. The lack of collection, treatment and proper disposal of waste can result in the contamination of water by toxic substances and pollutants present in solid waste, damaging water quality and affecting aquatic life and human health.

They often do not have adequate sewage treatment systems, resulting in the direct release of domestic and industrial effluents into water bodies. These effluents can contain chemical substances and pathogens that contaminate the water, compromising its quality and putting the health of the communities that depend on these water resources at risk.

In addition, a lack of planning can result in the silting up of water bodies such as rivers and lakes, due to soil erosion, deforestation, inadequate removal of vegetation and inappropriate occupation of areas adjacent to water bodies. Siltation can lead to a decrease in the depth of water bodies, a reduction in water storage capacity, alteration of aquatic ecosystems and an increased risk of flooding (SILVA; LINKE, 2018).

IMPACTS ON PUBLIC HEALTH

Unplanned occupations can have significant impacts on the public health of the local population. The increased risk of waterborne diseases, the inappropriate use of water resources and the contamination of water by solid waste, domestic and industrial effluents in unplanned occupations can lead to an increased risk of waterborne diseases such as diarrhea, cholera and hepatitis A.

The disorderly occupation of unplanned areas can lead to the population being exposed to chemical and biological pollutants from industrial activities, unsuitable agriculture, inadequate solid waste disposal and air and water pollution, which can cause negative health impacts such as respiratory, dermatological and other health problems related to exposure to toxic substances;

The lack of adequate basic infrastructure can result in limited access to health services, basic sanitation, regular solid waste collection, drinking water supply, electricity and public transportation. This can affect the quality of life of the local population and increase the risk of disease and other health problems (BRASIL, 2017).

IMPORTANCE OF WATER BODIES

The importance of the surrounding water bodies, such as rivers, lakes, dams and lagoons, in the municipality of Peruíbe is associated with various aspects, including the environment, society and the local economy.

Bodies of water are essential ecosystems for maintaining local biodiversity, sheltering various species of aquatic fauna and flora. They are important for the water cycle, acting as natural regulators of water flow and contributing to water purification and the balance of adjacent terrestrial ecosystems;

They are also important for leisure activities such as bathing, fishing and water sports, among others, contributing to the quality of life of the local population and to tourism in the region. The supply of quality, unspoiled water resources is an attraction for tourism, generating jobs and boosting the local economy;

The conservation of water bodies is also relevant to the local economy, as they can contribute to economic activities such as agriculture, fishing, tourism, industry and hydro-

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electric power generation. The degradation of these bodies of water can negatively impact these activities, compromising the local economy (SILVA, et al., 2017).

APPLICABLE LEGISLATION AND STANDARDS

The occupation of areas close to bodies of water is governed by various national and local laws and regulations aimed at protecting the environment and guaranteeing the conservation of water resources. Some examples of applicable legislation and standards are:

Environmental legislation, made up of federal, state and municipal laws, decrees, resolutions and regulations, establishes general guidelines for protecting the environment, including water bodies. In Brazil, Federal Law No. 9.605/98, known as the Environmental Crimes Law, provides for criminal and administrative sanctions for conduct harmful to the environment, including the irregular occupation of areas near water bodies (BRASIL, 1998); CONAMA Resolution No. 357/05: CONAMA Resolution No. 357/2005 is an important standard for the management and preservation of water resources in Brazil, and compliance with it is fundamental for the promotion of human health and the preservation of the environment;. and CONAMA Resolution 430/11: the resolution defines the parameters and maximum concentration limits for substances such as biochemical oxygen demand, pH and suspended solids and thermotolerant coliforms. Still on environmental impacts and the classification of receiving bodies of water, in the state of São Paulo we have Decree No. 8468/76 approving the Regulation of Law No. 997 of May 31, 1976, which provides for the prevention and control of environmental pollution and Decree No. 10.755/77 provides for the classification of receiving bodies of water in the classification provided for in Decree No. 8.468 of September 8, 1976.

Guidelines for occupying permanent preservation areas (APPs): APPs are areas protected by environmental legislation with the function of preserving water resources, biodiversity, ecological balance and the well-being of human populations. CONAMA (National Environment Council) Resolution 303/2002 establishes general guidelines for the occupation of APPs, including areas close to water bodies such as rivers, lakes, lagoons and springs, defining limits and restrictions for the occupation of these areas (BRASIL, 2002).

TESTS

Total Coliforms

Total coliforms are a group of bacteria found naturally in soil, plants and animal intestines in large quantities and is a tool used to assess the water quality of rivers and other bodies of water as it is indicative of pollution (APHA, 2017).

Testing for total coliforms is a microbiological procedure that involves taking samples of river water and growing them in a selective culture medium in the laboratory. The culture medium used is designed to encourage the growth of coliform bacteria, which are able to ferment the lactose present in the medium, forming characteristic colonies. After bacterial growth, the colonies are identified and counted to determine the amount of total coliforms present in the water sample (BARTRAM; BALLANCE, 1996).

Analysis of the results of the total coliform test can be used to assess the quality of the river water and determine whether it is within the limits set by environmental regulatory bodies for the protection of public health and the environment. If the amount of total coliforms found in the river water is above the permitted limits, mitigation measures can be taken, such as identifying and eliminating sources of pollution, implementing sewage treatment systems, regulating agricultural and livestock activities, and raising public awareness about the importance of conserving water resources (CANADA, 2019).

E. coli

The Escherichia coli (*E. coli*) test is a microbiological analysis carried out to detect the presence of this specific bacterium in samples of water, food, soil and other materials. *E. coli* is a gram-negative bacterium belonging to the Enterobacteriaceae family and is widely used as an indicator of fecal contamination, since its presence in certain environments can indicate the possible presence of fecally transmitted pathogens and the microbiological quality of these materials (EPA, 2018).

Testing for *E. coli* is carried out using microbiological techniques, generally following the standardized procedures established by organizations such as the American Public Health Association (APHA), the American Water Works Association (AWWA) and the Water Environment Federation (WEF). The most common method for detecting *E. coli* is the filter membrane technique, which involves filtering a water sample or other material through a special membrane that retains the bacteria present. The membrane is then placed in a selective and differential culture medium, such as *E. coli/Coliform* Chromogenic Agar, which contains specific substrates that allow the identification of *E. coli* based on their growth and staining characteristics (APHA, 2017). However, specific enzymatic chromogenic substrates can also be used to incubate and read the samples in 24 hours or 18 hours.

