

## Physicochemical characterization applied to the analysis of the water quality of the Bauru River, in support of water resources management

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### Abstract

The indiscriminate use of water resources has led to ecological, public health, social and economical problems. Many diseases that could be extinct still persist because of the lack of a proper sanitation policy. Therefore, due to the problems caused by the discharges of wastewater, the current importance given to environmental issues and the importance of drinking water for the population, it is necessary to monitor its quality, especially in areas such as the industrial district of a city. In order to check the quality of water in the industrial region of Bauru, where a sewage treatment plant (STP) will soon be constructed, the present study aimed at monitoring and comparing the analyzes of water from the streams “Água Comprida”, “Vargem Limpa”, “Ribeirão Vargem Limpa” and Bauru River between the center and the industrial district of the city of Bauru. This region has major companies, including chemical ones that somehow contribute, through their effluents to increase the pollution of these water bodies. For this comparative analysis, we conducted a quantitative and qualitative study in partnership with the Bauru Department of Water and Sewerage (DAE) in the Wastewater Laboratory. Through the analysis of the water quality it was possible to evaluate the quality of water that will soon be treated by the sewage treatment plant, thus informing the public about the serious problems that persist in the region and how an industrial district affects the water quality of a city.

### Keywords

Management of water resources, pollution, sewage treatment plant.

## Introduction

Water is precious and irreplaceable. Besides being a vital element for the existence of life on Earth, water is a natural resource which can provide comfort, health and wealth to men through its countless uses, among which are the needs of the population, irrigation, energy production, navigation and even the placement and removal of sewage and wastewater (BEZERRA; MUNHOZ, 2000).

However, the waste and the pollution of streams, rivers and seas by industrial waste and household waste has been a concern for both developed and developing countries (ALMEIDA; RIGOLIN, 2003). Due to inefficiency of the water resources management, the water inappropriate use and increasing demand are making the water issue one of the most serious problems facing humanity in the XXI century if a new way of dealing with the environment is not found.

As a consequence of the selfish interest of profit, some argue that it is not possible to carry out development without causing any damage to the environment (BRANCO, 1988). The same author states that the environmental impact is therefore a kind of ecological trauma following the shock caused by an action or human work in harmony with the characteristics and environmental balance. Branco (1988) further states that the problem of modern civilization, industry and technology is perhaps not realizing that they still depend on nature, at least in global terms, their release is still not complete and probably never will. The entire increase in human density, coupled with the technological development has caused mankind to assume a posture essentially exploratory towards natural resources, forgetting that the amount of fresh water available for human consumption (present in lakes, rivers and aquifers lower depth) is less than 1% of the global water availability.

Bezerra and Munhoz (2000, p.93) state that:

*[...] In Brazil, the condition of pollution of rivers and lakes is generally very serious. Rivers, reservoirs, bays and beaches and their nearby areas in Brazil are polluted due to the inappropriate target given to sewage, industrial effluents, solid waste, etc. (BEZERRA; MUNHOZ, 2000, p.93).*

Thus, Bezerra and Munhoz (2000) state the small streams crossing the agglomerations in Brazil are often used as wastewater spillways and landfills and often present a trouble of odor and vector proliferation. These courses usually overflow expanding health and environmental problems during heavy rains.

The nutrients present in urban sewage and agricultural inputs have increased the problem of eutrophication of lakes, reservoirs, estuaries and bays as a result of the very high levels of phosphorus which can lead to an abundant algae proliferation. That happens since phosphorus (phosphate) is an essential element for the growth of algae and, in high amounts, may lead to an overgrowth of these organisms (SPERLING, 1996). In addition to these problems of urban character, there are problems of pollution located in various parts of Brazil, more specifically in the industrial centers.

All this due to one of the main characteristics of the human being, which is the ability to use the environment forces and materials for their own benefit, constructing buildings for shelter and developing activities, food, transportation, comfort and leisure. Thus, the disposable culture, which brings the habit of always having the latest model let industries proliferate,

consuming increasing amounts of energy and raw materials, generating pollution and other problems for the environment (BRANCO, 1988).

