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Papers

Anthropic Action and the Eutrophication Process in the Paraíba do Meio River

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Abstract
The appropriation and use of a hydrographic basin by society is a historical process, necessary and, above all, a generator of environmental problems that greatly alter the quality of water. One of the problems related to water quality is eutrophication. Many aquatic ecosystems have suffered from this problem, which consists of large inputs of Phosphorus and Nitrogen introduced into the riverbed, for example, through domestic and/or industrial effluents. This context of change in water quality by human action triggers the significant growth of phytoplanktonic and phytobenthic organisms, thus causing an imbalance in the dynamics of the aquatic ecosystem, as well as damage to society. In this context, this study aimed to evaluate the Trophic State of the Paraíba do Meio River and understand the unfolding and influences of society's relationship with the river and how this relationship has contributed to the eutrophication process. The materials and methods were based on: data acquisition of chemical and physical parameters from campaigns carried out monthly during the hydrological year of 2013; flow and precipitation data; adequate sanitary sewage data; laboratory analyses; determination of the Trophic State Index by the TRIX Model. It was evidenced that due to the varied anthropic activities that occurred in the hydrographic basin in question, with the significant introduction of nutrients such as Phosphorus and Nitrogen in the river bed, during the hydrological year of 2013, the Paraíba do Meio river presented different stages of eutrophication that range from mesotrophic to eutrophic.

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INTRODUCTION

Rivers are a natural resource of extreme importance for human beings and which, in turn, are part of the historical process of development of many societies since ancient times, such as the Egyptian civilization with the Nile River and the Mesopotamia located between the rivers Tigris and Euphrates. The importance of water has long been attributed, mainly to meeting social interests, in terms of socio-economic growth and development. According to Rebouças (2006, p. 01) "fresh water is an essential element for the supply of human consumption and the development of industrial and agricultural activities and it is of vital importance to the ecosystems – both plant and animal – of emerged lands".

In the process of appropriation and use of water resources, society ends up changing the water quality of aquatic ecosystems, thus causing environmental degradation. Among the environmental issues generated, there is the eutrophication situation. The eutrophication process is currently considered an existing problem in several aquatic ecosystems in the world, as it affects lakes, dams, rivers and coastal waters from all over the planet, constituting a significantly widespread environmental problem. Eutrophication has generated countless losses in biodiversity, reduced water quality and, in turn, its low availability. Consequently, it has caused risks to human and animal health.

In Brazil and also in most developing countries, the lack of adequate sanitation has characterized a scenario of possibility and contribution for the eutrophication process to occur with more significance. The existence of domestic and/or industrial effluents releasing material directly, without prior treatment, into the water streams is one of several examples. Such inputs of organic material and pollutants have contributed to eutrophication in several aquatic environments.

Eutrophication is considered a major environmental concern to aquatic ecosystems, due to the high inputs of nitrogen (N) and phosphorus (P). Among these activities, the following stand out: sewage outfalls, industrial facilities, fertilizers used in agriculture, effluents from intensive livestock and aquaculture. This supply of N and P stimulates the excessive growth of phytoplanktonic and phytobenthic organisms, causing several deleterious effects on ecosystems and human populations (KITSIOU; KA-RYDIS, 2011 apud COTOVICZ JUNIOR et al, 2012).

Water bodies are used in many ways and for different purposes, such as water supply, irrigation of crops, leisure and dumping of raw wastewater, with eutrophication being one of the main changes caused by man, usually by the excessive supply of nutrients in aquatic environments. (MACEDO; TAVARES, 2010, p. 150).

Such a phenomenon can be natural or artificial, being a slow and continuous process, resulting from the input of nutrients brought by rains and surface waters that erode and wash the earth's surface. Under natural conditions, without interference from human activities, deep lakes with low biological productivity undergo a transformation process, becoming shallow, with high biological productivity and enriched by nutrients. However, the speed of development of the natural eutrophication process is quite slow, occurring due to the time (WETZEL, 1983; MARGALEF, 1983; SCHIEWER, 1998 apud MACEDO; TAVARES, 2010, p. 150).

When the phenomenon occurs with anthropic action, the tendency is to break the so-called ecological balance. It is in this context that Esteves (1998, p. 207) talks about homeostasis: "artificial eutrophication can be considered as a chain reaction of very evident causes and effects, whose main characteristic is the breakdown of ecosystem stability (homeostasis)".

Thus, the phenomenon of eutrophication is a worrying reality and it is necessary to involve researchers and public authorities in order to take preventive and corrective measures, through the process of managing water resources. Management must, for example, prevent a particular river from reaching an advanced stage of eutrophication where there is an increase in treatment costs. Esteves (1998, p. 215) points out that "the final stage of the artificial eutrophication process is practically irreversible and, only with the use of a lot of energy and capital, it will be avoided that the ecosystem becomes useless for man".

