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Bathymetric Survey and Characterization of the Bottom Sediment in the Public Supply Reservoir of the Municipality of Porto Nacional, Legal Amazon, State of Tocantins, Brazil

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Abstract

The reservoirs, formed by the construction of dams, act as true sediment retention basins. The sediments are particles derived from rocks or biological materials that are transported by water drains, being one of the main responsible for the modification of the terrestrial environment, involving processes of erosion, transport and deposition of particles. These processes are natural characteristics of the hydrosedimentological system, but with the human action along the banks of the reservoir, this process has intensified, becoming a huge problem that affects both the quality and volume of the water in the hydrous bodies. In this sense, the bathymetric survey was of fundamental importance for the selection of the sediment collection point, since it will be possible to determine the terrain bathymetry, liquid discharge, water velocity and water level. The objective of this work was to characterize the bottom sediment and to contribute to the management of the public supply reservoir by means of the bathymetric survey on the dam of the city of Ribeirão São João, municipality of Porto Nacional, State of Tocantins. By means of bathymetry, a data collection point was established, located near the water bed of the public supply reservoir, and were measured the area, width, water velocity, liquid discharge and sediment characterization. The study determined with the bathymetric survey the possible location where the largest accumulation of sediments will occur, according to the velocity changes, where the water flow loses its force and the sediments are deposited. It was also determined that the bottom sediment of the reservoir is mostly silty clay, which may affect the operation, as well as facilitating the chemical and physical pollution of the water, which could endanger the health of the population. The study determined these facts. Therefore, we can conclude that the results indicate that preventive, corrective and preservation measures must be adopted in the management of the reservoir to increase the water level and quality of the reservoir, and consequently we increase the time of use of this abstraction to supply the urban population of Porto Nacional – State of Tocantins.

Key words: Bathymetric Survey; Sediments; Reservoir.

INTRODUCTION

Water is a natural resource essential for the origin and preservation of life, and despite being a renewable resource, in the last few years there has been an intense concern about its scarcity, since it has lost its ability to recover in a natural way, as many sources of water have been exhausted by improper use. According to Tocantins (2008), the population supply represents 71% of the water demand in the current scenario.

According to UNESCO (2017), the approximately percentage of 12% is equivalent to the entire amount of potable water of the world concentrated in the Brazilian territory. Urbanization, soil sealing and the consequent deforestation by soybean monoculture in the municipality of Porto Nacional, result in a number of environmental problems, such as: soil erosion, basin siltation and climate change. The degree of siltation suffered by these impoundments in recent years has been decreasing its useful volume, with consequences on the quality and quantity of water available for abstraction. In this context, it is of great importance the study of methods that quantify the degree of sedimentation of these impoundments (Silveira, *et al*., 2009).

The sediment is of extreme importance as an indicator of the level of pollution when it is considered that the crop launches the agrochemicals or the industries launch their dumping in the aquatic environments, especially when there is no inspection. According to Esteves (2011), the sediment can register the pollution occurred in the water in the previous days.

The mineralogical characteristics are defined according to NBR-6508, the granulometric scale that divides the soils into the following fractions: clay, silt, fine sand, medium sand, coarse sand and gravel. The granulometric analysis, quantified in sediment samples, is related to the evaluation of the mineralogical characteristics that compose the limnological matrix, to verify the presence of silt, sand and clay. According to CETESB (2007), a greater quantity of fines, represented by high amounts of silt, clay and smaller sand, constitute a significant possibility of finding contaminants that allow the measurement of the quality of the sediment present in the water body, since the size of the particle influences the adsorption and retention of contaminants, as there is the tendency that when the grain decreases, the concentrations of nutrients and contaminants increase.

For Back and Bonetti (2012), the water flow measurement is usually obtained indirectly, since level or average velocity measurements are used, in addition to the topobathymetric survey of the section measurement. According to Krueger (1996), the main goal of bathymetry is to measure the depth of a water body related to the position of a vessel on the surface of the water, and it is possible to visualize the submerged topography through the representation of isobathic lines.

The performance of the bathymetry is of fundamental importance for the choice of the collection point of the sediment, since it will be possible to determine the biggest depth, liquid discharge, water velocity and water level. According to Álvares *et al*. (2001), the bathymetric survey is essential for the management of a water resource, since it allows to estimate the degree of sedimentation, modeling the submerged relief, calculating the volume of storage and subsiding information for decision making in the management and use of the water resources of the competent bodies.

Therefore, the present work had the objective to characterize the bottom sediment and contribute to the management of the public supply reservoir through the bathymetric survey in the Ribeirão São João basin, in the city of Porto Nacional, state of Tocantins, aiming the morphological characterization of the bottom sediment, which will enable new surveys, future analyzes of sedimentation and erosion processes, assisting in the rational use of the reservoir and, consequently, in the management of the studied basin.

