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Survey of Environmental Quality in Three Springs of an Integral Protection Conservation Unit in Manaus-Amazonas

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Abstract**—** *Springs are characterized as groundwater environmental hydro systems, in which they occur temporarily or perennially, and are present in natural and anthropic areas. The present study analyzed the environmental quality in three springs located in an integral protection conservation unit in the city of Manaus, Amazonas. To characterize the study area, there was georeferencing of images from the Google Earth software in the ArcGIS and Qgis programs, the survey of the environmental quality of the springs was performed through the methodological procedure of macroscopic analysis of 12 physicochemical and biological parameters and, the classification of spring conditions by the sum of the degree of criticality of each item evaluated, resulting in a score. It was verified that two springs were classified as "bad" and "bad", respectively, and only one spring was rated "optimal" for its environmental condition, due to its degree of distance from the urbanization limit. The results revealed a warning sign regarding the neglect of the environmental agencies regarding the protection of existing natural resources, consequently, indicate the need to carry out an inspection regarding compliance with the established laws for the preservation of water bodies and riparian forests.*

Keywords**— Hydro systems; Environmental Quality; Environmental impacts; natural resources; water bodies.**

I. INTRODUCTION

Natural territorial spaces intended for the protection of sites in certain zones are necessary for the maintenance of the environment, these spaces are defined as Conservation Units [29]. PAs are unique areas, given a range of ecological diversity and should therefore be protected by law [20]. In Brazil, the first movements for the establishment of conservation units started from the southeast region of the country, in which the concern with the protection of the predominant natural wealth of the locality arose.

These areas aim at maintaining ecosystems, regulating climate, supplying watercourses, guaranteeing social well-being and protecting places of great beauty, presenting the need to maintain natural resources and biodiversity from the establishment of protected spaces, in which limits of use and occupation are established according to legal instruments [4]. Only in the year 2000 there was the establishment of a legislation that protected the natural spaces.

Through Law No. 9,985 of July 18, 2000, protected areas were defined as "peculiar and highly relevant areas, legally established by the Public Authorities (municipal, state and federal), with conservation objectives and defined limits, under special regime. appropriate safeguards for protection "[6]. Based on this decree, the units were grouped into UC's of Integral Protection and Sustainable Use, where they have categories for the classification of protected areas [7].

The environmental protection functions that are applied in the concepts of conservation units also fall into the maintenance of springs and the formation of water bodies necessary for the life of the natural environment [14]. Law 12,651 of May 25, 2012, in its art. 3, clause XVII conceptualizes the springs as "groundwater outcrops that give rise to watercourses", having no definite location for their emergence [5]. The outcrops are protected entirely by riparian forest in their surroundings and are typical of lowland areas, characterized by having sandy terrain and surrounded by vegetation consisting of palm species [25].

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The delimitation of protected areas in urban areas is a positive point for the social and environmental environment, regarding the stabilization of rainfall regimes in cities and the supply of water bodies and groundwater. Despite the existence of legislation for the management and preservation of forest fragments, these spaces continue to shrink, one of the main factors being urban growth [8]. From this problem, the protected areas were classified according to their physical, chemical and biological characteristics in order to enable their control at the federal, state and municipal levels.

Municipal PAs also represent a relevant tool to influence the use and occupation of territories in municipalities by constituting an important element for the socioeconomic dynamics of the local landscape [12]. However, the complexity of the implementation of conservation units, their management and maintenance are becoming increasingly difficult, given the low investment in them and the lack of control of urban growth in the surroundings [22]. The problems for its establishment contribute to the reduction of these spaces in urban areas.

Given the need to preserve Conservation Units, especially those located in urbanized areas, methodologies for environmental analysis were developed [19]. These methods are intended to investigate the main indicators of degradation in the natural environment by macroscopic means. The macroscopic analysis consists in the determination of criteria of evaluation of the environmental impacts in a quantitative form.

In this conception, it should be noted that changes in the environment directly affect the social and economic environment, see the intertwining between these pillars. It should be noted that there is a dearth of in-depth studies that portray the environmental conditions surrounding the PNMN and its springs.