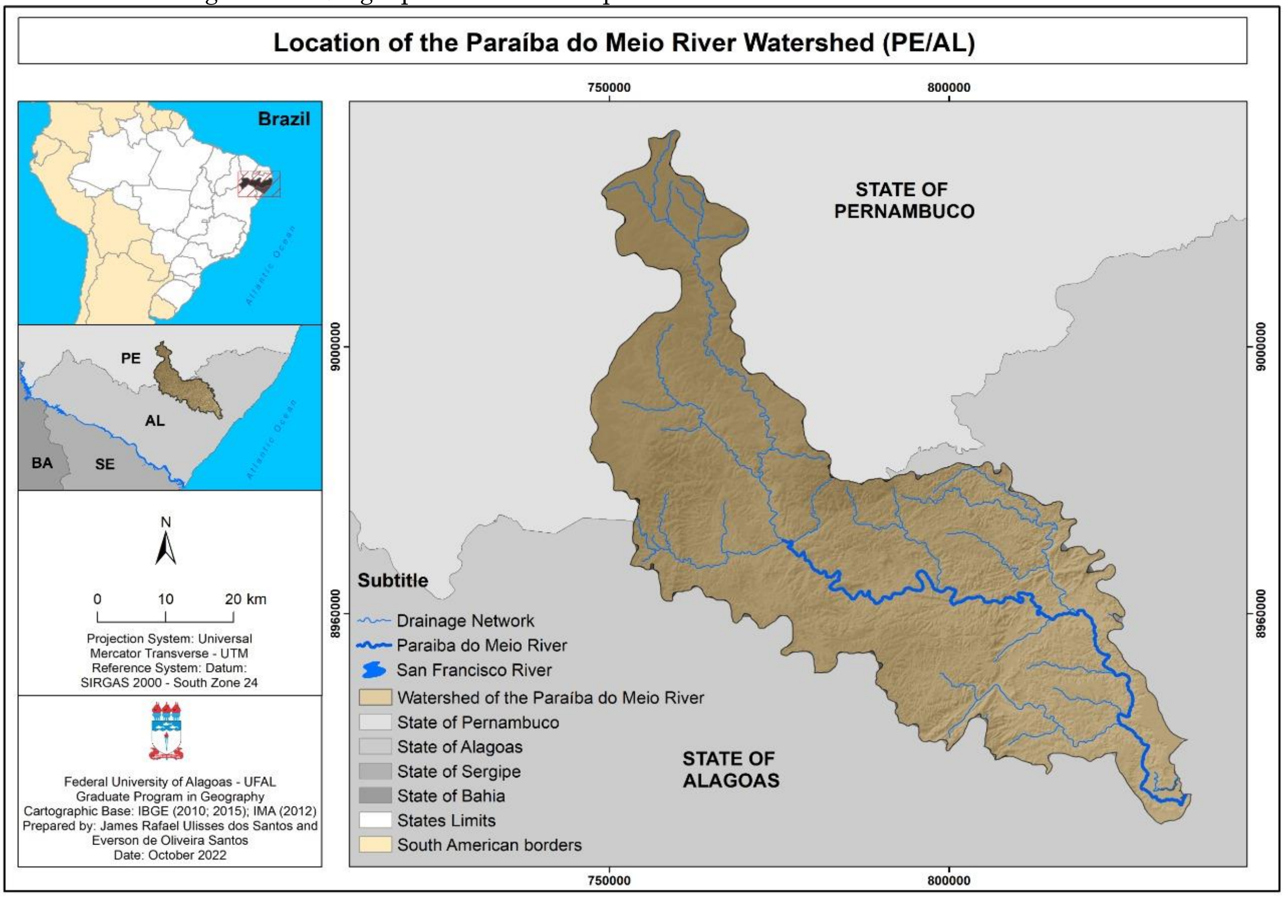
In this context, the present study aimed to evaluate the Trophic State of the Paraíba do Meio River and, in this context, to understand the consequences and influences of society's relationship with the river and how this relationship has contributed to the eutrophication process.

STUDY AREA

According to its Water Resources Master Plan (ALAGOAS, 1997), the hydrographic basin from the Paraíba do Meio River has a total area of 3,127.83 km² and it is located in the states of Alagoas and Pernambuco, northeast Brazil, with a perimeter of 478 km. In this sense, 37.6% of the basin corresponding to 1,175.33 km² are located in the State of Pernambuco, and most of the basin is in Alagoas territory with an area corresponding to 1,952.5 km² (62% of the total).

The geographic location (figure 1) of the basin is between the parallels 08°44' and 09°39' South latitude and between the meridians 35°45' and 36°45' West longitude of Greenwich.

Figure 1 – Geographic location map of the Paraíba do Meio River Basin.



Source: IBGE (2010a); IMA (2012).

The river basin has within its perimeter eight municipalities in Pernambuco (Bom Conselho, Brejão, Terezinha, Paranatama, Caetés, Garanhuns, Saloá and Lagoa do Ouro) and eight others in Alagoas (Quebrangulo, Paulo Jacinto, Viçosa, Palmeira dos Índios, Cajueiro, Capela, Atalaia and Pilar). Following its natural course, the Paraíba do Meio River flows into the Mundaú-Manguaba Lagoon Complex, in the municipality of Pilar - Alagoas.

Concerning the climatic aspects, according to Santos (2020, p.41), the portion of the basin in Alagoas is "characterized as a region with a hot and rainy tropical climate, with a dry summer of type As', according to the classification of Köppen". Therefore, the portion of the basin in Pernambuco climate is classified as sub-humid, according to the Köppen classification, BShs'.