MATERIALS AND METHODS

1.1. Site of the experient:

The public supply reservoir of the municipality of Porto Nacional is located within the legal Amazon between the parallels 10°43'04,52" in the south latitude and 48°22'19,77" in the west longitude, in the watershed of Ribeirão São João, which is located between the parallels 10°46'43 "and 20°41'20" in the south latitude and between the meridians 48°14'16" and 48°24'51" in the west longitude (Figure 1). According to Silva (2010), Porto Nacional has an estimated population of 52,510 inhabitants (IBGE, 2016) and is in a 62 km distance from the state capital of Palmas.

According to Balduino *et al.* (2018), the climate of Porto Nacional is sub-humid, with two well-defined seasons, rainy and dry, with a drought period in the winter season where it presents moderate and mega thermal water deficiency, with high values of annual evapotranspiration potential, with 28.29% of this evapotranspiration concentrated in the summer season and can be defined by the formula C2wA'a '. The precipitation concentration occurs during the rainy season, from November to April, corresponding to approximately 80% of the rainfall quantity. The dominant natural vegetation in the basin area is the savannah. In relation to the pedological aspects that influence the sediments, the predominance in the region is the Latosols with smaller portions of Litolic and Hydromorphic soils (CARVALHO *et al*., 2016).

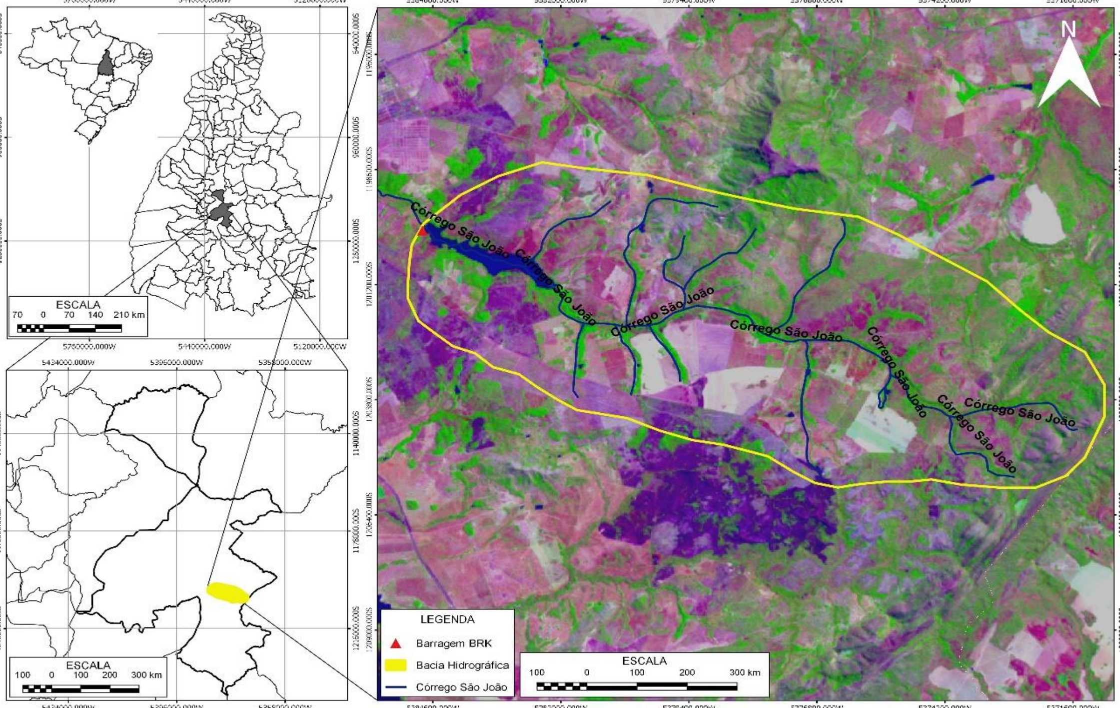

Fig. 1: Public Supply Reservoir in the municipality of Porto Nacional – Tocantins State.

The choice of the collection point of the bottom sediment was determined after the bathymetric survey, which was performed according to the water flow and where there was a large settlement of the reservoir, with a bigger sediment accumulation.

1.2. Bathymetric Survey:

The bathymetric survey, liquid discharge and water level in the São João river basin was performed using an acoustic method using the Doppler Acoustic Profiler, model ADCP SonTek RiverSurveyor M9. According to Geotech (2017), this equipment emits acoustic waves of frequency between 300 and 3,000 Hz, and through the response frequency of the water bed material it determines the distance between the source and the receiver. The apparatus was coupled to a motorized vessel, which covered the entire dam area, collecting pairs of coordinates and their respective point depth.measurements on each facet (radial and tangencial), totalizing 40 measurements per sample, for a total of 400 measurements per species(Lima *et al*., 2013).

The data obtained in the field were processed in the software of the device, named RiverSurveyorLive, generating a spreadsheet with the information collected in the field and the survey was performed in the beginning of the raining season, December 2017.

1.3. Granulometric analysis of the sediments:

For the study of the granulometric analysis of sediments, the bottom sediment samples were initially collected using the Pertesen type sampler, which consists of two buckets that close together when touching the water bed due to a rod device, to collect an upper layer of material. The sample was prepared for the characterization tests with the previous drying method, according to NBR 6457/2016.

