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Research Paper

# Implementation of the Municipal Integrated Urbanization Program in the Camaçari River Basin: socio-environmental assessment

## *Implantação do Programa Municipal de Urbanização Integrada na Bacia do Rio Camaçari: avaliação socioambiental*

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**ABSTRACT**: The disorderly urban occupation has been contributing to the degradation of the environment, with emphasis on water resources, where sewage is still dumped and becomes vectors for the proliferation of diseases. In this context is the Camaçari River, which crosses the municipality of Camaçari and stands out as an important affluent of the Joanes River Basin, responsible for the water supply of the Metropolitan Region of Salvador. Therefore, due to its importance, the Municipal Integrated Urbanization Program was implemented in the Camaçari River Basin to improve the infrastructure and sanitation of the municipality. Considering this scenario, the present study aimed to evaluate the socio-environmental results arising from the implementation of the program. The research had a descriptive nature and a quali-quantitative approach. Urban interventions were analyzed, which contained the processes of urban and environmental degradation and expanded the offer of public basic sanitation services. Also, environmental characterization was carried out through field observation protocols and physical-chemical and biological analyzes of water quality in seven sampling points distributed between the source of the Camaçari River and its mouth, which demonstrated improvements arising from the program. At the end of the study, it was verified that there was a 12% increase in water supply and 28% in sewage connections in households in the urban area of Camaçari and the consequent 18% decrease in hospitalizations from diseases related to inadequate environmental sanitation and 17% in the infant mortality rate between the years 2013 and 2017.
**Keywords**: Basic sanitation. Watershed. River revitalization. Waterborne diseases. Environmental preservation.

***RESUMO:*** *A ocupação urbana desordenada vem contribuindo para a degradação do meio ambiente com destaque para os recursos hídricos, onde esgotos ainda são despejados e se tornam vetores de proliferação de doenças. Nesse contexto encontra-se o Rio Camaçari, que corta o município de Camaçari e destaca-se como importante afluente da Bacia do Rio Joanes, responsável pelo abastecimento de água da Região Metropolitana de Salvador. Logo, devido a sua importância foi implementado o Programa Municipal de Urbanização Integrada na Bacia do Rio Camaçari no intuito de melhorar a infraestrutura e saneamento do município. Considerando este cenário, o presente estudo teve como objetivo avaliar os resultados socioambientais advindos da implantação do programa. A pesquisa foi de natureza descritiva e de abordagem quali-quantitativa. Foram analisadas as intervenções urbanísticas, as quais contiveram os processos de degradação urbana e ambiental e ampliaram a oferta de serviços públicos de saneamento básico. Também, foi realizada a caracterização ambiental por intermédio de protocolos de observação de campo e análises físico-químicas e biológicas da qualidade da água em sete pontos amostrais distribuídos entre a nascente do Rio Camaçari até a sua foz, as quais demonstraram melhorias oriundas do programa. Ao término do estudo foi verificado que ocorreu um aumento de 12% no abastecimento de água e de 28% nas ligações de esgotamento sanitário nos domicílios da zona urbana de Camaçari e a consequente diminuição em 18% das internações provenientes de doenças relacionadas ao saneamento ambiental inadequado e 17% na taxa de mortalidade infantil entre os anos de 2013 e 2017.*
***Palavras-chave****: Saneamento básico. Bacia hidrográfica. Revitalização de rios. Doenças de veiculação hídrica. Preservação ambiental.*

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**INTRODUCTION**

Cities are an environment in which human elements predominate over natural elements, which are in a particularly adverse situation, with different levels of alteration to their natural form and dynamics. These transformations can directly or indirectly affect the daily lives of people living in urban spaces, resulting in various problems for the dynamics of the natural environment, the infrastructure of cities and the health of the urban population (SANTOS et al., 2016).

In this sense, regarding Camaçari, it was observed that there was a disorderly occupation, without taking the necessary precautions to prevent damage to the environment, which is the main factor transforming the natural characteristics of the physical elements present in these spaces (SANTOS et al., 2016).

And in this regard, Chaves, and Santos (2009) made it clear in their observations that the watersheds most impacted in terms of water quality and availability are those that suffer from accelerated and unplanned occupation.

In this sense, as mentioned, it is important to note that Federal Law No. 9.433/1997, which established the National Water Resources Policy, defines the river basin as the territorial unit for implementing the National Water Resources Policy and the National Water Resources Management System (BRASIL, 1997). Trajano et al (2012) also added that river basin management is considered a tool to guide the actions of public administration and society in the long term, and its purpose is to guarantee the adequacy of man's means of exploiting natural resources, with a view to sustainable development.