Regarding the soils that characterize the area of the Paraíba do Meio River basin, it is essential to highlight that they have very different properties. Thus, there are the following types: Argisols, Regossols, Planosols, Red Yellow Latosol, Alluvial Soils and Gleysols (SANTOS, 2020, p. 41).

The relief of the basin, according to Gama (2011, p. 38), is "defined in the upper course by a flattened surface, with undulating relief at an altitude between 600 and 800m. The middle course is characterized by the presence of structural forms and homogeneous dissection, and the lower course by a sedimentary surface dissected in tubuliform interfluves and hills".

The Paraíba River Basin, in the State of Pernambuco, is characterized by crystalline basement rocks of the Precambrian Age, comprising both the Upper Precambrian (Quartzite Unit of the Garanhuns Region) and the Undivided Precambrian (Migmatite-Granitoid and Migmatitic Gneissic Complex). The crystalline terrains of the Paraíba River Basin in Alagoas, as belonging to the Lower Proterozoic, are represented by the Migmatitic-Granitic and Gneissic-Migmatitic Complexes. The Tertiary sedimentary terrains are represented by the Geographic Barrier Formation and the Holocene sediments included in the undifferentiated Quaternary unit (GAMA, 2011, p. 38).

Also, according to Gama (2011), the Upper and Middle Valley it is characterized by sub-evergreen and sub-deciduous hillside Tropical Forest. In Low Valley, the forest of Tabuleiro is noticeable that, in its turn, has patches of the Cerrado Biome. What's more, in the Coastal Lowland, the Sandbank Vegetation (Francês, Taperaguá and Massagueira) is somewhat conserved. In the lagoon plain, there are mangroves with brackish soils and in the sandier areas, there are woody mangroves.

MATERIALS AND METHODS

Data acquisition and sampling

To make the research happen, the database of the Laboratório de Geoquímica Ambiental – Instituto de Geografia, Desenvolvimento e Meio Ambiente, as well as the Laboratórios Integrados de Ciências do Mar e Naturais, da Universidade Federal de Alagoas, was taken as a basis. Flow data were obtained from the website of the Agência Nacional das Águas (ANA, in Portuguese – the federal agency responsible for the implementation of Brazilian water resources management), through Hidroweb. Precipitation data were obtained from the Secretaria do Estado do Meio Ambiente e Recursos Hídricos de Alagoas (SEMARH, in Portuguese – the state agency responsible for the management of water resources in Alagoas). Adequate sanitary sewage data were obtained from the Instituto Brasileiro de Geografia e Estatística (IBGE, in Portuguese – a federal agency responsible for collecting geographic and statistical information from Brazil).

Sampling Plan

Samples for analysis of nutrients, chlorophyll and suspended material were collected in plastic flasks with a volume of 5 liters, with a Van Dorn acrylic collection bottle on the sub-surface, around 30 centimeters below the waterline. In Situ measurements of temperature, electrical conductivity, salinity, pH and dissolved oxygen were performed with a YSI-6600 Multiparametric Probe.

Determination of the Sampling period

The sampling carried out to obtain the data were done monthly, during the year of 2013, and such campaigns were carried out in parallel with the collections to determine the amount referring to the flow of Dissolved Inorganic Nutrients, as well as the concentration of Nitrite, Ammonia, Nitrate, Dissolved Phosphorus, Dissolved Oxygen, Oxygen Saturation, Water Temperature and Chlorophyll a.

Laboratory analyzes

Dissolved inorganic nutrients (Ammonia, Nitrite, Nitrate, Phosphate and Silicate) and Total Phosphorus were determined according to Carmouze (1994).

The methodology applied to determine the phosphorus load:

CTm = dissolved phosphorus load (T/year)
Q = river flow (m^3/s)
Cm = Individual concentration of each monthly average of phosphorus (µg /l).

The flow of nutrients and suspended materials was determined according to Medeiros (2007). The Chlorophyll autotrophic pigment and the suspended material (MS) were determined according to Strickland and Parsons (1972).

The method of Strickland and Parsons (1972) was used to calculate the concentrations of dissolved inorganic nutrients (dissolved phosphorus, etc.) based on the difference (in µg) between the corrected weight of the filter with the sample and the weight of the empty filter, divided by the volume of filtered sample.

Determination of the Trophic State Index and the TRIX Model

To determine the Trophic State Index and the TRIX Model, the equation used for calculation follows:

$$x_c = \frac{1}{n}\sum_{1}^{i=n}[\frac{(M-L)}{(U-L)}]i$$

The equation is applied to a set of n parameters, namely: chlorophyll a, oxygen as absolute deviation from saturation, nitrogen and phosphorus (inorganic or total). M is the measured value of each of the parameters and U and L are the confidence limits (upper and lower, respectively) of each parameter, determined as the mean ± 2.5 x standard deviation.

The values must be transformed (applying logarithms) in order to normalize the distribution (BERTOLDI, 2014, p. 36).