The presence of *E. coli* in a sample may indicate recent fecal contamination and may be indicative of a risk to human health, since some strains of *E. coli* are pathogenic and can cause serious gastrointestinal illness in humans. Therefore, the detection and quantification of *E. coli* in water and food samples are important to assess the microbiological safety of these materials and to take appropriate measures to control and prevent water- and food-borne diseases (FDA, 2019).

Chemical Oxygen Demand

Chemical Oxygen Demand (COD) is a test used to determine the amount of oxygen needed to oxidize the organic and inorganic matter present in a water sample, and thus estimate the total organic load present in the sample. It is a parameter widely used to assess water quality in terms of its organic load, and is applied in various areas, such as water treatment, industrial effluent control and environmental monitoring (APHA, 2017).

The sample is mixed with the oxidizing agent and heated in a water bath at a specific temperature for a certain period of time. After the reaction, the excess oxidizing agent is titrated with a reducing agent, and the amount of oxygen consumed during oxidation is determined indirectly from the amount of reducing agent consumed (EPA, 2018).

COD is a useful measure for assessing the organic load of effluents and wastewater, as it can provide information on the efficiency of water and effluent treatment processes, as well as on the presence of oxidizable chemical substances and their ability to deplete the oxygen available in the receiving bodies of water (METROHM APPLICATION BULLETIN, 2018).

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) is a test used to determine the amount of oxygen consumed by aerobic microorganisms during the biochemical decomposition of organic matter present in a water sample. It is a parameter widely used to assess water quality in terms of its biodegradable organic load, and is applied in various areas such as water treatment, industrial effluent control and environmental monitoring (APHA, 2017). The difference between the dissolved oxygen content before and after incubation is the BOD, expressed in milligrams of oxygen consumed per liter of sample (mg/L O2) or in other equivalent units (EPA, 2018).

BOD is used to assess the efficiency of water and effluent treatment processes, as well as the capacity of receiving water bodies to assimilate the biodegradable organic load present in effluents and their self-depuration capacity (FDA, 2019).

Total Phosphorus

The Total Phosphorus test is an analytical method used to determine the total concentration of phosphorus in samples of water, soil, sediment or other types of environmental matrix. Phosphorus is an essential chemical element for life and is present in various forms in the environment, including inorganic phosphorus and organic phosphorus (APHA, 2017).

Increasing the concentration of phosphorus in water can lead to eutrophication, a process in which there is excessive enrichment of nutrients in bodies of water, resulting in excessive growth of algae and plants, consumption of dissolved oxygen and deterioration of water quality (STANDARD METHODS ONLINE, 2017). There are several methodologies available for the determination of total phosphorus, including colorimetric, gravimetric and spectrophotometric methods. The results are expressed in terms of total phosphorus concentration in mass units, such as milligrams of phosphorus per liter of sample (mg/L of P) or other equivalent units (CLESCERI; GREENBERG; EATON, 2012).

Nitrate

The nitrate test is an analytical method used to determine the concentration of nitrate (NO_3^-) in samples of water, soil, sediment or other environmental matrices. Nitrate is an oxidized form of nitrogen that can be naturally present in the environment, but can also be introduced by human activities such as intensive agriculture, livestock farming, inadequate waste disposal and pollution from sewage and industrial effluents (APHA, 2017).

Drinking water contaminated with high levels of nitrate can cause health problems, especially in babies and children, such as blue baby syndrome, which interferes with the blood's ability to carry oxygen (STANDARD METHODS ONLINE, 2017).

There are various methodologies available, generally involving the conversion of the nitrate present in the sample into nitrite (NO_3) by means of a specific chemical reaction, followed by the detection and quantification of the nitrite formed. The results are expressed in terms of nitrate concentration in mass units, such as milligrams of nitrate per liter of sample (mg/L of NO_3^-) or other equivalent units (CLESCERI; GREENBERG; EATON, 2012).

Nitrite

The nitrite test is an analytical method used to determine the concentration of nitrite (NO_2^-) in samples of water, soil, sediment or other environmental matrices. Nitrite is a reduced form of nitrogen that can be naturally present in the environment, but can also be introduced by human activities such as intensive agriculture, livestock farming, inadequate waste disposal and pollution by sewage and industrial effluents (APHA, 2017).

In high concentrations, nitrite can be toxic to aquatic life and can cause health problems in humans, such as the formation of methemoglobin in the blood, which can lead to the condition known as methemoglobinemia (STANDARD METHODS ONLINE, 2017). The results are expressed in terms of nitrite concentration in mass units, such as milligrams of nitrite per liter of sample (mg/L of NO_2^-) or other equivalent units (CLESCERI; GREENBERG; EATON, 2012).

Ammoniacal Nitrogen

The Ammoniacal Nitrogen test is an analytical method used to determine the concentration of ammoniacal nitrogen (NH_3-N) in samples of water, soil, sediment or other environmental matrices. Ammoniacal nitrogen is a form of nitrogen that can be naturally present in the environment, but can also be introduced by human activities such as intensive agriculture, livestock farming, inadequate waste disposal and pollution from sewage and industrial effluents (APHA, 2017). Ammoniacal nitrogen is an important nutrient for the growth of aquatic organisms and can influence water quality and the health of aquatic ecosystems (STANDARD METHODS ONLINE, 2017). The results are expressed in terms of ammonia nitrogen concentration in mass units, such as milligrams of ammonia nitrogen per liter of sample (mg/L of NH_3-N) or other equivalent units (RICE, et al., 2017).

Dissolved Oxygen

The Dissolved Oxygen test is an important measure for assessing water quality in natural bodies of water and in water and wastewater treatment systems. It is used to determine the concentration of dissolved oxygen in water, which is essential for aquatic life and the health of aquatic ecosystems (APHA, 2017). Dissolved oxygen concentration is measured in concentration units, usually in milligrams per liter (mg/L) or in percent saturation (%) (STANDARD METHODS ONLINE, 2017).

It is important for assessing the impact of human activities and the health of aquatic ecosystems, as well as for ensuring compliance with water quality standards set by regulatory bodies (RICE, et al., 2017).