However, in most cases there is no such management of river basins that prioritizes sustainable development, and when there is, it is generally inadequate and ineffective, especially in urban environments, where the incidence of pollution is commonplace. Pollution of urban rivers is caused both by the dumping of domestic sewage in areas where there is no sanitation, in which open sewage ends up in watercourses, and by the inadequate routing of pipes in public systems (PENA, 2022).Nesta mesma conjuntura encontrava-se o rio Camaçari, importante afluente da Bacia do Rio Joanes, responsável pelo abastecimento de água da Região Metropolitana de Salvador, o qual apresentava características semelhantes aquelas abordadas por Santos, em 2018, haja vista que o aumento da densidade urbana contribuiu para o aumento da poluição em alguns trechos do rio. Com o aumento da densidade urbana e industrial, as taxas de poluição são altíssimas e alguns trechos do rio se transformaram em um esgoto a céu aberto (SANTOS, 2018).

The Camaçari River has a territorial extension of approximately 12 km, an average depth of 2.5m, reaching 6 meters in flood periods (SANTOS, 2018). It is in the municipality of Camaçari, which belongs to the Territory of Identity of the Metropolitan Region of Salvador - RMS, with an estimated population of 304,302 people in 2020. Its GDP per capita is R$81,105.66 and its average MHDI is 0.694 (IBGE, 2021).

Therefore, faced with this scenario of degradation of the Camaçari River, the Municipal Program for Integrated Urbanization of the Camaçari River Basin and its tributaries was proposed to improve the living conditions of the population.

The families that remained on the river's path benefited from revitalization and urbanization works, such as the implementation of a linear park with a micro and macro-drainage network, sewage, water, public lighting, cycle and pedestrian paths, kiosks, sports courts, gym equipment, children's toys, the implementation of sanitary kits in houses without bathrooms and the connection of the remaining houses to the planned sewage network.

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These interventions were recommended by the Term of Commitment No. 350.977-09/2011 through the implementation of the program, which made it possible to mitigate the pollution and/or contamination of the Joanes River that occurred through the outflow of the Camaçari River.

The general objective of the study was to assess the socio-environmental results of implementing the Municipal Integrated Urbanization Programme in the Camaçari River Basin.

## METHODOLOGICAL PROCEDURES

This was a descriptive study with a qualitative-quantitative approach, developed with the aim of describing characteristics, properties or relationships existing in the community, group or reality being researched, since it aimed to detail the context of the insertion of a revitalization and reurbanization program in the Camaçari River and its results over ten years of implementation, making it possible to identify, record, analyze and relate parameters present in the scenario studied.

The research was carried out in the Special Zones of Social Interest (SEZs) of the Camaçari River Basin established by Decree No. 7.239/2019 (CAMAÇARI, 2019) (Figure 1).

Figure 1 - Location plan of the Camaçari River SEZs

Source: Camaçari, 2019.

Data collection took place in two stages between January and June 2022. The first stage consisted of compiling data and information extracted from official municipal, state and federal public administration websites (IBGE, DATASUS, Transparency Portals, CAPES Journals, SNIS, etc.), among other various materials that have or have not received analytical treatment, with the aim of gaining a detailed understanding of the actions implemented in the municipal program.

This information was used to evaluate issues related to the provision of basic sanitation services during the implementation of the program and its relationship with the possible fall in hospitalizations due to diseases related to inadequate environmental sanitation and infant mortality.

The second stage consisted of reproducing the procedures of the research carried out by Sommer (2013), who determined the quality of the water by exploring the Camaçari River from its source to its mouth at the meeting with the Joanes River in order to observe

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the peculiarities of the sub-basin and locate the same seven sampling points for water collection (Table 1). All the points were identified using the Global Positioning System (GPS).

Table 1 - Location of the water sampling points

| Ponto | Localização | Latitude (S) | Longitude (O) | Altitude (M) |
|---|---|---|---|---|
| P1 | Avenida Perimetral | 12°40'56" | 38°19'14" | 50 |
| P2 | Nova Vitória | 12°41'59" | 38°18'45" | 36 |
| P3 | Centro | 12°41'55" | 38°19'08" | 30 |
| P4 | Camaçari de Dentro | 12°41'59" | 38°19'43" | 29 |
| P5 | Quarenta e seis | 12°42'20" | 38°19'48" | 26 |
| P6 | Burissatuba | 12°42'46" | 38°20'17" | 22 |
| *P7* | Parque Verde II | 12°44'12" | 38°20'51" | 17 |

Source: Sommer, 2013.

After identifying the sampling points along the Camaçari River, called P1, P2, P3, P4, P5, P6 and P7, two samples were taken, one during the sunny season and the other during the rainy season. The samples were taken in the early hours of the morning, as this is the time of day when there is the least interference from temperature. These procedures made it possible to identify the results of the physical, chemical and biological analysis of the water, by the laboratory of the company Bioagua Produtos Químicos e Serviços de Tratamento de Água Ltda, for comparison with the results obtained through the research carried out by Sommer (2013) between the years 2012 and 2013, i.e. in the same period that the implementation of the Municipal Program for Integrated Urbanization of the Camaçari River Basin began.