Given the above, this study aimed to perform a macroscopic analysis in three springs that originate the Igarapé do Mindu, during the ebb and flow of the river, which are located in the Municipal Park of Spring water of Mindu.

II. MATERIALS AND METHODS

2.1. Study Classification

This study was conducted through qualitative and quantitative research, considering that the study was divided into two parts. The first part consisted of a bibliographic analysis in which the main articles that addressed the efficiency of applying macroscopic analysis in a conservation unit were classified. In the second part of the research a field visit was made to survey the macroscopic data about the site.

2.2. Study area

The study was carried out at the Spring water of Mindú Municipal Park - PMNM, where it is classified as an integral protection conservation unit. The UC is located in the Cidade de Deus neighborhood, Manaus, between the geographic coordinates 3º00'33.93 ”(south latitude) and 59º56'01.72” (longitude West of Greenwich), as shown in Figure 1.

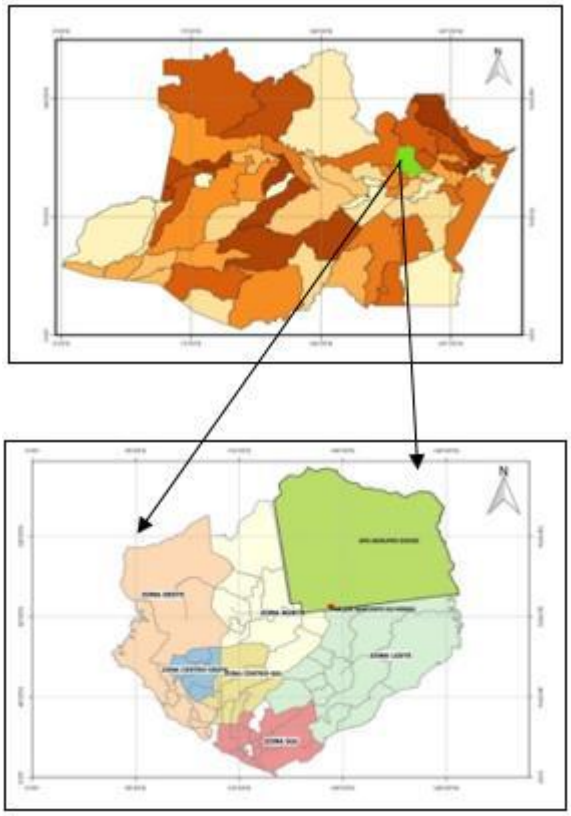

Fig. 1: Location map of the Municipal Park, Mindú Springs, Amazonas and Manaus.

Created from Decree No. 8.351 of March 17, 2006, the Mindu Springs water Municipal Park is home to the three (3) main springs that originate the Igarapé do Mindú. The neighborhood where it is located is one of the most populous in northern Manaus, with about 70,000 inhabitants. [26]

The PMNM is inserted in a region of humid equatorial climate, with annual average temperature of 31º, with maximum temperatures of 36º C and minimum of 29ºC [2]. Relative humidity ranges from 77 to 80%, considered a normal percentage for the area where the study is being performed. And precipitation in the Amazon basin currently ranges from 1,000 to nearly 3,000 millimeters annually [17].

Regarding the predominant vegetation inside the park, it is characterized as Tropical Rainforest, typical of the Amazon region, with predominance of secondary forests, shoal forest and area with low vegetation. It was observed

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that the topography of the park is common feature of the Amazon forest areas, having flattened zones (plateau), slope zones and shoal zones.

2.3. Data Processing

Geographic data were collected for the location maps assembly using the GPSmap 76CSx and the photographic survey of the area was performed by a mobile phone model iPhone 6S. The georeferencing of the images was performed using the software ArcMap 10.3 and QGIS 2.8.1, the satellite images were collected by Google Earth and the shapefiles were made available by the Municipal Secretariat of Environment and Sustainability - SEMMAS.