MATERIALS AND METHODS

A literature review will be carried out on the subject of unplanned occupations and their impact on water bodies, based on scientific articles, technical reports and relevant legislation. A field survey will be carried out in the municipality of Peruíbe, visiting the areas affected by unplanned occupations on the banks of the identified water bodies, to collect primary data, such as direct observation and the collection of water samples; the water samples collected will be analyzed in the laboratory, using standardized physical-chemical and microbiological analysis methods, to assess water quality and identify possible contaminants. The data collected will be analyzed using CONAMA resolution 357/05, as a descriptive and inferential analysis, to verify possible relationships between unplanned occupations and the water quality of the bodies of water studied.

L LOCATION

Peruíbe is a municipality located on the south coast of the state of São Paulo, in Brazil. Its geographical coordinates are 24° 19' 34" S latitude and 46° 59' 23" O longitude. It is bordered to the north by the municipality of Itariri, to the south by Itanhaém, to the east by the Atlantic Ocean and to the west by Pedro de Toledo, as shown in figure 1.

Figure 01 - Image - source Portal g1.com.br

Source:https://g1.globo.com/sao-paulo/noticia/2012/02/alem-de-praias-peruibe-sp-conta-com-complexo termal.html

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EXISTING ALLOTMENTS AND IRREGULAR OCCUPATIONS

Existing subdivisions with areas of irregular occupation in their surroundings face a number of challenges, including a lack of proper urban planning, a shortage of basic infrastructure, environmental degradation and vulnerability to risks and natural disasters.

Figure 02 shows the areas of existing allotments and irregular areas in the Peruíbe study area.

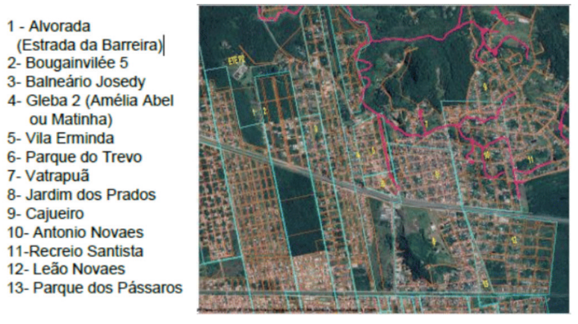

Figure 02 - Areas of existing allotments and irregular areas in the study area in Peruíbe

Source: Prepared by the author

LOCATION OF IRREGULARLY OCCUPIED AREAS

The presence of irregular occupations in the vicinity of a subdivision can negatively affect the value of properties, as well as the quality of life of residents, who can face problems such as lack of basic sanitation, insecurity and pollution. Figure 03 shows the location of the areas in the study site.

Figure 03 - Location of the areas in the study site.

Source: Prepared by the author

Figures 04 to 10 show the location of the regular allotment areas in the study site.

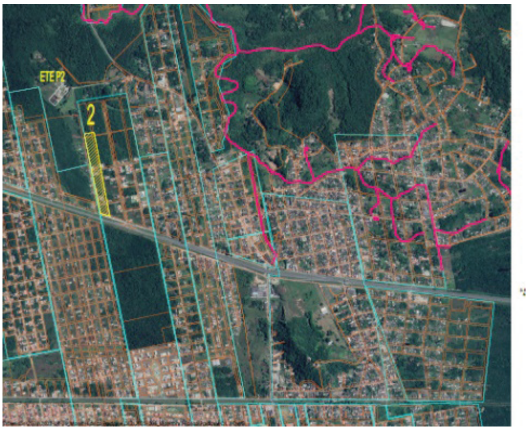

Figure 04 - Location of the Bougainville V subdivision

Source: Prepared by the author

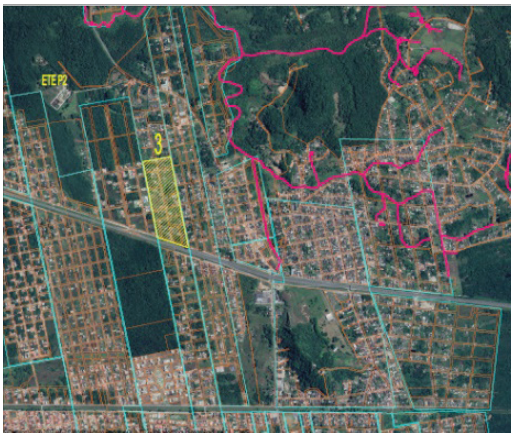

Figure 05 - Location of the Balneáreo Josedy subdivision

Source: Prepared by the author

Figure 06 - Location of Vila Erminda subdivision

Source: Prepared by the author

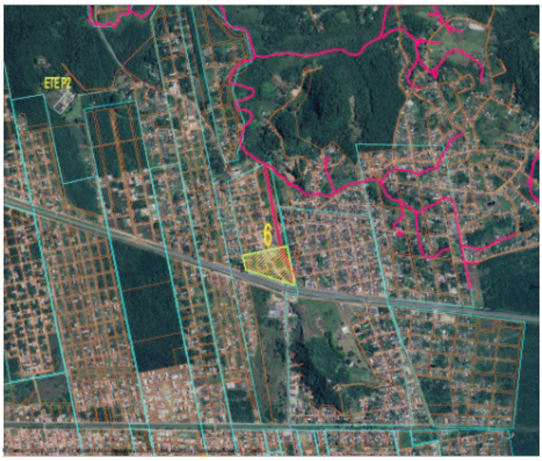

Figure 07 - Location of the Vatrapuã subdivision

Source: Prepared by the author

Figure 08 - Location of Jardim dos Prados subdivision

Source: Prepared by the author

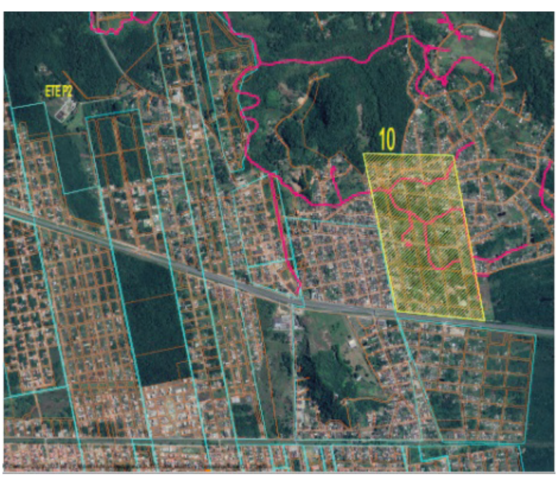

Figure 09 - Location of the Antonio Novais allotment

Source: Prepared by the author

Figure 10 - Location of the Parque dos Pássaros subdivision

Source: Prepared by the author

GENERAL SITUATION OF ALLOTMENTS AND IRREGULARLY OCCUPIED AREAS

The irregular occupation of areas brings with it various problems, such as the lack of basic infrastructure like water, electricity and sanitation, legal insecurity, environmental degradation, violence and vulnerability to natural disasters. Figures 11 and 12 show the situation of all the streets in the allotments and irregular areas, with no rainwater drainage and open sewers.