Then, pollution, especially water pollution, has become an increasingly serious problem for society and, in this sense, governments have tried to raise awareness of the fact that the situation tends to worsen over time if nothing is done. According to Salomão (2006), water pollution caused by industrial development, demographic growth and inappropriate land occupation, with a consequent impairment of its multiple uses and considerable increase in the risk of disease transmission and waterborne, has been occurring rapidly over the years. That is, the lack of sewage treatment as well as the inadequate sanitation contributes to the spread of numerous ailments and infectious parasites, and cause degradation of the water body. These diseases are responsible for high mortality rates in developing countries such as Brazil. The children are more often their victims, since the association of these diseases with malnutrition is usually fatal.

In this sense, the effective treatment of wastewater has a key role in the sustainable management of water resources as it offers the possibility to reuse the water after appropriate treatment for agricultural irrigation among others. Thus, large volumes of potable water can be saved through its reuse when lower quality water is used to meet the needs that can do without this reuse within the standards of portability.

The Bauru River is the main river in the city of Bauru. Its source is located close to the urban area, in the southern region of the city, close to the SP-225 highway which links Bauru to Ipauçu. According to the State Decree nº 10755 (SAO PAULO, 1977), it is framed as Class 4 (water used for navigation; landscape harmony, and less demanding uses) from its source to the confluence with the "Ribeirão Grande", in the municipality of Pederneiras, where it becomes Class 3 (water intended for human consumption after conventional treatment; irrigation of tree crops, cereals and fodder, watering livestock) to its confluence with the Tietê River also in the municipality of Pederneiras.

The Streams "Água Comprida", "Vargem Limpa" and "Ribeirão Vargem Limpa" are tributaries of the Bauru River and are located near the industrial district of the city, suffering, therefore, effluent discharge mainly from the industries located there. In fact, the city has 96% of its area covered with sewage systems and it produces about 884 liters of wastewater per second (average flow), which is released without any treatment in the Bauru River, a total organic load of 17,010 kg BOD5/day, that is, 17,010 kilograms of oxygen is consumed for 5 days by the organics present in the water body.

In Bauru, the number of deaths from infectious diseases and digestive tract is in 6<sup>th</sup> and 7<sup>th</sup> place respectively in the overall ranking. According to the Environment Secretariat Municipal (SEMMA), about 6.13% of the population of Bauru suffers from waterborne diseases (SEMMA, 2007). The city, thus, reflects the situation of the country, where the few articulated programs for combating pollution of water systems are restricted to the area of urban sanitation, such as installation of sewer, for example. In general, the most serious problems in the area of water systems pollution can be described as follows: domestic sewage pollution, industrial pollution, solid waste disposal, agricultural nonpoint source pollution, accidental pollution, eutrophication of lakes and reservoirs, salinization of rivers and dams, mining pollution, lack of protection of surface and underground springs.

The city of Bauru has already signed the Term of Conduct Adjustment, which undertakes the treatment of wastewater produced by the city; however, while the STP (Sewage Treatment Plant) is still in the design phase, it is essential to know, and monitor how the quality of

bodies of water in the city is, as well as the region where the STP will be installed, in order to achieve further treatment suited to its demand, resulting in a better health status for the population. This can be obtained through physicochemical analyzes of the streams “Água Comprida”, “Vargem Limpa” and “Ribeirão Vargem Limpa”, which are located adjacent to the industrial district. In addition to the factories, a hospital and several residences are located there, which demonstrates the relevance of the place for a detailed study in order to keep the public informed, even if indirectly, of how industries treat effluents, as they are often evicted in a criminal way in many rivers and streams causing environmental damages and diseases not only in humans but also in animals that live around them.

Thus, for the full development of a city, considering the health of its population and the importance that water has for all terrestrial life, to know the quality of their streams is of fundamental importance to enable a future treatment for pollution and / or the prevention of the current pollution.