In order to carry out the on-site environmental characterization of the area surrounding the sampling points, field observation protocols were used, the results of which were later compared to those of Sommer's study (2013). The environmental aspects of the sites were noted, such as: the existence of erosion and/or lack of riparian forest on the river banks, silting up of the river bed, discharge of domestic and industrial effluents at the site, among others.

To analyze the data related to the actions implemented in the Municipal Program for Integrated Urbanization of the Camaçari River Basin, a qualitative approach was used, in which information and documents were chosen in line with the research objectives, followed by the exploration of the material, with the aim of reaching the core of understanding the context and finally the treatment of the results obtained and interpretation.

According to Guerra (2014), in the qualitative approach, the scientist aims to deepen their understanding of the phenomena they are studying - the actions of individuals, groups or organizations in their environment or social context.

The quantitative approach was explained by analyzing the evolution or regression of the behavior of the indicators for Brazil, the state of Bahia, the Metropolitan Region of Salvador and the municipality of Camaçari relating to basic sanitation and their influence on other indicators, i.e. the percentage of hospitalizations for diseases related to inadequate environmental sanitation and the infant mortality rate in the period of one year after the start of the program and one year after its stoppage (2013 to 2017).

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**RESULTS AND DISCUSSIONS**

In two of the 18 sections of the program located in districts of the municipalities bordering the river, the Permanent Preservation Area (PPA) has already been flanked by a bypass road and leisure and collective use spaces have been built, preventing new occupations. The families who remained in the river's path benefited from revitalization and urbanization works, such as the implementation of a linear park equipped with a micro and macro-drainage network, sewage, water, public lighting, cycle and pedestrian paths, kiosks, sports courts, gym equipment, children's toys, the implementation of sanitary kits in houses without bathrooms and the connection of the remaining houses to the planned sewage network.

In the execution of the program's works, the urban actions presented practical alternatives to contain the processes of urban and environmental degradation that had taken hold in the area. The stretches that had already been urbanized were integrated into the fabric of the formal city, with the necessary roads for this integration and for mobility within it, as well as creating the public spaces and facilities needed for sociability, education, health, work and leisure.

After analyzing the physical interventions already carried out, it became clear that the program's main guideline was the proper implementation of basic sanitation and, in a complementary way, a structuring road system along the rivers, with the implementation or requalification of roads, sidewalks and bike paths.

Special attention was given to squares, which represent the public space par excellence, supporting community life in the open air, a space for leisure, meeting and socializing. This action offered qualified public spaces for a positive change in the community's quality of life and the exercise of citizenship itself.

The design and execution of the squares and public spaces met the requirements of

Federal Law No. 10.098/2000, Federal Decree No. 5.296/2004 and NBR 9050, which governs the adaptation of space to universal accessibility, with the implementation of raised lanes, ramps and accessible spaces, as well as sidewalks with adequate widths and accessible routes with directional and warning tactile flooring.

The urban facilities along the urbanization were designed using local materials and construction technologies from the region, with the best cost/benefit ratio in mind, mainly looking at future maintenance aspects, as well as catering for various user profiles.

After the work was halted in 2016, a new bidding process took place, with DP Barros Pavimentação e Construção Ltda winning the bid and, as a result, contract No. 408/2019 was signed with the municipal government, with a total value of R$ 86,239,351.07 and a 17-month execution period for the services, in accordance with the works provided for in Basic Project No. 4772/2019, namely:

- Section 3: preliminary services, earthworks, drainage, sanitary sewage system, paving and road works, signaling, vegetation cover, equipment and furniture for a total of R$8,787,779.76.
- Section 4: preliminary services, earthworks, drainage, sanitary sewage system, paving and road works, signaling, vegetation cover, artwork - pier, equipment and furniture for a total of R$5,732,953.72.
- Section 5: preliminary services, earthworks, drainage, sanitary sewage system, paving and roadworks, signaling, vegetation cover, equipment and furniture, enclosures and bleachers for a total of R$6,319,240.88.

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- Section 8: preliminary services, earthworks, drainage, sanitary sewage system, paving and roadworks, signaling, vegetation cover, bleachers, equipment and furniture for a total of R$21,808,067.61.
- Section 9: preliminary services, earthworks, drainage, sewage system, paving and roadworks, signage, vegetation cover, equipment and furniture, totaling R$12,819,074.21.
- Section 10: preliminary services, earthworks, drainage, sanitary sewage system, paving and road works, signaling, vegetation cover, work of art - pier, equipment and furniture, enclosures and bleachers for a total of R$4,594,139.83.
- Section 11: preliminary services, earthworks, drainage, paving and roadworks, signaling, vegetation cover, artwork - pontoon, artwork - bridge, closures, equipment and furniture for a total of R$6,440,796.77.
- Section 13.3: preliminary services, earthworks, drainage, sanitary sewage system, paving and road works, signaling, vegetation cover, closures, equipment and furniture for a total of R$12,672,590.64.