Figure 11- Streets without rainwater drains

Source: Prepared by the author - Photo of streets in the study area

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Figure 12 - Streets with open sewers

Source: Prepared by the author - Photo of streets in the study area

COLLECTION POINTS

The collection points were defined according to the area of influence of the water bodies in the study site, where allotments and irregular areas are concentrated and where there are no sewage collection systems in place. Figure 13 shows the locations on a satellite image, while Figures 14 to 16 show the water bodies where the collection and analysis points are located.

Figure 13 - Location of Collection Points

Source: Prepared by the author

Figure 14 - POINT 1 - AV. GERSON DE SOUZA REIS - Stream

Source: Prepared by the author - Photo point

Figure 15 - POINT 2 - R JOSÉ DE LIMA - COM R. OITO - Stream

Source: Prepared by the author - Photo point 2

Figure 16 - POINT 3 - R. ALABASTRO - PRÓX. R. TURQUESA (PONTE) - C orrego

Source: Prepared by the author - Photo point 3

COLLECTION EQUIPMENT

There is a variety of equipment used for collecting and preserving samples in streams, such as recyclable ice, a thermometer, a stainless steel bucket, a rope, a thermal box and bottles, which are listed and illustrated in figure 17. A spreadsheet is used to keep track of field data and is filled in at the time of collection.

1 -OD bottles
2-Bottles of Bac/ Phosphorus
3-COD flasks
4 -Reagent beaker
5 -Nitric and Sulfuric Acid
6 -OD reagents
7 -BOD bottle

Figure 17 - Collection storage jars

TESTING EQUIPMENT

For the Total *Coliforms* and *E. coli* (Quantitative) test**, a** biosafety cabinet**,** microbiological incubator, sealer, enzymatic substrate and aluminized plastic cartons are used. For the Chemical Oxygen Demand (COD) test, a COD reactor, spectrophotometer and COD kit are used. For the ammonia nitrogen test, the main equipment used is a selective ion meter. Calibrated glassware and a digital burette are used to determine Dissolved Oxygen, as well as a standardized titrating solution. For the Biochemical Oxygen Demand (BOD) test, the main equipment is **an** incubator**,** bottles and electronic sensors. The ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry) and microwave digester are used for determining metals (phosphorus). For the Ammoniacal Nitrogen test, the main equipment is the selective ion meter.

SAMPLE COLLECTION METHOD

There are various methods for collecting samples from rivers, and the choice of method depends on the purpose of the collection and the characteristics of the river in question:

The collecting technician separates the material, including the collection sheet, lists the labels on the vials with a pen, noting the points on the set of vials for each sample, as shown in figure 19, which shows the samples taken. For this sampling, tests requiring 5 vials per sample for 3 collection points were defined. Each collection point corresponds to a sample.

Figure 19 - Samples taken at the points

Source: Prepared by the author

Once the materials have been checked, the collector goes to the sampling site and assesses any possible changes in the environment that could interfere with the results. If there are any relevant environmental changes, the technician makes a note in the observations field of the spreadsheet.

Then the bucket, tied by a rope, is thrown into the water body, filling it completely. This first collection is discarded, as part of the procedure is to fill the bucket with the sample to be collected. In the second batch, the collector collects the bucket and immediately submerges the glass bottle for the Dissolved Oxygen (DO) test, filling it completely, avoiding spaces for bubbles. The preservatives are then added fix the DO. Next, the collecting tech-

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nician fills a sterile 100 mL plastic bottle for bacteriological testing (Total *Coliforms* and *E. coli*), closing it immediately and storing it in the refrigerated collection box. Next, the 2 L plastic bottle is filled and immediately stored in the refrigerated collection box for BOD determination and 2 other plastic bottles, one 100 mL for the Phosphorus test and the other 250 mL for the COD test. The latter are also preserved with 10 drops of nitric acid (HNO_3) for phosphorus and 10 drops of sulfuric acid (H_2SO_4) for COD. They are then stored in the refrigerated collection box. The glass vials for the DO test are stored outside the refrigerated box to prevent the low temperature (4+/-2° C) from interfering with the sample result due to the formation of bubbles.

While the collecting technician is storing the sample bottles, a thermometer is inserted into the bucket with the rest of the sample to check the temperature of the sample. The air temperature is also checked by the thermometer and the results noted on the collection sheet, in the respective fields for that sample. The spreadsheet also records the rainfall conditions in the last 24 hours prior to sampling, checking for light, medium or heavy rainfall.

SAMPLE TESTING METHOD

Total *Coliforms* and *E. coli* Test (Quantitative) - Reference: Standard Methods for Examination of Water and Wastewater 23rd Edition, 2017 - Sections: 9223 A and B.

Before starting the test, the analyst must turn on the laminar flow hood and disinfect the work area with 70°INPM ethyl alcohol. Then switch on the carton sealer and wait for it to warm up. The analyst then organizes the samples to be analyzed and lists them on the form for recording and traceability, along with the dilution factor that was carried out for each sample.

The necessary material should be laid out on the bench to carry out the test: flasks with dilution water, test tubes, 10 mL pipettes, culture medium, cards, 100 mL flask. All materials must be sterilized beforehand.

The sample must then be homogenized vigorously and diluted in sterile water to obtain the desired dilutions, as shown in figure 24. The culture medium is added to the flask containing the diluted sample, and the mixture is transferred to a quantification card. The card is sealed and incubated in an oven for a period of 20 to 24 hours at a temperature of 35 ± 0.5°C. All this handling takes place in a biosafety hood (Figure 21). The quantification cards are sealed in the sealing machine (Figure 22).