Given the above, the aim of this study was to use the analysis of physicochemical parameters to assess the influence of human interventions in the contamination of the Bauru River and, thereby, assist in the management of this water resource.

## Methodology

The monitoring of streams is essential to preserve the quality of life in the watershed area. To obtain information about a water system depends basically on the study of the interactions which occur between biotic and abiotic factors that govern the functioning of this ecosystem. However, one cannot forget that these interactions are linked to a timescale, reflecting dynamic and unpredictable behaviors, which are intrinsic to each environment.

Thus, this study held the characterization of the Bauru River through the analysis of parameters, such as pH, temperature, conductivity, total dissolved solids (TDS), dissolved oxygen (DO), alkalinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate, hardness and nitrogen in the form of nitrate, nitrite and ammonia.

Bauru is 345 km away from the state capital, São Paulo. The city is surrounded by the cities of Arealva, Reginópolis, Piratininga, Agudos, Pederneiras and Avaí. It has an area of 667.681 Km<sup>2</sup>, with an altitude of 526 m, where 23.85% of the topography is flat and 64.71% has dimples (PREFEITURA DE BAURU, 2011). It has a population of 343,937 inhabitants according to the 2010 census conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2010).

Its climate is tropical highland Aw, according to the Köppen classification, i.e., with a megathermal climate, with winter temperatures averaging around 18°C, with a high annual level of rainfall, especially during the summer, the vegetation consists of Cerrado and Mata Atlântica. Its hydrography is constituted by the Bauru River, which has 100% of sewage flowing in it (PREFEITURA DE BAURU, 2011).

Figure 1 shows the 5 points of Bauru River which were analyzed: (1) in the city center, concentration of domestic sewage; (2), (3), (4) where the streams “Água Comprida”, “Vargem Limpa” and “Ribeirão Vargem Limpa” meet and (5) after the river leaving the urban / industrial area. The Stream “Ribeirão Vargem Limpa” is near the sewage treatment plant. All collection points present release of raw sewage.