Fig. 2: PMNM area and its respective springs

2.4. Environmental Impact Classification

The classification of urban interferences of the park occurred through on-site visit and macroscopic analysis, occurring in September 2018 and July 2019. The implementation of the respective method occurred by physical-chemical and biological analysis. The model used comes from the environmental impact matrix and the Water Quality Assessment Guide [13].

After collection, the information obtained was analyzed and structured in Table 1, and the evaluation of the parameters by the quantification method was applied [11]. The method works as a score, in which it determines the class that each source analyzed is regarding its degree of environmental preservation.

Table. 1: Structure of macroscopic parameters

APPLIED MACROSCOPIC PARAMETERS			
Indicator	Bad (1)	Medium (2)	Good (3)
Water coloring	Dark	clear	Transparent
Solid waste	Much	Little	There is not
Floating material	Much	Little	There is not
Oil	Much	Little	There is not
Site Protection	No protection	With protection	With protection and with access
Insertion Area	Absent	Private property	Parks or protected areas
Odor	Strong	Weak	There is not
Sewer	Domestic sewage	Surface flow	There is not
Foam	Much	Little	There is not
Vegetation	High degradation	Low degradation	Preserved
Human use	Presence	Brands Only	There is not
Animal use	Presence	Brands Only	There is not

2.5. Spring Preservation Indexes

The classification regarding the degree of preservation of the three (3) Mindú springs was performed by summing the current situation of the indicators shown in Table 2 as previously seen, being characterized as springs under the conditions: Great (A), Good (B), Fair (C), Bad (D), and Poor (E), as shown in Table 2.

Table. 2: Classification of spring conditions

Class.	Preservation Level	Total score
A	Great	31 – 33
B	Good	28 – 30
C	Reasonable	25 – 27
D	Bad	22 – 24
E	Terrible	Under 21

III. RESULTS AND DISCUSSIONS

In the present study, for the cataloging of the sources, we used nomenclatures from 01 to 03, each number referring to one of the analyzed sources.

3.1. Spring 01 - (03º00'30.0 "S / 59º55'55.2" W)

The results obtained in this source were organized and inserted in Table 3 for better visualization of the analyzed parameters.

Table. 2: Result of visual analysis

INDICATOR	RESULTS
Coloring	Transparent
Solid waste	Absent
Odor	Absent
Floating materials	Absent
Oils and foams	Absent
Domestic sewage	Absent
Vegetation	Predominant
Site Protection	Predominant
Human presence	Medium
Animal use	Medium

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By collecting the physical parameters of the present spring during the ebb season, it was found that it has a transparent water color, with no solid residues around the water body and no odor. A study along the same lines found that with regard to the water color parameter, it is found that 75% of their analyzed streams are light or transparent in color and 25% of their collected points are dark in color [10]. Water color is an analytical parameter that indicates the presence of dissolved substances in water [28].

No floating materials on their surface, oils and foams in their respective surface, nor the proximity of domestic sewage causing any disturbance or degradation were identified. Other studies that performed the same analysis presented satisfactory results regarding the evaluation of the present indicators, since of their 15 observed sources, four sources presented low contamination [15]. However, it should be considered that it is necessary to prove it by chemical analysis of water quality [1].

It was observed that the vegetation is native, in which some palm species were observed, such as buritis (Mauritia flexuosa L. f.), Acai (Euterpe oleracea) and several other species that are adapted to surfaces that have sandy terrain (also characterized like shoal zones).

In the preservation parameter, a research in the same field of analysis found that 72.73% of the vegetation-predominant springs are still preserved; however, 36.36% (3 springs) have a distance greater than 100 m from homes and establishment. , only one spring has a minimum distance of 50 m in compliance with current legislation [30].

Fig. 3: Arboreal species around Spring 01

Regarding the protection of the site, it is located in an area of closed vegetation, preventing direct access by people, requiring the support of environmental agents who are in the park and who make such a path to visit the source. In another study on the environmental quality of springs, it was found that they are devoid of fence to protect the surroundings, but legally protected [16]. Although there is some level of difficulty in accessing springs that are overgrown by vegetation, yet access to water bodies by humans is unavoidable [32].