After incubation (Figure 23), the samples are evaluated for the presence of total coliforms and *E. coli*. The detection of total coliforms is carried out by changing the color of the substrate, while the presence of *E. coli* is determined by fluorescence under ultraviolet light. This can be checked using the quantification card (Figure 24). The colonies that develop on the substrate are counted and the concentration of microorganisms is calculated. The final result is expressed as the Most Probable Number (MPN) of total coliforms and *E. coli* per 100 mL of water.

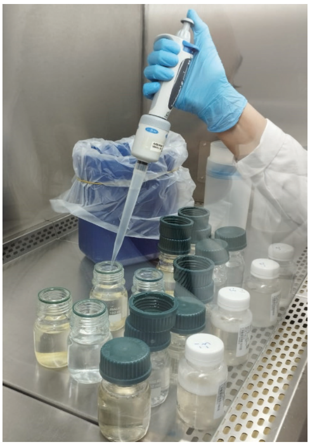

Figure 20 - Sample bottles being analyzed

Source: Prepared by the author

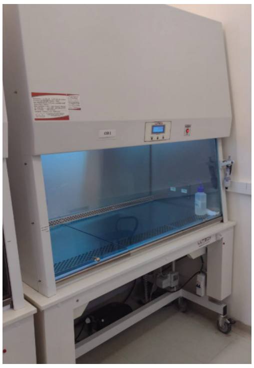

Figure 21- Biosafety cabin
Source: Prepared by the author

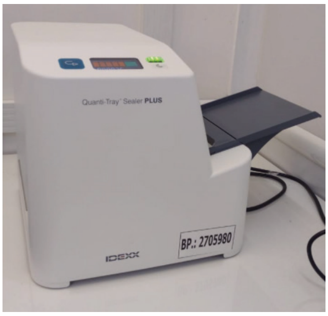

Figure 22- Carton sealer
Source: Prepared by the author

Figure 23- incubator greenhouse
Source: Prepared by the author

Figure 24- Aluminized plastic cards
Source: Prepared by the author

Chemical Oxygen Demand (COD) Test - Reference: Standard Methods For Examination of Water and Wastewater 23^{rd} Edition 2017 - Section 5220 D - Closed Reflux, Colorimetric Method.

The Chemical Oxygen Demand (COD) test using the closed reflux method is used to assess the amount of organic matter present in a water or effluent sample. The samples, standard solutions and blank must be at room temperature. Before starting the test, the technician must turn on the digester block (figure 25) and wait for the temperature to stabilize.

The procedure consists of adding the sample to a test tube containing an oxidizing solution of potassium dichromate ($K_2Cr_{(2)}O_7$) and sulfuric acid ($H_2SO_{4)}$. The mixture is then heated for a period of 2 hours at 150 ºC ± 2ºC, with continuous reflux to ensure complete oxidation of the organic matter.

At the end of the digestion, the technician should wait around 20 minutes and invert the tube several times while it is still warm. After the cooling period, using the tube in which the sample was digested, a spectrophotometer (figure 26) is used to take the reading at the appropriate wavelength for the concentration range used. The result is expressed in milligrams of oxygen consumed per liter of sample (mg/L).

Figure 25 - COD reactor

Source: Prepared by the author

Figure 26 - Spectrophotometer

Source: Prepared by the author

Biochemical Oxygen Demand (BOD) test - Reference: Standard Methods for Examination of Water and Wastewater 23rd Edition, 2017. Section 5210 D.

Before carrying out the test, the analyst determines the COD concentration for each sample to be analyzed. The calculation of the expected BOD, and its respective incubation range, is obtained by dividing the COD result by 2.

At the start of the test, the analyst checks the pH of the samples at room temperature and, if necessary, adjusts it to pH 7.00 using diluted solutions of H_2SO_4 or NaOH. He then takes a sufficient quantity of sample, according to the expected BOD concentration, and transfers it to a special bottle (figure 27). The higher the expected concentration, the smaller the volume of sample to be used for incubation.

The technician adds about 0.08 g (a dosing cap) of nitrification inhibitor for every 150 mL of sample. 1 mL of each nutrient is added to the same bottle: 1.5 N Phosphate Buffer Solution, 0.41 M Magnesium Sulphate Solution, 0.25 M Calcium Chloride Solution, 0.018 M Ferric Chloride Solution and 0.71 N Ammonium Chloride Solution.

Finally, the technician adds the magnetic bar and NaOH lentils to the respective support of each bottle and closes them with the electronic sensor. The sensors are set to start measuring and the "bottle+sensor" set (figure 28) is positioned on the stirring tray inside the incubator (figure 29) set to a temperature of 20 ± 1 °C. After 3 hours of incubation, the timer on the electronic sensor starts marking the incubation time.

Every 24 hours the sensor records the result of one day's incubation. After an incubation period of 5 days, the sensor is used to measure the amount of oxygen remaining in the sample and the amount of oxygen consumed by the microorganisms is calculated. This value represents the BOD of the sample and is expressed in milligrams of oxygen consumed per liter of sample (mg/L).

Figure 27 - BOD test preparation

Source: Prepared by the author

Figure 28- Bottle and electronic sensor set

Source: Prepared by the author

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Figure 29 - BOD incubator

Source: Prepared by the author

Test for the Determination of Metals (Phosphorus) by ICP-OES - Reference: Standard Methods for Examination of Water and Wastewater 23rd Edition, 2017 - Sections 3120-B and 3030 K

The ICP-OES equipment (figure 30) uses inductively coupled plasma to excite the atoms present in the sample, generating light that is measured to determine the concentration of metals in water and effluent samples.

The test begins by preparing the samples through the microwave oven digestion step, the aim of which is to minimize the effects of matrix interferents. The analyzing technician must pipette a 45 mL aliquot of sample into a vessel and add 5 mL of HNO3. The tube containing the sample is then transferred to the carousel, the positions of the respective samples are identified, and digestion begins using the temperature program configured in the equipment. After digestion, the samples are transferred to their respective test tubes.

In the ICP equipment, a calibration curve must be prepared with the certified reference material (CRM) for the metal of interest, before the sample is read. In the equipment's software, the analyst must open a new Worksheet from an existing template and register each of the samples to be analyzed, as well as the analytical controls that accompany the batch of samples.