The rest of the cost of the work relates to the local administration of the work and the mobilization and demobilization of all the sections, which respectively amounted to R$ 6,868,301.61 and R$ 15,774.51.

Within the context of the improvement in basic sanitation indicators due to the program, when analyzing data from the National Sanitation Information System (SNIS), it could be seen that there was an increase in the percentage of households connected to the water supply network in the urban area of Camaçari, even reaching the historic level of 100% in 2016, a higher rate compared to the rates in the country, the state of Bahia and the Metropolitan Region of Salvador, which showed a certain stability (ATLAS BRASIL, 2022).

The analysis carried out in relation to the sewage system showed that although the municipality of Camaçari has lower rates of urban households connected to the sewage system compared to the country, the state of Bahia and the Metropolitan Region of Salvador, the municipality recorded a significant increase of more than 28% in this indicator between 2013 and 2017 due to the influence of the Municipal Program for Integrated Urbanization of the Camaçari River Basin, especially through structuring works for sanitary sewage and micro- and macro-drainage in the ZEIS (ATLAS BRASIL, 2022).

The improvement in these indicators linked to basic sanitation has helped to keep hospitalizations from diseases related to inadequate environmental sanitation at a low level.

The municipality of Camaçari and the Metropolitan Region of Salvador showed low and similar percentages, unlike the averages for the state of Bahia and the country. Hospitalizations for these diseases in the municipality were equivalent to only 16.33% and 21.49% respectively of the averages found in the state of Bahia and the country (ATLAS BRASIL, 2022).

Analysis of the infant mortality rate, an indicator of quality of life and development, showed that the municipality of Camaçari increased from 2013 to 2015, but from 2016 onwards there was a significant drop, which represented a difference of 30.74% between 2017 and 2015, making it the lowest rate compared to the country, the state of Bahia and the Metropolitan Region of Salvador (Figure 2).

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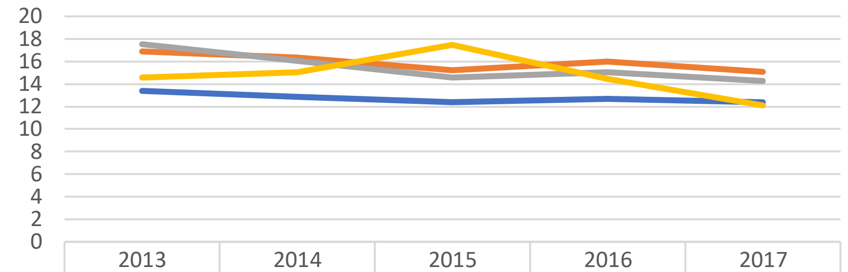
Figure 2 - Infant mortality rate (deaths per thousand live births)




| | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Brasil | 13.39 | 12.88 | 12.41 | 12.71 | 12.38 |
| Bahia | 16.89 | 16.34 | 15.22 | 15.97 | 15.08 |
| RMS | 17.53 | 16.07 | 14.6 | 15.04 | 14.27 |
| Camaçari | 14.56 | 15.04 | 17.47 | 14.43 | 12.1 |

Source: ATLAS BRASIL, 2022.

However, to improve these indicators, it is necessary to raise awareness among the population and preventive planning on the part of the Municipal Administration, and among other factors, a greater concern with the structure of urbanization and adequate basic sanitation before the irregular occupation of public spaces, avoiding the occurrences found in the areas covering the Camaçari River sub-basin.

To analyze the current scenario of these occurrences in the municipality, the real situation of the Camaçari River basin was evaluated in loco, which showed that the form of land use and occupation directly interfered with the environmental quality of its surroundings.

The first evaluated water collection point was identified at the source of the Camaçari River, located in the Forestry Ring of the Camaçari Industrial Estate between Avenida Henry Ford and the Bahia State Highway, commonly referred to as Via Parafuso (BA-535). According to Santos (2012), this area of the Forest Ring is an important piece of vegetation that separates the city from the industrial estate. It was designed when the petrochemical complex was set up in the 1970s, with the aim of reducing the effects of gaseous effluents on the urban population and keeping the population at a safe distance from the industrial plants.

Similarly, to Sommer's research (2013), at this point the riparian forest was preserved and quite dense, even making access to the spring difficult. This scenario protected the watercourse and contributed to the absence of erosion or siltation at the site. The water was clear in color and had no odor.