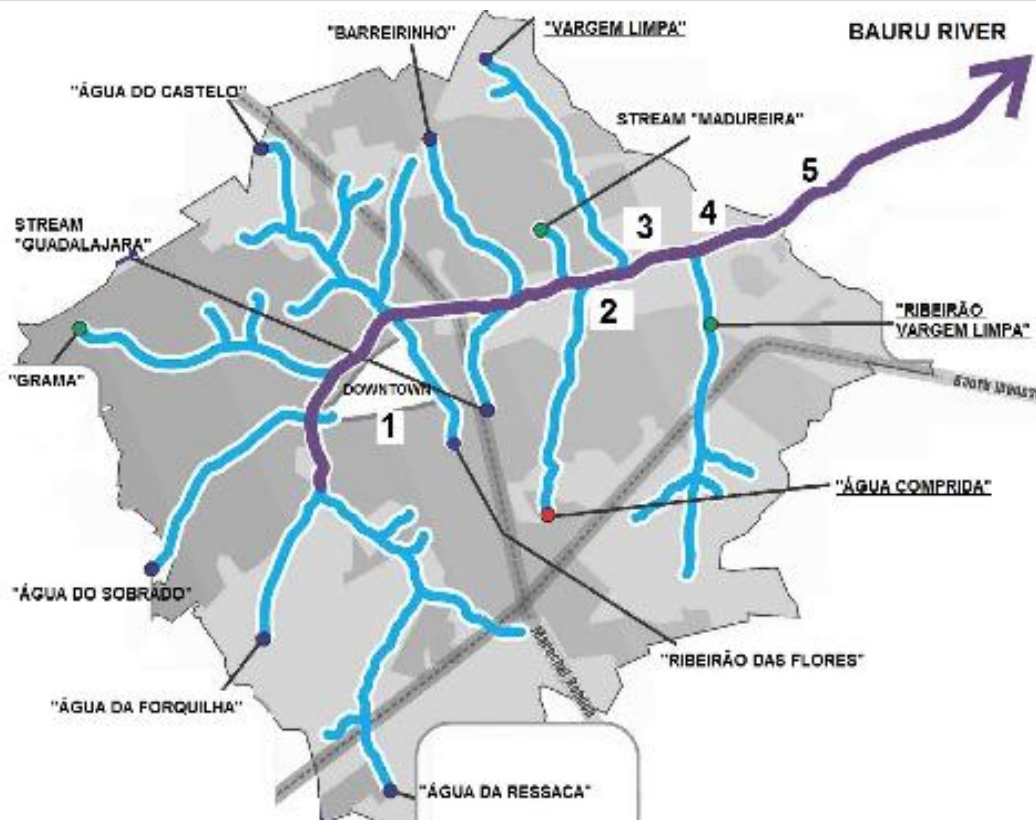


Figure 1. Streams in the city of Bauru [São Paulo, Brazil]. Reference: LUONGO, 2011.

## Results and Discussion

Table 1 shows the results of the physicochemical parameters which were analyzed.

Table 1. Mean values of the analyzes performed in the Bauru River.

Points of analysis	pH	T (°C)	Conductivity (µS 25°C)	TDS (mg/L)	DO (mg/L)	Alkalinity (mg/L)
1	7.27	25	510	250	2.84	108
2	7.34	22	461	241	0.9	156
3	6.99	22	200	92	5.7	60
4	6.90	21	340	204	4.20	80
5	6.65	21	318	240	1.89	136

The analysis of pH is important in the control of corrosion and fouling, since the solubility of many materials present in water varies with pH. The pH can be considered one of the most important environmental variables, but one of the most difficult to interpret. This complexity in the interpretation of pH values is due to the large number of factors that can influence it, and to the close interdependence among the plant and animal communities and the aquatic environment. The same way the Aquatic communities interfere with pH, the pH interferes in different ways with the metabolism of these communities.

The pH of all the points analyzed was between 6 and 8, consistent with most continental water bodies. When the turbidity of the water is low, the concentration of inorganic nutrients and water temperature are higher (which was observed from January to May), favoring the photosynthetic process, in which a higher consumption of CO<sub>2</sub> occurs by the aquatic primary

producers (phytoplankton, macroalgae and/or macrophytes), thus reducing the possibility of formation of  $H_2CO_3$  and observing, then, alkaline pH values. When the aerobic decomposition process is the predominant medium, it becomes more acidic (ESTEVEES, 1998).

In the analysis of the overall conductivity and of dissolved solids (TDS), the stream "Vargem Limpa", point 3, was found to have lower values (200  $\mu S$ , 92 mg/L). Bauru River in the city center, point 1, was found to have the highest values (510  $\mu S$ , 250 mg/L), though. According to Dalberto (2007), a water system whose water has a high electrical conductivity and, therefore, is rich in minerals (inorganic nutrients), theoretically shows a condition that favors the proliferation of algae (primary producers) which enables a high productivity in the environment. However, one cannot ignore the fact that high yields also mean a high consumption of  $O_2$  (respiration and decomposition) and, therefore, the possibility of installing hypoxia or anoxia and impairment of aquatic life at the site. The high values of total dissolved solids indicate a process of soil leaching and dump sewage, mainly industrial, in this body of water.

In ecological terms, the most harmful effect of pollution of a body of water by organic matter is the drop in the levels of dissolved oxygen (DO), which is caused by the respiration of microorganisms involved in the clearance of drains. The stream "Água Comprida", point 2, had the lowest concentration of dissolved oxygen (0.9 mg/L), a problem of increasing awareness of the industries located in its proximity and, therefore, it requires an intervention so that companies do treat their waste before discarding in the collection network.

The stream "Vargem Limpa" showed the lowest values of alkalinity (60 mg/L) and the "Água Comprida" the highest values (156 mg/L). According to Esteves (1998), aquatic environments with high alkalinity have low pH (7-8), the same occurring with high photosynthetic rates. This fact can be proved by checking the pH of water bodies analyzed. The high values are undesirable as they may cause problems of corrosion and deposits in pipelines, which is a serious problem even for industries as they use water in their production processes (OLIVEIRA, 2007).