An adaptation of the formula to the Brazilian System was carried out and, in this process, it was rewritten as:

$$TRIX = \frac{[\log 10(\text{Chla} * \text{aD\%0} * \text{NID} * \text{PT}) + k]}{m}$$

Chla is equivalent to the concentration of chlorophyll a; aD%O is the absolute deviation of the percentage of dissolved oxygen saturation; NID, is dissolved inorganic nitrogen concentration and PT, is the total phosphorus concentration. The parameters k = 1.5 and m = 1.2 are scalar coefficients that were proposed by Giovanardi and Vollenweider (2004), introduced to fix the minimum limit of the index and the extension of the trophic scale between 0 and 10 (BERTOLDI, 2014, p. 36).

Taking into account the results of the calculations of this index, they are classified as follows (table 3):

Table 1 – Trophic State Classification for estuarine waters according to TRIX Model.

TRIX	Conditions	Trophic State
<2	Very poorly productive and very low trophic state	**Excellent (Ultraoligotrophic)**
2-4	Poorly productive and low trophic state	**High (Oligotrophic)**
4-5	Moderately productive and medium trophic state	**Good (Mesotrophic)**
5-6	From moderate to highly productive and high trophic state	**Moderate (From Mesotrophic to Strophic)**
6-8	Highly productive and highest trophic state	**Poor (Eutrophic)**

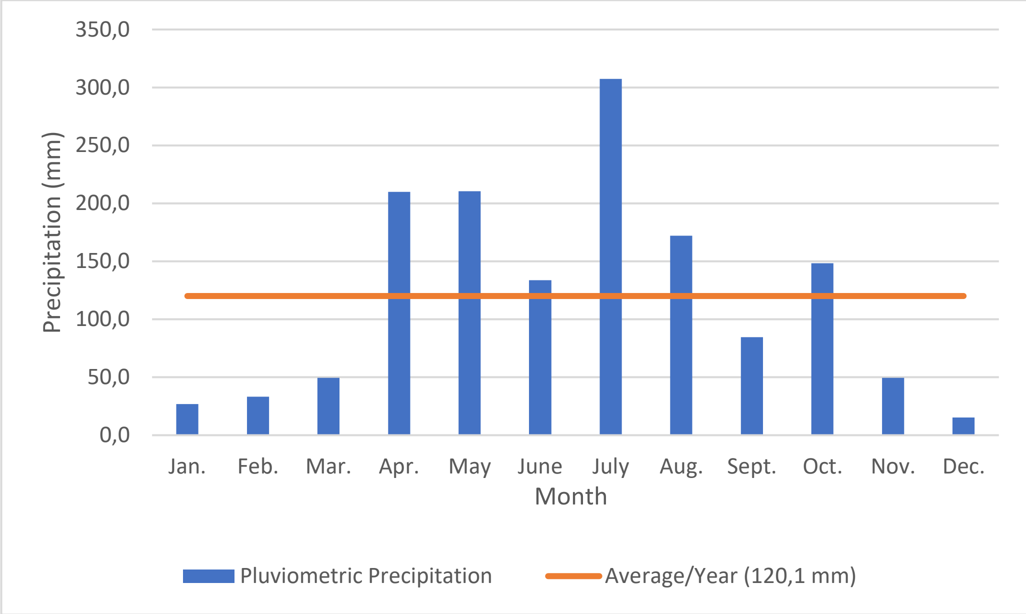
Source: The authors (2021).

RESULTS AND DISCUSSION

Precipitation and flow during the hydrological year 2013

The precipitation data for the hydrological year of 2013 (figure 2) detail that the month with the highest rainfall was July, with 307.4 mm, so the lowest value was in December, with 15.2 mm. The average rainfall for the year 2013 was 120.1 mm. The rainy season lasts from April to October, varying between 84.7 mm and 307.4 mm (such fluctuations are above the average annual precipitation – during this period, only the month of September was below the average annual precipitation). After October, there was a downward trend in precipitation values below the annual average. The period from January to March presented precipitation values below the annual average, ranging from 26.8 mm to 49.4 mm.

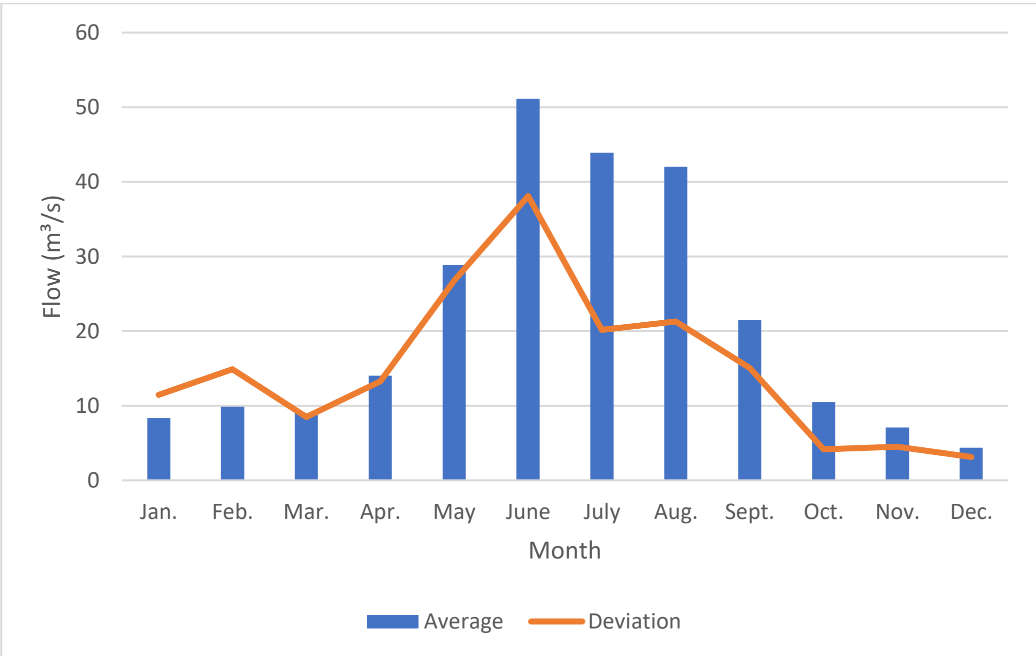
Figure 2 – Graphic of the Pluviometric Precipitation of the Paraíba do Meio River (2013).