Point 7 was in the area where the Camaçari River meets the Joanes River. In this area, the riparian forest was quite dense and there were no erosion or silting areas, a similar situation to point 1.

Similarly to Sommer's study (2013), all the points located in the central areas of the municipality (2, 3, 4, 5 and 6) showed the absence of riparian forest caused by various constructions close to the river banks, due to the population increase resulting from vegetative growth and the strong migratory flow, attracted by the dream of employment in industries (GILEÁ; SPINOLA; SOUZA, 2020).

According to the Forest Code, the riparian forest should be left untouched, as it can be understood as forest systems naturally established in strips on the banks of rivers and

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streams, around lakes, dams and springs, performing the function of a tool to reduce siltation and environmental degradation and as a natural means of processing and transforming environmental diversity (CASTRO M.; CASTRO R.; SOUZA, 2013).

Also visible at these points was the presence of siltation in the riverbed and erosion on the riverbanks. In addition, the water was dark in color and had a foul smell characteristic of sewage, since it was possible to observe the discharge of fresh effluent directly into the riverbed through pipes coming out of homes and concrete walls built on the riverbank.

At the same time, water quality was assessed by analyzing physical-chemical and biological parameters to identify possible alterations to the aquatic environment due to anthropogenic actions.

Monitoring these water quality parameters, as provided for in CONAMA Resolution 357 of 2005 (BRASIL, 2005), has emerged as a fundamental tool for assessing the quality of the water body, with a view to the sustainability of the aquatic biota, as well as subsidizing an evolutionary history of the water environment and corroborating the definition of progressive targets for water depollution, where appropriate (GONÇALVES, 2011).

The results of these parameters at the sampling points along the Camaçari River were obtained from the laboratory of the company Bioagua Produtos Químicos e Serviços de Tratamento de Água Ltda (Table 1), which make it possible to compare these parameters individually with the results obtained from the research carried out by Sommer in 2013 (Table 2), i.e. in the same year that the implementation of the Municipal Program for the Integrated Urbanization of the Camaçari River Basin began.

Table 1 - Results of chemical, physical and biological water analysis

| Sample point / Parameters | Point 1 Collection | | Point 2 Collection | | Point 3 Collection | | Point 4 Collection | | Point 5 Collection | | Point 6 Collection | | Point 7 Collection | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª |
| Water Temperature (ºC) | 29.6 | 28.7 | 31.8 | 29.7 | 30.5 | 28 | 30.5 | 28 | 30.5 | 27.8 | 32.8 | 27.7 | 27.6 | 27.2 |
| Hydrogen Potential - pH | 7.28 | 6.35 | 6.93 | 6.56 | 6.68 | 6.62 | 6.83 | 6.72 | 7.05 | 6.85 | 6.88 | 6.75 | 6.52 | 6.72 |
| Dissolved Oxygen - DO (mg/l) | 2,54 | 2,05 | 0.932 | 1.725 | 1.244 | 1.116 | 0.699 | 1.006 | 0.612 | 1.879 | 1.112 | 1.406 | 2.995 | 3.115 |
| Turbidity (NTU) | 16.93 | 7.42 | 55.96 | 12.62 | 55.48 | 38.97 | 63.77 | 23.54 | 58.95 | 13.55 | 67.22 | 9.93 | 25.46 | 4.93 |
| Electrical Conductivity (µS/cm) | 220 | 165 | 790 | 410 | 760 | 439 | 860 | 419 | 830 | 480 | 820 | 419 | 410 | 168 |
| Total Solids (mg/l) | 136.56 | 125.82 | 412.55 | 248.96 | 404.38 | 412.15 | 568.69 | 341.12 | 542.12 | 411.13 | 535.95 | 322.11 | 232.1 | 112.33 |
| Salinity (0.5‰) | 0.92 | 0.09 | 1.2 | 0.1 | 1.1 | 0.12 | 1.3 | 0.12 | 1.3 | 0.11 | 0.9 | 0.08 | 0.6 | 0.07 |
| Biochemical Oxygen Demand - B(mg/l) | 4.826 | 3.221 | 116.82 | 44.141 | 94.216 | 88.126 | 184.86 | 102.12 | 245.02 | 83.05 | 105.121 | 49.162 | 41.6 | 12.525 |
| Thermotolerant Colifor (NMP/100ml) | 0 | 0 | 2900 | 2500 | 3200 | 3500 | 4200 | 4000 | 4800 | 4000 | 4000 | 4500 | 3100 | 2500 |
| Total Coliforms (NMP/100ml) | 0 | 0 | 3000 | 2800 | 3200 | 3500 | 4500 | 4100 | 5100 | 4200 | 4100 | 4500 | 3500 | 2700 |