By analyzing the biochemical oxygen demand (BOD) we can determine the amount of pollution caused by biologically oxidizable organic substances which correspond to the amount of oxygen consumed by the microorganisms to stabilize the material in an effluent or polluted water in 5 days at 20°C. In this study, it was found that point 3 presents the lowest average (44 mg/L of  $O_2$ ) and points 1 and 2 show values above 200 mg/L of  $O_2$ . This is due to the concentration of people and generating trade which increase the wastewater release.

However, it was found that the point 5, after passing through the city of Bauru, presents a large load of pollutants mainly due to industrial waste, as they are considered resistant to biodegradation because they cannot be degraded by the action of enzymes in microorganisms (BRANCO, 1980 apud OLIVEIRA, 2007), confirming the fact that the people are not the only ones that must think about the environment, but the industries too. Further study in this area is, therefore, necessary as well as a greater supervision and control of the responsible public agencies.

Table 2 shows the results of analysis of BOD, COD, color, P and N.

Another parameter analyzed was the color, which is mainly the result of decomposition processes that occur in the environment. It is noticed that the color of point one varies greatly suggesting that this parameter may be influenced by several others, mainly by solid and rain,

not forgetting that this point is located in the center of the city which undergoes many conditions of pollution. These values might be considered intermediate for this type of effluent, but they are above the World Health Organization suggestion, which are 20 uH.

**Table 2.** Mean values of analyses performed in the Bauru River.

Points of analysis	BOD (mg/L)	COD (mg/L)	Color (uH)	PO <sub>4</sub> <sup>-3</sup> (mg/L)	NO <sub>3</sub> <sup>-</sup> (mg/L)	NO <sub>2</sub> <sup>-</sup> (mg/L)	NH <sub>3</sub> (mg/L)	Hardness (mg/L)
1	206	293	50	9.32	10.06	0.12	8.55	105.04
2	218	209	61	14.10	9.19	0.04	14.60	61.36
3	44	67	60	6.15	4.11	0.05	13.65	36.40
4	82	100	23	5.70	8.10	0.01	8.63	69.68
5	120	142	44	11.22	10.09	0.09	8.72	83.20

The second point presented the highest values in the analysis of phosphorus (14.10 mg/L), whereas, in the sewers, its presence is mainly due to detergents and very high levels can lead to a proliferation of abundant algae. In sewage treatment plants, a common procedure is to add PO<sub>4</sub><sup>-3</sup> to raw sewage and final effluent to verify if treatment processes remove the same.

Nitrate is the most completely oxidized nitrogen. It is formed during the final stages of biological decomposition in both water treatment plants and natural water springs. According to the State Decree nº 8468 (SAO PAULO, 1976), as well as Resolution nº 357 of the National Council for the Environment (CONAMA, 2005), the maximum permissible nitrate should not exceed 10 mg/L for water class 3 and 4, as Bauru River and its tributaries are classified. Thus, it depicts the plight of these water bodies which reach concentrations near the maximum allowed, as the excess of nitrate ions in drinking water is problematic once it has a potential relationship with stomach cancer (BAIRD, 2002) Since the maximum value allowed for the nitrite is 1.0 mg/L, all points analyzed in this study are below the maximum allowable value. But that does not mean this concentration does not bring problems to the environment and its balance. According to Esteves (1998), concentrations greater than or equal to 0.5 mg/L of ammonia are considered fatal to fish, which discards the possibility of the presence of fish fauna in the river points that have been studied in Bauru.

A water characteristic conferred by the presence of alkaline-earth salts (calcium, magnesium, and others) and metals, to a lesser extent, the hardness parameter, was also analyzed, and point 1 showed larger values (105.04 mg/L) and point 3 the lowest values (36.40 mg/L). Studies show that people who live in regions of "hard" water show an average rate of heart disease mortality lower than those of very soft water, but there is no certainty if this advantage in consuming hard water is a consequence of magnesium ions or other ions, such as sodium and metal ions (BAIRD, 2002).