Source: SEMARH (2019).

In terms of the monthly average data for the historical series from 1989 to 2013 (figure 3), it is represented in the graphic as follows: all of January in the series, all of February in the series, etc. In this context, the statistical parameter Standard Deviation is inserted.

Figure 3 – Graph of Monthly Average and Historical Deviation (1989-2013) of the Paraíba do Meio River.



Source: SEMARH (2019).

It is evident that in many time periods the flow values are below the deviation value, as in January and February of the series. It is important to note that it is during the rainy season of the series that an extrapolation of flow values above the deviation occurs, with emphasis on June, July, August and September.

Socio-environmental and economic activities in the Alagoas portion of the river

Society, throughout its evolutionary history, has improved, through work, its instruments and techniques to relate to nature and, above all, to transform it. This means that more and more it has increased its power of transforming the natural environment.

In this relationship between society and nature, the landscape is constantly and historically modified. Bringing this premise to the present case study, it is possible to say that this transformation of the landscape has included in it a resource of social, economic, environmental and, above all, vital relevance: the water resources of the Paraíba do Meio River. The process of appropriation and use of the river to meet the needs of the population along the hydrographic basin has historically occurred in a disorderly manner, without concern for the consequences of environmental degradation arising from this process.

According to the research by Santos, Medeiros and Santos (2018), entitled "Socio-environmental implications of the process of appropriation and use of the Paraíba do Meio River in Viçosa (AL)", the existence of several socioeconomic activities was identified (Chart 1), such as:

Chart **1** – Socioeconomic activities of the Paraíba do Meio River in Alagoas.

Socioeconomic activities on the Paraíba do Meio River
Fishing (currently scarcer)
Removal of sand from the river bed for civil construction
Installation of water pumps for irrigation of agriculture activity in the vicinity of the floodplain
River banks: agricultural activities based on simple mercantile production (planting cassava, potato, sugar cane, lettuce, coriander, corn, beans, etc.)
River banks: simple livestock

Source: Santos et al. (2018).

These activities significantly contribute to the degradation of water resources and their natural attributes, since such activities occur and modify the landscape without technical supervision or adequate guidance and facilitated by the government. Emphasizing that this problem is not an endemic situation to a particular municipality in Alagoas, as this reality is similarly repeated in the various municipalities in the Alagoas portion of the basin.

According to Santos et al. (2018), the case of the municipality of Viçosa highlights this reality:

> It should be considered that the erosion caused by the removal of riparian forest induced the appearance of sandbanks along the river bed, indicating the silting to which it is subjected. Over the years, this degradation has made the river unsuitable for navigation by small boats, which was once possible, according to residents' reports (SANTOS et al., 2018, p. 60).

The socioeconomic activities listed here as elements that are part of the reality of the municipalities that make up the hydrographic basin of the Paraíba do Meio River in Alagoas have, over time, caused various environmental problems that have significantly contributed to the change in water quality. One of them, for example, is the deforestation of the riparian forest. It is of fundamental importance in the protection of springs and riverbanks, which are prohibited from being removed because they are APAs (Permanent Preservation Areas), according to the Forest Code, Law N° 12.651/2012. The removal of this vegetation influences the increase in fluvial erosion processes and, consequently, in the enlargement of the drainage area, decrease in the water depth of the river and increase in turbidity. Economic activities, even if simple, on the banks of the river, added to the deforestation of the riparian forest, are worrying.

The silting has been occurring in the river bed precisely because the water depth has decreased, since the erosive processes, due to the removal of the riparian forest, became more expressive and thus there is no flow with sufficient energy to transport the sandbanks then deposited on the riverbed.

Hence, another problem comes into focus: unsupervised and technically oriented dredging. It has been common for residents to remove the sand sediments from the banks that form along the riverbed and for use in civil construction. This economic activity contributes to the income of many riverside families. According to Santos et al. (2018, p. 61), the "inappropriate removal of sediments ends up causing a change in the natural regime of concentration of nutrients and sediments, which, in turn, influences the Mundaú-Manguaba Lagoon Complex in Alagoas".