Source: Data organized by the author, 2022

Table 2 - Results of the chemical, physical and biological analysis of the water in the study by SOMMER (2013)

| Sample point / Parameters | Point 1 Collection | | Point 2 Collection | | Point 3 Collection | | Point 4 Collection | | Point 5 Collection | | Point 6 Collection | | Point 7 Collection | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª | 1ª | 2ª |
| Water Temperature (ºC) | 23.6 | 27.4 | 26.8 | 28.2 | 26.4 | 30 | 26.4 | 30.4 | 27.8 | 30.6 | 26.6 | 30.3 | 26.5 | 29,7 |
| Air Temperature (ºC) | 28 | 29 | 31 | 30 | 33 | 34 | 34 | 34 | 34 | 36 | 34 | 36 | 34 | 38 |
| Hydrogen Potential - pH | 4.61 | 4.85 | 7.04 | 6.75 | 6.71 | 6.71 | 6.82 | 7.07 | 6.91 | 7.06 | 6.62 | 7.03 | 6.83 | 7.13 |
| Dissolved Oxygen - DO (mg/l) | 2.32 | 1.44 | 1.08 | 1,63 | 2.59 | 1.16 | 0.77 | 1.06 | 0.43 | 2.27 | 0.8 | 1.64 | 1.35 | 2.77 |
| Turbidity (NTU) | 1.8 | 1.5 | 120 | 90.1 | 59.3 | 95.7 | 641 | 126 | 404 | 107 | 278 | 67.4 | 128 | 55 |
| Electrical Conductivity (µS/cm) | 1798 | 2180 | 2360 | 2160 | 2280 | 2220 | 2500 | 2030 | 2210 | 1654 | 2270 | 2320 | 1954 | 1920 |
| Total Solids (mg/l) | 1354 | 1496 | 1785 | 1504 | 1748 | 1536 | 1913 | 1424 | 1680 | 1457 | 1711 | 1665 | 1478 | 1367 |
| Salinity (0.5‰) | 0.8 | 0.9 | 1.2 | 0.9 | 1.1 | 0.9 | 1.3 | 0.9 | 1.1 | 0.7 | 1.1 | 1.1 | 0.9 | 0.8 |
| Biochemical Oxygen Demand - BOD (mg/l) | 2 | 2 | 171 | 98.6 | 58.8 | 68.6 | 264 | 117.5 | 340 | 90 | 70.8 | 47.8 | 40.8 | 25.6 |
| Thermotolerant Coliforms (NMP/100ml) | 0 | 0 | >2400 | >2400 | >2400 | >2400 | >2400 | >2400 | >2400 | >2400 | >2400 | >2400 | >2400 | >2400 |

Source: Sommer, 2013

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**Water temperature**

The water temperature was checked at the time and place of sampling. The minimum and maximum temperatures ranged from 27.2ºC to 32.8ºC respectively, so, except for the 7th point, the study showed higher temperatures than in Sommer's (2013) samples, which ranged from 23.6ºC to 30.6ºC. It is possible that the lower temperature found at the last point is due to a different scenario to that found by Sommer (2013), i.e. amounts of solid waste and effluents from the urban area, which were carried by the rain and became trapped in the vegetation or formed large deposits on the river banks.

These variations in water temperature were due to natural sources (solar energy) and anthropogenic sources such as the discharge of water from cooling towers, boilers and other domestic sewage or industrial effluents into water bodies (ALVES, 2006 apud HESPANHOL, 2009).

Points 1 and 7 had lower temperatures than the others because the depth of the river was greater and these areas were further away from residential areas, which helped preserve the riparian forest. According to Souza (2012), riparian forests reduce wind speed and the incidence of solar radiation, avoiding temperature peaks, creating a microclimate favorable to the dynamic balance of both the aquatic and terrestrial ecosystems.

As in Sommer's study (2013), the highest values found for water temperature were recorded at the points that were in the central area of the municipality (P2, P3, P4 and P5), but the current study added P6, which also became a relatively anthropized area.

The rise in temperature was also due to the discharge of domestic effluents, since according to Martins (2005), the temperature of sewage is generally slightly higher than that of water supplies due to the contribution of domestic waste.

Among these points, the 2nd showed a greater discrepancy compared to the previous study, which showed a temperature of 26.8ºC in the first collection and 28.2 ºC in the second, compared to 31.8 ºC and 29.7 ºC respectively in the present study.

CONAMA Resolution 357/2005 did not establish maximum temperature limits for the classification of water bodies, but it did determine that in the case of effluent discharge, the water temperature should not exceed 40 ºC.

**Total Solids**

When analyzing the results found in this study for total solids, it was observed that all the sampling points analyzed showed much lower quantities than those found by Sommer (2013).