Through this study we can verify the Bauru River, even before receiving the load of industrial effluent, has been already impaired, with some high concentrations, e.g., COD, NO<sub>2</sub><sup>-</sup> and NH<sub>3</sub>. This is due to the fact that multiple types of effluents are received by it in the collection point. Thus, it is observed that the river is directly influenced by all domestic sewage it receives and also by the influence of the pollution of industrial districts. Given the results, it appears that despite the lower load of industrial sewage that is released into the river, this presents a much larger potential polluter, which is evident when comparing the points in which the predominant industrial sewage is greater than the domestic sewage.

In general, the point where the water body is less impaired is point 3, this is due to the fact of it presenting predominantly domestic sewage. Point 4 presents slightly higher values than

point 3, thus showing to be more depreciated, but it has better rates of dissolved oxygen. This oxygen is due in small part to the location of water collection which features a small waterfall and most of the characteristics of its source, which is well preserved, and the distance from the point of collection that can also enable a small self-purification of the water body. Point 2, however, presents the most worrying results because of the highest values of pH, conductivity, TDS, alkalinity, BOD, phosphate, nitrate and ammonia, for example. This data reveals the high level of pollution due to the fact this point gets a big load of industrial wastewater, as electroplating industries are close to it, for example, so this point deserves special attention because it represents not only a risk to the local population, but also the main aggravating pollution in the Bauru River. In point 5, the flow is greater by the junction of the streams, which means more water, which could then dilute/reduce the concentration of pollutants in the water body. After the points 2, 3 and 4 emptying into the Bauru River, it is observed that this point has a high level of environmental impact. Although the flow rate is higher than that found in point 1, point 5 presents high levels of conductivity, TDS, COD, nitrite, phosphate and a smaller amount of OD. It can thus be concluded that the discharge in these streams, the industrial waste received causes a large environmental impact. If we think about the self-purification of water bodies, point 5 should provide better results than the first point, but not too close when these values are higher, thus underlining the impairment of aquatic life and, directly or indirectly, problems for humans, because it makes the water unfit for any kind of use, especially as a food source, irrigation or for leisure.

## Conclusions

Given the above, the pollution found in the Bauru River is evident and so the urgency in taking preventive measures is mainly aimed at the recovery of the water body. The results, although being from occasional collections, are presented in linear time, but it is known that the problem can be much higher since many industries dispose their waste illegally in night shifts and weekends, and on holidays, when usually no sampling and inspection are carried out. When analyzing a global way, the stream “Água Parada” and especially the “Vargem Limpa” and the “Ribeirão Vargem Limpa”, it turns out that they influence the pollution of the Bauru River through varied parameters presented here. It also shows the need to settle in this region interceptor’s industrial district, as well as the urgent need to build a sewage treatment plant. However, the solution will occur in long-term since it occurs only after the diversion of these effluents by the interceptors and the subsequent treatment station and also by the time required to recover Bauru River alone, or being able to promote the self-purification of the pollutants present in its water body.

We verified that the industrial sewage is not the only problem; the sewage is a problem as serious as it, mainly due to the amount of sewage that is thrown into the sewer system, which then goes into streams and rivers. The industrial wastewater has become the main problem in that small quantities are sufficient for a large environmental degradation. In some points, garbage and animal waste were found near the edge of the water body, which shows the lack of public awareness of the problems that these attitudes can cause. However, it seems that there is the belief that nobody will be hurt or killed by a mere piece of paper or a can of soda thrown on the floor. Thus, people forget that no matter how small one’s part is, it makes a difference when grouped together. To make the world a better place, we need to start with ourselves before we want to demand from whoever the rulers and authorities may be. Further studies are needed to see which companies are behaving erratically, what can be done by registering this same information by the Municipal Authority responsible for water and sewage, Bauru (DAE). Thus, the main challenge faced by DAE is the consent of these



companies to commit to follow the legislation, as well as inform their working conditions and dispose of their waste at the risk of penalties.

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