However, as it is a source of income, when the sandbanks run out, the dredging process continues and this has caused changes in the balance of flow and transport of sediment in the river.

The Sanitary Sewage System of the municipalities of Alagoas and Pernambuco

The qualitative degradation of water bodies is directly linked to organic pollution. Inadequate discharges of sanitary sewage and solid waste into water resources promote the gradual contamination of water, transforming it into a serious public health problem. Currently, domestic sewage represents one of the main problems of water resources in Brazil, due to the lack of a collection network, treatment or inefficient treatment of collected effluents (SANTOS et al., 2018, p. 24).

With the process of domination, expansion and urbanization, man has transformed and still transforms natural environments to create artificial environments, that is, the urban environment, to meet his needs as a social being. This brings the importance of studying, conceptualizing and characterizing the relationships of the urban environment, so that one can contribute to the discussion of improving the quality of life within urban agglomerations and the existing socioeconomic and environmental problems (SALLES et al., 2013, p. 282).

It is important to point out that the disorderly urbanization process contributes significantly to the degradation of water resources. In the case study, this reality is evidenced when the process of disordered urbanization in the Paraíba do Meio River basin is questioned. The relationship between appropriation and use of water resources by society is historical. According to Santos et al. (2017, p. 113), "since the dawn of time, humanity has developed and expanded the urban near rivers, which had, and in some cases still have, fundamental importance in the economic development of cities.". Santos et al. (2018, p. 62), also corroborate that "the major problem in this regard is due to the fact that, especially in Brazil, this expansion occurred in a disorderly and unplanned way.

Thus, a way was sought to understand the structuring of Adequate Sanitary Sewage in the municipalities that are part of the Paraíba do Meio River basin and the percentage of Adequate Sanitary Sewage existing and effected by the government. The data used here for discussion were obtained from the IBGE (2010b) given the characterization of reality in a time frame within the scope of this research, in this case the year of 2013.

An Adequate Sanitary Sewage System is defined as an ingenious set of works and installations aimed at ensuring the collection, transport, removal, treatment and final disposal of structured sewage to serve the community, and this must be in a way that is adequate to the sanitary standard. This involves domestic, industrial and storm sewers.

It turns out that all this requirement of "sanitary standard" is practically deficient in a significant way in Brazilian municipalities and this is related to the lack of urban planning. Since almost in their entirety, the cities were developed on the banks of the Paraíba do Meio River and this in itself is already an indication of the need to carry out adequate sewage.

Knowing in detail each municipality in the State of Pernambuco belonging to the basin, in order to understand the sanitary sewage data, it is essential to also make an association with the demographic data (Table 2).

Table 2 – Demographic and Sewage Data for the BHRPM municipalities in Pernambuco.

BHRPM'S DEMOGRAPHIC AND SANITARY SEWAGE DATA OF MUNICIPALITIES IN PERNAMBUCO					
PERNAMBUCO	**POP. CENSO 2010**	**EST. POP. 2019**	**DEMOG DENS..**	**TERRIT. AREA**	**SANIT. SEWAG.**
MUNICIPALITY	**Hab.**	**Hab.**	**Hab./km²**	**km²**	**%**
Bom Conselho	45503	48554	57,44	792,185	54,4
Brejão	8844	8993	55,35	159,786	29,8
Terezinha	6737	7169	44,48	151,450	56,3
Paranatama	11001	11523	47,65	185,371	4,6
Caetés	26577	28739	80,66	294,946	24,4
Garanhuns	129408	139788	282,21	458,552	52,1
Saloá	15309	15843	60,73	251,549	36,4
Lagoa do Ouro	12132	13145	61,04	198,762	52,3

Source: IBGE (2010b).

Taking into account the data presented, it was found that only four municipalities in Pernambuco in the basin have more than 50% of Adequate Sanitary Sewage System: Bom Conselho (54.4%), Terezinha (56.3%), Garanhuns (52, 1%) and Lagoa do Ouro (52.3%). The other municipalities, Brejão, Paranatama, Caetés and Saloá are below the percentage of 50% of implementation of a Sanitary Sewage System, which means that there is a significant number of effluents being dumped directly into the river.

In this context, it is interesting to discuss the case of Garanhuns, as it has the highest Demographic Density (282.21 inhab./km²) and this ends up indicating that despite having 52.1% of sanitary sewage, this percentage is very low when compared to the number of inhabitants per km² that exist in its territorial area, which suffers intense anthropic pressure. There is also the case of Paranatama, which has the lowest and most alarming percentage of sewage disposal, that is, of the necessary area, only 4.6% received adaptation works.

Following the same logic, there is a breakdown of the portion of the basin in the State of Alagoas (Table 3).

Table 3 – Demographic and Sewage Data for BHRPM municipalities in Alagoas.