Then, on the main screen, the test begins with the aspiration of the sample. Through the nebulization system, the sample is converted into an aerosol and introduced into the equipment by dragging argon gas to the injector tube located inside the torch, where the atoms are subjected to a temperature of approximately 6,000 to 8,000 K, causing the molecules to dissociate almost completely, significantly reducing chemical interferents. The temperature of this magnitude is responsible for the excitation and emission of the atoms, producing a spectrum that is detected and converted into concentration by the equipment.

The results are expressed in parts per million (ppm) or in other concentration units, depending on the test requirements.

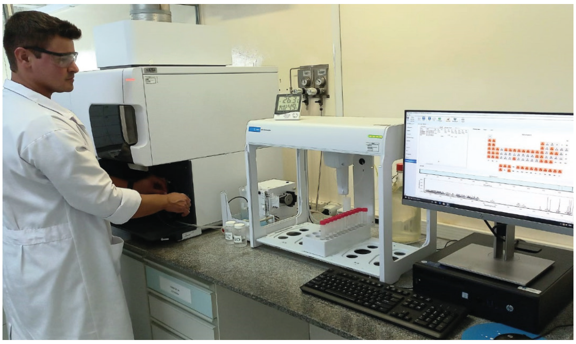

Figure 30 - Technician reading the samples on the ICP-OES

Source: Prepared by the author

Dissolved Oxygen Test by the Winkler Method - Reference: Standard Methods for Examination of Water and Wastewater 23rd Edition 2017 Method 4500-O C

The Dissolved Oxygen determination test by the iodometric method modified by Sodium Azide (Winkler Method) is a titrimetric chemical analysis used to control the treatment process of sewage and water pollution and also to monitor water quality in natural environments such as rivers, streams and lakes.

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During collection, the samples should be placed in BOD bottles with an approximate capacity of 300 ± 3.0 mL. Oxygen fixation should be carried out immediately after collection by slowly adding 1 mL of Manganese Sulphate Solution followed by 1 mL of Sodium Azide Iodide Solution, so that each reagent flows through the mouth of the bottle and is immersed in the sample without aerating it. The technician then carefully caps the flask to exclude air bubbles, shakes the flask a few times and waits for the precipitate to settle. In the laboratory, the analyst adds 1 mL of P.A. sulfuric acid or 2 mL at a 1:1 concentration (figure 31) and titrates the solution with 0.025 N sodium thiosulfate ($Na_2S_{(2)}O_3$) until it turns "straw yellow". In the next step, drops of the starch indicator solution are added and the titration is continued until it turns from blue to colorless. The dissolved oxygen concentration is calculated by the volume of titrant used and the result is expressed in mg/L.

Figure 31 - Bottle with OD sample

Source: Prepared by the author

Ammoniacal Nitrogen Test - Reference: Standard Methods For Examination of Water and Wastewater 23rd Edition - Method: 4500-NH_3 D

Before starting the test, the analyst must calibrate the selective ion meter with at least 02 points that cover the expected range of the analyte (figure 32). Then transfer 50 mL of the sample to be analyzed and 1.0 mL of the ionic strength adjuster solution. For reading, the electrode is dipped into the sample and the read button is pressed. The method is based on the electrometric quantification of Ammoniacal Nitrogen (N-NH_3), after its conversion to soluble ammonia (NH_3) at alkaline pH. The electrode uses a hydrophobic gas-permeable membrane to separate the sample solution from the electrode's internal ammonium chloride solution (NH_4Cl). Dissolved ammonia (NH_3 (aq) and NH_4^+) is converted to NH_3 (aq) by increasing the pH to 11 using a strong base. The soluble ammonia (NH_3) diffuses through the electrode membrane and changes the pH of the internal solution in proportion to the concentration of Ammoniacal Nitrogen and this change is sensed by a pH electrode. This measurement is made with a specific pH/ion meter.

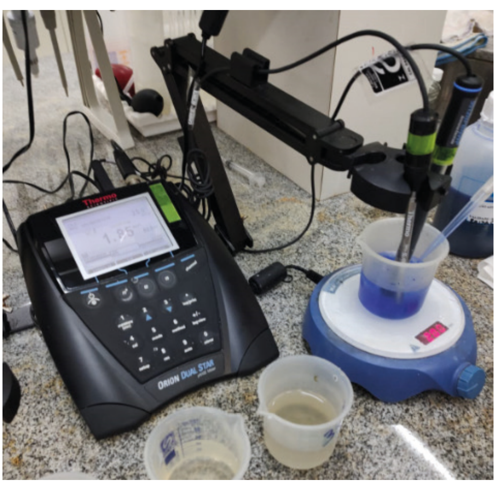

Figure 32 - Ammonia nitrogen test

Source: Prepared by the author

Point 1 - Av. Gerson de Souza Reis - stream														
Month/ Year	**Date**	**Time**	**Sample**	**Total Coliforms (MPN/ 100 mL)**	**E-coli (MPN/ 100 mL)**	**Chemical Oxygen Demand (mg/L)**	**Biochemical Oxygen Demand (mg/L)**	**Total phosphorus (mg/L)**	**Nitrate (mg N/L)**	**Nitrite (mg N/L)**	**Ammoniacal Nitrogen (mg N/L)**	**Dissolved oxygen (mg/L)**	**pH**	**Conductivity (µS/ cm 25ºC**	**Sample temperature (ºC)**
Jun-22	22/06/22	10:53	15679	770.100	82.000	84	32	1,04	< 2,0	< 0,025	12,0	< 1,0	6,8	321	21,9
Jul-22	01/07/22	07:42	16054	980.400	145.500	58	24	1,06	< 2,0	< 0,025	-	< 1,0	-	-	22,0
Jul-22	05/07/22	09:49	16277	648.800	156.500	72	28	1,15	< 2,0	< 0,025	-	< 1,0	-	-	22,0
Jul-22	12/07/22	08:24	17199	410.600	40.800	72	28	1,22	< 2,0	< 0,025	10,9	< 1,0	-	-	23,0
Jul-22	18/07/22	09:00	17499	1.046.200	65.000	61	42	< 0,02	2,1	< 0,025	14,5	< 1,0	-	-	21,0
Jul-22	25/07/22	09:00	18169	866.400	79.400	67	30	1,33	< 2,0	< 0,025	14,7	< 1,0	-	-	18,0
Aug-22	01/08/22	09:01	18700	816.400	44.100	67	23	0,28	4,14	< 0,025	8,11	< 1,0	-	-	17,0
Aug-22	15/08/22	08:54	20067	488.400	32.300	80	18	1,65	-	-	9,31	< 1,0	-	-	22,0
Sep-22	05/09/22	09:01	21991	1.699.950	84.150	113	14	-	-	-	2,17	1,0	-	-	18,0
Sep-22	19/09/22	10:19	23084	613.100	46.850	126	26	1,80	-	-	2,59	< 1,0	-	-	24,0
Oct-22	03/10/22	08:00	24294	>2.419.600	40.700	257	60	1,70	-	-	3,28	< 1,0	-	-	19,0
Oct-22	17/10/22	08:49	26200	1.643.000	28.350	162	90	1,96	-	-	6,80	< 1,0	-	-	27,0
Nov-22	01/11/22	09:34	27093/2022	1.986.300	100.200	89	41	0,87			20,90	< 1,0	-	-	20,0
Dec-22	07/12/22	08:54	30716/2022	218.700	18.550	99	5	0,59			1,83	< 1,0	-	-	26,0
Jan-23	09/01/23	08:34	965	474.750	62.300	79	-	-			-	< 1,0	-	-	23,0