The 1st collection from point 2 of this study showed the greatest discrepancy in the total solids result, with a difference of 1,372.45 mg/l, i.e., 23.11% of the result found by Sommer (2013) in this same collection.

The 2nd collection from point 5 showed the smallest difference in results (1,045.87 mg/l) but represented only 28.11% of the same collection carried out by Sommer (2013).

Despite the significant improvement in the number of total solids in all the samples, CONAMA Resolution 357/2005 established that in freshwaters classified as Class 3, solid waste must be virtually absent. Therefore, the results found are still in disagreement with the resolution.

These measurements of total solids have caused damage to aquatic life in general, such as lowering the incidence of light, increasing sedimentation on the riverbed, and

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destroying organisms that could provide food, or spoiling fish spawning beds. The solids also trapped bacteria and organic waste at the bottom of the rivers, promoting anaerobic decomposition (ANA, 2016).

**Water turbidity**

The results for this parameter in this study showed that all the samples were in line with the requirements of CONAMA Resolution 357/2005, unlike Sommer's study (2013), in which 50% of the samples were not in line with the maximum permitted limit of 100 UNT.

The highest turbidity result was found in the 1st collection from point 6 (67.22 UNT) on a sunny day and with the river level low, but within the resolution standard. The 2nd collection at this same point showed a drastic reduction, reaching a level of 9.93 UNT due to the rainy season which increased the river level considerably.

All the results were below 70 UNT, therefore within the compliance parameters recommended by CONAMA Resolution 357/2005. They also showed that there was a considerable decrease in the turbidity of the water, i.e. the suspended materials in the water, such as clay, silt, finely divided organic and inorganic matter, colored soluble organic compounds, plankton and other microscopic organisms, which reduced the scattering and absorption of light (ANA, 2016).

Therefore, the presence of turbidity in these natural waters has had a decisive influence on the characteristics of their ecosystem. And when sedimented, these particles form sludge banks where anaerobic digestion leads to the formation of methane and carbon dioxide gases, as well as nitrogen gas and hydrogen sulphide gas, which is foul-smelling (MARQUES *et al.*, 2007).

**Water salinity**

The results for this parameter in this study showed that half of the samples and all of those from the rainy season were in line with CONAMA Resolution 357/2005. Since salinity generally increases during dry periods due to increased evaporation, as well as the discharge of domestic effluents into water bodies (BRAGA et al., 2005).

On the other hand, all the results of the samples carried out by Sommer (2013) were above 0.5% salinity, i.e. in disagreement with the maximum limit allowed by the aforementioned resolution.

This reduction in salinity between the two studies has had an impact on improving water quality, both in the context of domestic consumption and for use in irrigation. Therefore, this parameter was of great importance for characterizing the bodies of water, which established various physical and chemical properties, including the density of the water, the type of fauna and flora and the potential uses of the water (ANA, 2016).

**Electrical conductivity**

The results found by Sommer (2013) in relation to electrical conductivity were much higher than those of the present study, showing higher ionic concentrations that indicated changes in the composition of the water, especially in its mineral concentration (CETESB, 2014).

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Collections between 2012 and 2013 showed values ranging from 1,654 μS/cm to 2,500 μS/cm, while in 2022 the variation was only 165 μS/cm to 860 μS/cm.

In both studies, the analysis of the parameter showed an intense variation in electrical conductivity at the 7 sampling points, with the results rising as the Camaçari River entered the urban area of the municipality.

As electrical conductivity varied according to the level of dissolved solids in the water, the results found for the parameter in the water of the Camaçari River in the two studies follow the same pattern of behavior as total solids.

CONAMA Resolution 357/2005 did not establish the electrical conductivity parameter, but it is constantly used as an indication of effluent discharge, making its determination significant in assessing water quality.

**Biochemical Oxygen Demand (BOD)**

The results presented for the BOD load in the study by Sommer (2013) between 2012 and 2013 were very similar to the results of the present study.

In both studies, the lowest oxygen demand occurred in P1, both in the first and second collections, and from the moment the Camaçari River entered the urban area of the municipality and received a greater amount of fresh effluent, the higher values indicated that the receiving body was receiving an organic load greater than its natural biological degradation capacity.

This led to a huge consumption of oxygen gas by microorganisms, increasing BOD and harming aerobic living beings, since anaerobic living beings started to oxidize organic compounds, which led to the production of substances with an unpleasant smell, such as hydrogen sulphide (DIAS, 2022).

In the two studies, only the results found in P1 were in line with the maximum limit established by CONAMA Resolution 357/2005. Therefore, freshwaters classified as Class 3 should not have BOD higher than 10mg/l.

These results showed the consequences of discharging organic loads, especially domestic sewage, into the body of water. This has led to a reduction in dissolved oxygen values in the water, which can cause fish kills and the elimination of other aquatic organisms (ANA, 2016).