BHRPM'S DEMOGRAPHIC AND SANITARY SEWAGE DATA OF MUNICIPALITIES IN ALAGOAS					
ALAGOAS	**POP. CENSO 2010**	**EST. POP. 2019**	**DEMOG DENS..**	**TERRIT. AREA**	**SANIT. SEWAG.**
MUNICÍPO	**Hab.**	**Hab.**	**Hab./km²**	**km²**	**%**
VIÇOSA	25407	25733	74,00	371,612	31,7
QUEBRANGULO	11480	11294	35,89	319,829	11,7
PAULO JACINTO	7426	7564	62,69	118,457	12,6
PALMEIRA DOS ÍNDIOS	70368	73218	155,44	450,958	13,6
CAJUEIRO	20409	21264	164,24	94,357	9,2
CAPELA	17077	17053	70,39	257,561	55,3
ATALAIA	44322	47185	83,82	533,258	23,2
PILAR	33305	35111	133,37	251,066	26,3

Source: IBGE (2010b).

It was verified that the situation of sanitary sewage in the Alagoas is the most deficient in the whole hydrographic basin. It is evident that there is no concern on the part of the state and municipal public authorities in the sense of providing an adequate, necessary and proper structure to the population, especially with better management and preservation of water resources.

In this sense, the only municipality that has more than 50% of sanitary sewage is Capela (55.3%). The others have a relatively low percentage of sewage and the attention given here is precisely to municipalities that have a considerable demographic density, such as Palmeira dos Índios (155.44 inhab./km²), Cajueiro (164.24 inhab./km²) and Pilar (133.37 inhab./km²), with only 13.6%, 9.2% and 26.3% of sewage works carried out in necessary areas, respectively.

The IBGE data expressed in the table and graph above draw attention to the municipality of Cajueiro, which has a high Demographic Density (164.24 inhab./km²) and with the lowest sewage value: 9.2%. If there is no greater attention on the part of the public authorities to carry out the sewage works necessary to meet this population demand, the impacts will be even greater referring to the introduction of substances through domestic effluents into the Paraíba do Meio River.

The Trophic State of the Paraíba do Meio River Basin in the Alagoas portion

From the application of the TRIX model, the results of the calculations can be classified as follows: the classification values for this index can vary from 0 to 10. Values close to 10 indicate strong eutrophication and close to 0 indicate low anthropogenic impact (CLOERN, 2001).

The data below bring the entire classification by the TRIX Trophic State Index, based on the Brazilian System, as well as the values of Phosphate, Dissolved Inorganic Nitrogen, Chlorophyll *a* and Saturation that were taken into account for the application of the calculations (Table 4).

Table 4 - Parameter data used for TRIX calculation and Trophic State classification in each month of the 2013 hydrological year.

	Phosphate Orto	**DIN**	**Chlorophyll *a***	**Saturation**		
	µg L-1 P.PO43	**µg L-1**	**µg L-1**	**%**	**Braz. Syst.**	**Classification**
Month	**log10**	**log10**	**log10**	**log10**		
January	0,86923172	1,530392	1,690196	1,900913	6	**From mesotrophic to Eutrophic**
February	0,836710966	1,45057	1,732836	1,897077	6	**From mesotrophic to Eutrophic**
March	1,495252313	1,836023	0,436957	1,954243	6	**From mesotrophic to Eutrophic**
April	1,638343312	2,109355	0,564666	1,763316	6	**From mesotrophic to Eutrophic**
May	2,058559715	2,209074	1,286793	1,625312	7	**Poor (Eutrophic)**
June	2,137740961	1,78656	0,177536	0,78533	5	**Good (Mesotrophic)**
July	1,653320468	2,711892	0,680789	0,808211	6	**From mesotrophic to Eutrophic**
August	1,939373308	2,566867	0,985426	0,911158	6	**From mesotrophic to Eutrophic**
September	1,31383222	2,134237	-0,40894	1,70927	5	**Good (Mesotrophic)**
October	1,64589645	2,452083	0,405688	1,587149	6	**From mesotrophic to Eutrophic**
November	1,5984718	1,86178	0,529559	0,886491	5	**Good (Mesotrophic)**
December	1,667798291	1,880443	0,40654	1,567614	6	**From mesotrophic to Eutrophic**