In the parameter of human presence, some domestic wells were seen, possibly opened by the surrounding population. Near the source, the presence of people was visualized using the resource. The analysis of this indicator shows that in 53% of the studied sources there were signs of human presence through the deposition of residues to the ground and 23% of the sources had people close to the water body.

Fig. 4: Presence of artesian wells near the Spring 01

During the course, excessive rain-borne solid waste was observed in the park interior and an advanced gully in the ground in the slope zone, as shown in Figure 5. Briefly, gullies are large holes of erosion from human action or Natural. In this spring, the amount of solid waste was lower compared to Springs 2 and 3. In some studies on this parameter, there was a certain fluctuation in the amount of predominant waste near the sources [24].

Fig. 5: Presence of solid waste near east 01

Regarding the collection during the flood period, which reaches its maximum peak in July, the indicators analyzed in the present spring did not change significantly. One observation that differs from the first collection of the study in the ebb season was the finding of the soggiest terrain near the source, since at this time there is also extreme rainfall and an increase in the amount of water in the water table [22]. .

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3.2. Spring 02 - (3º00'31.7 "S / 59º56'06.1" W)

Spring 02 had some opposite characteristics to Spring 01 and 03, as it was directly influenced by the discharge of domestic effluents from a sewage treatment plant that is located in the vicinity of the park. Considering that the degradation in water bodies is due to effluent discharge, such waste comes from residences and commercial establishments and from the growth of the surrounding community without adequate infrastructure [35].

Fig. 6: Sewage treatment station

As visited on site, observed the dark color of the water due to the large amount of organic matter deposited in it. A study carried out by four surveyed springs showed dark coloration and three springs fit as light, considering that they are in private properties and in public areas. However, it was observed that in the research carried out at Nascente Douradinho, in São Paulo, the water coloring characteristics visualized were similar to that of Nascente 02 and both presented the domestic sewage discharge activity in its bed.

The surface of the water body showed the presence of floating materials and domestic solid waste (television and pet bottles) inside the spring, as shown in Table 3. This parameter analyzed in other cases, resulted in only 18% of the verified sources were without floating materials [31]. On the other hand, other studied areas could observe the non-predominance of residues in the area of interest, however, floating materials were visualized in the water, such as PET`s bottles. possibly coming from homes near the study site [23].

There was a moderate degree of foam and absence of oil on the surface of the spring. There was an advanced degree of odor from the WWTP, however, the odor from the outcrop was characterized as weak. It can be observed that the distance from the source to the sink was at least 50m.

With regard to vegetation, the characteristics are similar to those of Springs 01 and 02, since all are in lowland. The predominance of vegetation around the springs is an important parameter due to its preservation capacity, as the vegetation cover promotes soil protection and stabilization [33]. Other factors affect the quality of the spring, even if there is a predominance of riparian forest in its surroundings [21].

The analysis of this spring during the flood period only found the human presence through clothes left in the vicinity of the study area, as shown in Figure 7. A weak odor and low foam on the surface of the outcrop were also found.

Fig. 7: Clothes around the Spring 02

3.3. Spring 03 - (0300'35.7 ”S / 59º56'06.9” W)

Spring 03 was the first to be found along the way. In the first survey, the abovementioned survey had a large amount of solid waste in and around it, was odorless and contained an irrelevant presence of foams and oils.

Despite the presence of solid residues, the spring water coloration was defined as clear and considered in good condition. The water color parameter is the result of substances in solution that can be caused by elements such as iron or manganese, the decomposition of organic matter from water (mainly vegetables), algae or the introduction of industrial and domestic sewage [18].

As for the surrounding vegetation, it does not differ from the other sources studied. In contrast, Nascente 03 is more vulnerable due to its proximity to the urbanized area. One of the main consequences arising from the interference of anthropization on the springs is the flow, which may occur to the reduction of water flow and consequently its disappearance [9].