Table 1 - Results of POINT 1 - - Av. Gerson de Souza Reis – stream

Source: Prepared by the author

Point 2 - R José de Lima - with R. Oito - stream													
Date	**Time**	**Sample**	**Total Coliforms (MPN/ 100 mL)**	**E-coli (MPN/ 100 mL)**	**Chemical Oxygen Demand (mg/L)**	**Biochemical Oxygen Demand (mg/L)**	**Total phosphorus (mg/L)**	**Nitrate (mg N/L)**	**Nitrite (mg N/L)**	**Ammoniacal Nitrogen (mg N/L)**	**Dissolved oxygen (mg/L)**	**pH**	**Conductivity (µS/ cm 25ºC**	**Sample temperature (ºC)**
22/06/22	11:15	15680	18.300	583	64	34	0,21	< 2,0	< 0,025	0,62	2,8	6,4	193	21,6
01/07/22	07:20	16055	**81.640**	100	98	29	0,19	< 2,0	< 0,025	-	< 1.0	-	-	21,0
05/07/22	09:31	162778	12.033	292	100	52	0,42	< 2,0	< 0,025	-	< 1.0	-	-	22,0
12/07/22	08:11	17200	9.590	310	89	24	0,26	< 2,0	< 0,025	0,76	< 1.0	-	-	22,0
18/07/22	08:47	17500	14.670	862	70	48	< 0,02	< 2,0	0,047	2,17	< 1.0	-	-	21,0
25/07/22	08:42	18170	18.596	109	59	22	0,19	< 2,0	< 0,025	0,78	1.0	-	-	19,0
01/08/22	08:40	18701	15.733	210	92	30	1,19	< 2	< 0,025	0,9	< 1.0	-	-	17,0

15/08/22	08:31	20068	>24.196	14.136	40	11	0,31	-	-	0,78	< 1.0	-	-	21,0
05/09/22	08:42	21992	658.600	6.131	39	8	-	-	-	0,36	3.0	-	-	18,0
19/09/22	10:04	23085	167.000	10.900	51	19	0,72	-	-	0,89	< 1.0	-	-	24,0
03/10/22	08:30	24295	125.400	1.860	153	35	0,99	-	-	0,97	< 1.0	-	-	20,0
17/10/22	08:27	26201	579.400	3.255	105	< 3	0,89	-	-	1,73	< 1.0	-	-	27,0
01/11/22	08:57	27094/2022	>241.960	48.840	52	15	0,4			0,56	1.8	-	-	20,0
07/12/22	08:36	30717/2022	488.400	35.000	61	6	0,4			0,84	< 1.0	-	-	26,0
09/01/23	08:21	966	155.310	2.430	126	-	-			-	< 1.0	-	-	23,0

Table 2 - Results of POINT 2 - R José de Lima - with R. Oito

Source: Prepared by the author

Point 3 - R. Alabastro - near R. Turquesa (Bridge) - stream														
Date	**Time**	**Sample**	**Total Coliforms (MPN/100 mL)**	**E-coli (MPN/100 mL)**	**Chemical Oxygen Demand (mg/L)**	**Biochemical Oxygen Demand (mg/L)**	**Total phosphorus (mg/L)**	**Nitrate (mg N/L)**	**Nitrite (mg N/L)**	**Ammoniacal Nitrogen (mg N/L)**	**Dissolved oxygen (mg/L)**	**pH**	**Conductivity (µS/cm 25°C**	**Sample temperature (°C)**
07/06/22	11:46	14953	77.600	4.352	< 25	< 3	-	-	-	-	4,2	6,9	369	21,9
22/06/22	11:45	15681	**325.500**	21.800	47	28	0,58	< 2,0	< 0,025	9,55	2,9	7,0	395	22,8
18/07/22	08:26	17501	198.900	38.400	33	30	< 0,02	< 2,0	< 0,025	7,21	< 1,0	-	-	19,0
25/07/22	08:21	18171	62.400	5.475	34	24	< 0,02	< 2,0	< 0,025	5,13	2,0	-	-	17,0
01/08/22	08:29	18702	78.900	7.500	32	14	0,58	2,94	2,94	4,37	1,0	-	-	14,0
15/08/22	08:12	20069	67.600	5.100	35	7	0,70	-	-	5,36	< 1,0	-	-	19,0
05/09/22	08:21	21993	80.100	13.200	57	< 3	-	-	-	0,80	3,0	-	-	18,0
19/09/22	09:49	23086	49.600	3.100	34	10	0,37	-	-	2,13	2,0	-	-	23,0
03/10/22	09:00	24296	307.600	36.900	31	10	0,38	-	-	3,21	2,0	-	-	17,0
17/10/22	08:16	26202	49.500	7.500	29	15	0,52	-	-	4,00	< 1,0	-	-	27,0
01/11/22	08:24	27095/2022	>241.960	57.940	34	10	0,23	-	-	0,60	3,9	-	-	19,0
07/12/22	08:09	30718/2022	193.500	2.000	45	4	0,27	-	-	2,18	2,3	-	-	24,0
09/01/22	08:06	967	104.620	11.060	34	-	-	-	-	-	2,4	-	-	23,0

Table 3 - Results from Point 3 - R. Alabastro - near R. Turquesa (Bridge) - stream

Source: Prepared by the author

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RESULTS OBTAINED

POINT 1 - AV. GERSON DE SOUZA REIS, presented the most worrying results, in all the parameters analyzed, such as, in Oct/2022 it presented total \coliforms 2,419,600 NMP/100mL, *E. coli* 40,700 NMP/100 mL, and a BOD 60 mg/L. In August 2022, it was decided to withdraw the nitrite and nitrate tests due to the low variation in results. These results may be related to the location of the point, which is in the center of the studied area, receiving a large contribution of raw sewage.