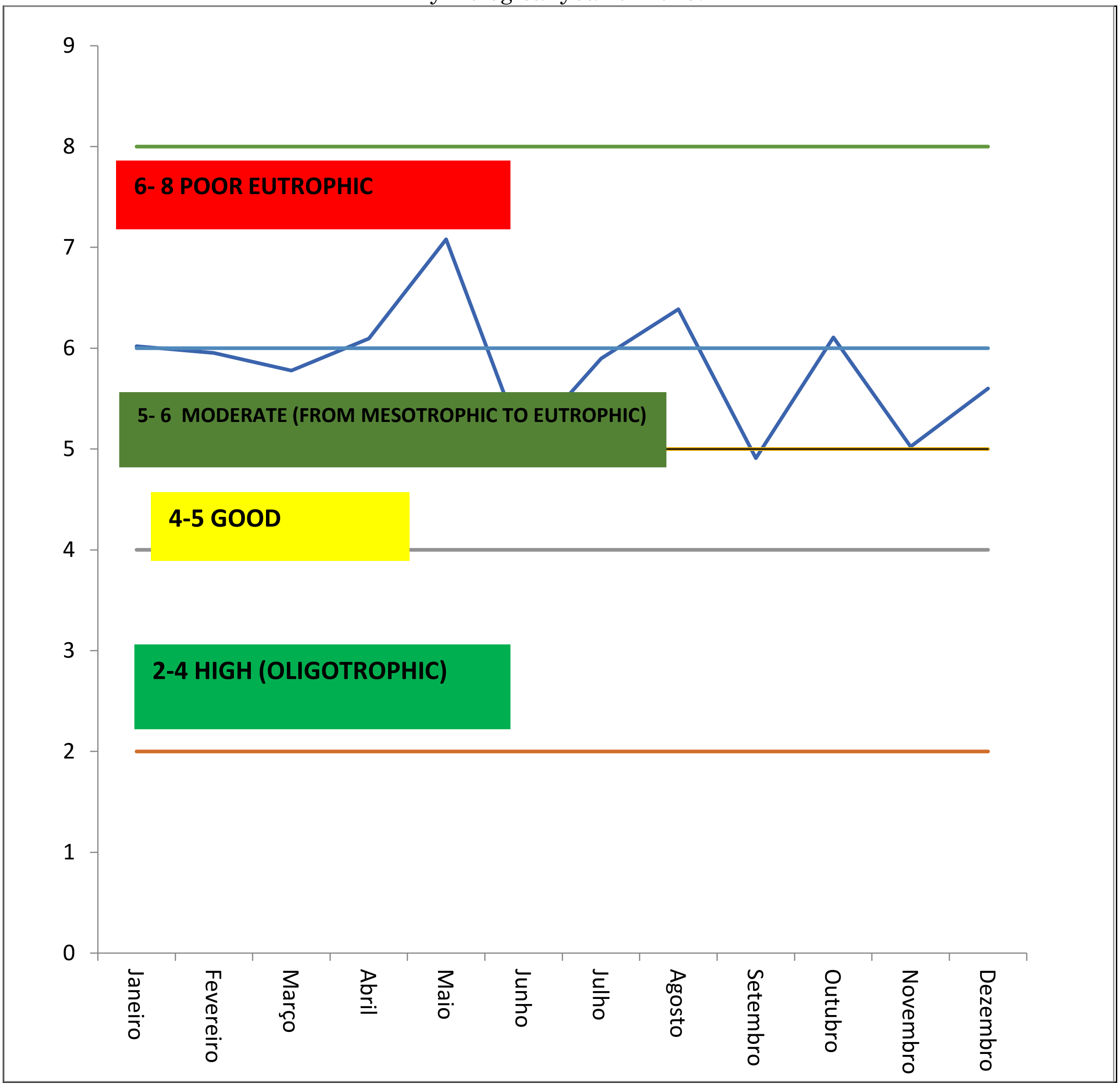
Source: The authors (2019).

Thus, in the hydrological year of 2013, the Trophic State of the Paraíba do Meio River varies from Mesotrophic (Good) to Eutrophic (Poor). In the majority part of the year, the trophic state of the river ranges from Mesotrophic to Eutrophic (moderate to highly productive and considered to have a high trophic state). In the months of June, September and November the situation is specifically classified as Mesotrophic (moderately productive and considered to have a medium stage of eutrophication). It is only during the month of

May that the river reaches its highest peak, that is, classified as Eutrophic (considered highly productive and the highest trophic state of eutrophication).

This described variation can be visualized and detailed, throughout the hydrological year of 2013, through a graph that demonstrates the behavior and variation of the trophic state of the Paraíba do Meio River (figure 4).

Figure 4 – Trophic State classification chart of the Paraíba do Meio River and its variability in the hydrological year of 2013.



Source: The authors (2019).

Given the situation described, it is evaluated that the human activities, indicated in this research, namely: domestic effluents, inadequate sanitary sewage, pollution and contamination, deforestation of the riparian forest, disorderly and unplanned urban expansion, among others, are influencing the enrichment of nutrients that, in turn, are leading to the existence and increase of the eutrophication process of the aquatic ecosystem, due to the entry, above all, of nutrients such as phosphorus and nitrogen, which in turn, end up contributing to eutrophication.

FINAL CONSIDERATIONS

The existing eutrophication process is significant, varying, according to the TRIX model, between Mesotrophic (medium and moderately productive stage) and Eutrophic (high and highly productive stage). The existing human activities along the river basin listed in the study, such as agriculture, livestock, irregular occupation on the banks of the river and consequently the existence of domestic effluents, as well as the deficient situation of adequate sanitary sewage in the municipalities belonging to the basin, demonstrate how the relationship between anthropic action and the high stages of the trophic state of water are related and, above all, intensified eutrophication.

Therefore, the present study contributed to the scientific literature regarding the subject in question-related to the hydrographic basin of the Paraíba do Meio River, since there is a lack of research on this theme on that river. Moreover, it not only made it possible to understand the current and worrying situation, but, above all, it can help environmental agencies and the public power in decision-making, since the aforementioned research with its respective data, results and discussions can serve as a reference and guidance in the elaboration of environmental reports, as well as of some action as public and/or private environmental policy aiming at the recovery of the existing environmental degradation.

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AUTHORS CONTRIBUTION

Everson de Oliveira Santos gave the original idea; elaborated the text and the original draft; systematized information and data. Paulo Ricardo Petter Medeiros revised and edited the text; collected the data; carried out the application of statistical parameters.