**Dissolved Oxygen (DO)**

The results found for the seven sampling points indicated concentrations lower than those permitted by CONAMA Resolution 357/2005, both in the current study and in the study by Sommer (2013). In both studies, the low DO content at Point 1 was possibly related to oxygen consumption in the natural biological decomposition of organic matter at the site.

The results in general indicated insufficient levels of oxygen, a fundamental item for living beings, especially fish, where most species cannot withstand concentrations of dissolved oxygen in water lower than 4.0 mg/l (PIVELI, 2010).

In the two studies, when comparing the variables DO and BOD, it was noted that there was a correlation between the results found for the parameters, since lower levels of DO were found at the points where BOD was highest.

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**Hydrogen Potential (pH)**

The 14 samples in this study were in the pH range of the water within the limit set by the legislation, despite the discharge of effluents in some areas of the Camaçari riverbed.

In the study by Sommer (2013), only point 1 was not within the limit set by the legislation, both in the 1st and 2nd samples.

For the proper maintenance of aquatic life, CONAMA Resolution 357/2005 established that the pH of water bodies classified as Class 3 must be between 6.0 and 9.0. Conditions outside this range have an indirect effect and can contribute to the precipitation of toxic chemical elements (ANA, 2016).

In natural aquatic ecosystems, this influence is direct due to its effects on the physiology of various species. However, pH outside this range, in addition to harming aquatic organisms, also interferes with human health, since this range is ideal for toxins and acidity to be eliminated from the body, because when the pH cannot be balanced with that of the body, the body becomes prone to infections, parasites and degenerative diseases (CASAGRANDE, 2018).

**Thermotolerant coliforms**

In the study by Sommer (2013), these bacteria were only not found at point 1 in both the 1st and 2nd samples. All the other results exceeded the maximum limit established by CONAMA Resolution 357/2005, which establishes that the maximum permitted limit for Thermotolerant Coliforms should not exceed 2500 CFU/100ml for use in secondary contact recreation in water bodies classified as Class 3.

The results of this study also indicated the absence of bacteria at point 1 in both samples. However, they also indicated results within the maximum permitted limit for Thermotolerant Coliforms in the second samples from points 2 and 7, thus complying with current legislation.

The incidence of these bacteria indicated pollution by domestic sewage and, consequently, the possibility of the existence of pathogenic microorganisms that are responsible for the transmission of waterborne diseases such as bacillary dysentery, typhoid fever and cholera (ANA, 2022).

Some thermotolerant bacteria such as Escherichia coli, which generally do not cause health problems when they are in the intestine, as they are normal bacteria there, have some variants that can cause hospital infection, urinary and intestinal infections, with a pathogenic density capable of causing intestinal infection by various mechanisms (SALEH et al., 2019).

**Total Coliforms**

The study by Sommer (2013) did not analyze this water quality parameter, making it impossible to compare it with the present study, but the results showed compliance with the resolution in most of the 14 samples, apart from the two samples from points 4, 5 and 6.

The results, which exceeded 4,000 CFU/100ml for Total Coliforms, in disagreement with CONAMA Resolution 357/2005, made it impossible to use the water for all uses, except for secondary contact recreation and the watering of confined animals, in bodies of water classified as Class 3.

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Therefore, the presence of this group of bacteria, despite not causing disease, has been shown to be an important indicator of water contamination through the feces of warm-blooded animals, including humans (ANA, 2016).

## CONCLUSIONS

By evaluating the various phases of implementation of the Municipal Integrated Urbanization Programme in the Camaçari River Basin, Camaçari-BA, over the years 2013 to 2022, it was possible to conclude the socio-environmental aspects listed below:

- An increase in the number of households connected to the water supply network because of the program's influence, between 2013 and 2017, rising from 88.67% to 99.46% in the urban area of Camaçari, a rate higher than the country, the state of Bahia and the RMS.
- A significant increase of 28% in the number of urban households connected to the sewage system over the same period, resulting in an 18.33% drop in hospitalizations due to diseases related to inadequate environmental sanitation and in the infant mortality rate, which fell from 14.56% to 12.1%, also lower than the country, the state of Bahia and the RMS.
- Improvement in the environmental quality of the surroundings of some sampling points made possible by the program, through sanitary sewage and micro- and macro-drainage works and the removal of properties that were dumping domestic sewage into the riverbed or solid waste by their residents.
- Improvement in the results of the physical, chemical, and biological parameters of water quality as a result of obtaining more results in line with the compliance parameters determined by CONAMA Resolution 357/2005, especially those relating to Total Solids, Turbidity, Salinity, Electrical Conductivity, Hydrogen Potential and Thermotolerant Coliforms.

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