It has been found that accessibility to this spring is of mild degree, with no protection in its surroundings. The proximity to homes and establishments is a factor that influences their environmental degradation.

In a last survey carried out during the ebb period, Nascente 03 was silted due to the carry-over of sand and

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solid waste into the park, mainly affecting the water system. The disordered growth of communities around protected areas causes social and environmental problems, mainly contributing to the degradation of water bodies and green areas [3].

Some parameters analyzed in the flood period differ from the first analysis, such as the amount of floating material on Source 3, the presence of surface domestic sewage and an advanced gullet from the surface runoff, as just above the surface. PMNM there are access roads.

3.4. Analysis of spring preservation indicators

Considering that there were no exorbitant differences in the comparisons made between the flood and ebb periods of the river, we obtained as a result the classification of springs 02 and 03 in low preservation condition, as shown in Table 4. These areas are located near public places and homes, they do not have protection. Both were critical for the presence of solid waste, floating materials, sewage and human use. Thus, applying the preservation index through the sum of the points, Spring 02 scored 20 and Spring 03 scored 23, being classified respectively in Class D and E, as bad and bad [11].

Table. 4: Indicator Results

SPRINGS WATER	SW1	SW2	SW3
Water Coloring	3	1	2
Solid Waste	2	1	1
Floating Materials	3	2	1
Oils	3	3	3
Site Protection	3	1	1
Insert Area	3	3	3
Sewer	3	1	3
Odor	3	1	3
Foam	3	2	2
Vegetation	3	2	2
Human Use	1	2	1
Animal Use	2	1	2
Equipment Urban	-	-	-
Visits	-	-	-
Punctuation	32	20	24
Preservation Level	Great	Terrible	Bad

However, Spring 01 is in adequate preservation condition, since the analyzes of its macroscopic characteristics were satisfactory, obtaining the classification A, as excellent. It should be emphasized that these data are considered alarming, given that the three springs are located in an integral protection conservation unit. Considering that one of the main functions of protected areas is to fully protect the natural areas of interest to future generations [34].

In the urban equipment parameter considered in the present study, the results were weighted by the distance from each source to the nearby urban areas, given that the conservation unit is in an anthropic pressure area. As for the visits, it was verified through the layout of the visitation book that, at the entrance of the park, about 300 people access the park freely for the practice of sport and leisure. In the data collection of three of its studied sources were under anthropic pressure due to its proximity to the anthropized areas [27].

Being a Conservation Unit of Integral Protection, it was verified the absence of signs, banners or informative that signal the existence of the present springs and the animals that occur in the park. The springs influence changes in the surrounding vegetation, together with urban facilities and facilitated access, their degradation becomes faster, affecting their entire environment [24]. Given that only one spring is preserved and performing its environmental activities normally, it is necessary to develop recovery techniques in the other two outcrops.

The park has an administration department that controls the entry and exit of visitors and employees who clean the unit. However, the solid residue parameter and, concomitantly, its impacts on the springs was the most critical data of this study, considering that in times of precipitation these residues are carried into the water body and green areas. These findings influence the environmental quality of the park and its springs.

IV. FINAL CONSIDERATIONS

The study of the seasonality of the three springs located inside the conservation unit was necessary, as they give rise to one of the main streams that cross the city of Manaus: The Mindu Stream. Thus, research on these outcrops becomes important not only for their representativeness in the capital, but above all for the importance of preserving water bodies and their challenges faced in the urban growth surrounding them. It is also emphasized that the studied sources are vulnerable.

From the above, it was concluded that the springs 02 and 03 are in a critical state of preservation, requiring direct intervention by the public agency. Despite the level of preservation of spring 01, this one is still vulnerable due to the amount of solid waste found in its path. Thus, it is of utmost importance to tighten existing environmental laws, meeting the unique needs of these areas, especially the increased security around the park. In this sense, it is suggested to deepen new researches that portray the environmental conditions of that unit and send this information to the competent agency.

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