POINT 2 - R JOSÉ DE LIMA - COM R. OITO, showed the most stable results, in Sep/2022: Total *coliforms* 658,600 NMP/100 mL, *E. coli* 6,131 NMP/100 mL, and a BOD of 8 mg/L. Also in August 2022, it was decided to withdraw the nitrite and nitrate tests due to the low variation in results. These results may be related to the flow of the stream, as it also receives a large amount of raw sewage.

POINT 3 - R. ALABASTRO - NEXT TO R. TURQUESA (PONTE), showed the least worrying results, in Sep/2022: Total *coliforms* 49,600 NMP/100 mL, *E. coli* 3,100 NMP/100mL, and a BOD of 10 mg/L. Also in August 2022, it was decided to withdraw the nitrite and nitrate tests due to the low variation of the results. These results may be related to the location of the point, as the surrounding area already has a sewage collection system in place.

ANALYSIS AND DISCUSSION OF RESULTS

For a better analysis and discussion, it is necessary to address aspects of the classification of rivers according to CONAMA Resolution 357/2005. For a Class 1 river, some standards are BOD up to 3 mg/L, DO not less than 6 mg/L, pH from 6.0 to 9.0, N-Nitrate up to 10.0 mg/L and thermotolerant coliform should not exceed the limit of 200 per mL. For Class 2 rivers, BOD of up to 5 mg/L, DO of not less than 5 mg/L, pH of 6.0 to 9.0, N-Nitrate of up to 10.0 mg/L and thermotolerant coliforms must not exceed the limit of 1000 per mL, for Class 3, BOD of up to 10 mg/L, DO of not less than 4 mg/L, pH of 6.0 to 9.0 and thermotolerant coliforms must not exceed the limit of 4000 per m and for Class 4, DO of more than 2.0 mg/L and pH of 6.0 to 9.0. It should be noted that according to CONAMA 357/2005, *E. coli* can be determined instead of the thermotolerant coliform parameter.

The stream at Point 1 showed a BOD variation of between 5 and 90 mg/L, and all the OD results were below 1 mg/L, therefore characteristics below a classification 4 for rivers, i.e. totally impacted by sewage discharges from irregular and regular areas without a collection network. Point 1 was also found to have an excessive accumulation of ammoniacal nitrogen in the water, which can be toxic to many forms of aquatic life, such as fish, invertebrates and aquatic plants.

The stream at Point 2, on the other hand, only 3 samples had DO above 1 mg/L, and the lowest number of total coliforms was 9,590 NMP/mL, which still does not qualify as Class 4 Rivers, according to CONAMA Resolution 357/2005, making it clear that the streams are impacted by irregular discharges.

For the stream at Point 3, BOD varied between 3 and 30 mg/L, DO, results between 1 and 4.2 mg/L, but due to the high Total Coliform results, which varied between 49,500

NMP/100 mL and 325,500 NMP/100mL, and *E. Coli* between 3,100 and 57940 NMP/100 mL. *Coli* between 3,100 and 57940 NMP/100 mL, this stream has characteristics equivalent to Class 4, according to CONAMA 357/2005.

Decree 8468/76 of the State of São Paulo sets more restrictive quality standards for the classification of water bodies, such as BOD, which cannot exceed 10mg/l, and DO, with a minimum limit of 4.0 mg/l. The streams at points 1 and 2 analyzed showed results outside the standards, and the stream at point 3 showed results that tend to meet class 4 standards, according to this legislation, and the reasons for this improvement should be better analyzed.

For Decree 10.755/77, which determines the classification of rivers, more specifically in its Annex A, which classifies the basins and classes of rivers belonging to the State of São Paulo, the class 1 rivers of the South Coast basin, in its item d) are:

"All coastal watercourses from the border of the municipalities of Itanhaém and Mongaguá to the border of the municipality of Cananéia with the state of Paraná, up to elevation 50."

Therefore, there is a need to monitor and restore all the water bodies in the municipality, especially the streams analyzed.

CONCLUSION

The implementation of an urban zoning plan can be one of the main tools for preventing the irregular occupation of areas near water bodies. This plan should delimit specific areas for different types of use, including green areas and environmental protection. It is important that inspections of areas close to water bodies are carried out regularly and efficiently to prevent people from occupying these areas irregularly. Inspection must be accompanied by punitive measures to discourage irregular occupation.

Land regularization is an important measure to reduce irregular occupation in areas near streams. This can be done by regularizing irregularly occupied properties, which can reduce the number of people in vulnerable situations. The installation of containment devices, such as retaining walls and barriers, can help prevent the erosion of stream banks and, consequently, reduce the possibility of floods and landslides.

The implementation of rainwater drainage systems can help prevent the accumulation of water in areas close to streams, reducing the risk of flooding.

Improving quality of life, the absence of sewage collection systems can affect the health and quality of life of the local population. The accumulation of sewage can cause infectious diseases and affect the general well-being of the population. The implementation of sewage collection systems can guarantee a healthier and safer environment for the population. Preservation of the environment: Sewage discharged into water bodies can cause environmental damage, such as water pollution and the death of aquatic species. The implementation of sewage collection systems can help preserve the environment by ensuring that sewage is treated properly before being discharged into rivers.

Environmental education is an important measure to make the population aware of the risks of irregular occupation in areas close to streams. Environmental education campaigns can include lectures, booklets and social mobilization actions, and monitoring and inspection are essential measures to ensure that irregular occupations do not cause damage to the environment and the local population.

Finally, the results of the analysis of the samples collected show the need to install sewage networks in the area. This research is all the more important given the information on the implementation, already underway,

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of sewage collection, removal and treatment equipment in the study region. These works should prevent effluent from being discharged directly into the streams, reducing water pollution, improving its quality and preserving aquatic life. This monitoring will continue, with the aim of showing positive results after the installation of the sewage system.

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