The experimental procedure for the granulometric test was divided into coarse screening, fine screening and sedimentation test.

For the performance of the coarse screening, the amount of soil that was retained in the sieve of 2.00 mm was used in the moment of the sample preparation. Next, the experimental procedure was performed, washing the material in the 2.00 mm sieve which was then brought to the oven, then the sieves of larger openings and 2.00 mm were placed on top of each other with the openings of the meshes growing from the bottom up. Under the smaller sieve was placed the plate to collect the grains that passed through it. The larger aperture sieve was capped to prevent loss of particles at the beginning of the vibration process. With the set of sieves organized the shaking was carried out in the sieve. The soil fraction retained in each sieve was weighed until a sieve of 2.00 mm was reached.

For the fine screening, about 120 g of soil was used at 2.00 mm in the moment of the sample preparation. Subsequently, the material was placed in the 0.075 mm sieve which was washed and then placed in the oven. The set of sieves was organized comprising between the openings of 2.00 mm and 0.075 mm, the material was placed dry in the sieve assembly and the same procedure of the coarse screening was performed.

Finally, for the sedimentation test, it was used a sample of the fine screening test, weighing between 50 and 100 g, immersed for 12 hours with deflocculant (sodium hexametaphosphate solution). Soon after the material was transferred to the dispersion cup where distilled water was added until the level was 5 cm below the edges of the beaker, then it was subjected to the action of the dispersing apparatus for 15 minutes, and finally the mixture was transferred to a graduated beaker , completing with distilled water up to 1000 ml and then shaking the soil / water mixture.

The densimeter readings were taken at the instants of 30 seconds, 1 and 2 minutes, 4, 8, 15 and 30 minutes, 1, 2, 4, 8 and 24 hours. After the last reading was performed , the material of the test tube was placed in the 0.075 mm sieve, so that the sample can be washed in the sieve with low pressure potable water, removing all material from the sides.

1.4. Specific mass of particules:

The specific mass of the particles was also a parameter of analysis for the characterization of the sediments, their determination was made based on NBR 6508.

For the calculation of the specific mass of the soil particles, the following formula was used:

$$\delta = \frac{M1\ x\ 100/(100+h)}{[M1\ x\ 100/(100+h)] + M3 - M2}\ x\ \delta T \qquad \text{(Equation 1)}$$

Where:
δ = specific mass of the soil particles, in g / cm³;
M1= mass of the wet soil;
M2= mass of the pycnometer + soil + water at the test temperature T;
M3 = mass of the pycnometer filled with water in the reference mark at the test temperature (T);
h = initial humidity of the sample;
δT = specific mass of the water at the test temperature T.

RESULTS AND DISCUSSION

1.5. Hydrographic profile:

The performance of the bathymetric survey was of fundamental importance for the choice of the collection point of the bottom sediment of Ribeirão São João, which was performed according to the water flow and in the location of the greatest repression of the dam, where there is the higher sediment accumulation, as shown in Figure 2. From this it was possible to determine the greatest depth, flow and velocity of the water.

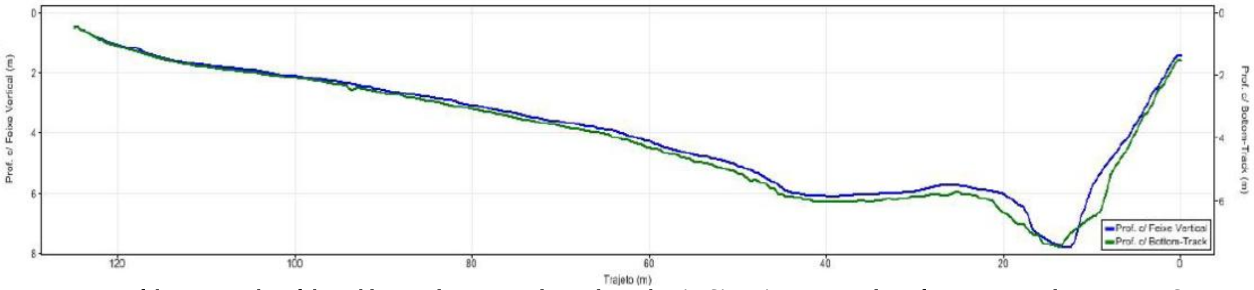

Fig. 2: Representation of the topography of the public supply reservoir located in Ribeirão São João, municipality of Porto Nacional – Tocantins State.

The area of the reservoir under study was 488.04 m², with a width of 127.29 meters and a maximum depth of 7,847 meters in its main channel. In a study carried out by Oliveira (2015), in the basin of Rio Monday, Paraguay, it was found basin width values of 65.62 meters and depth of 9.54 meters.

1.6. Water flow in the reservoir:

For the ten crossings performed, the software generated a transversal profile of the creek in the measurement section, according to Figure 3, referring to the first crossing of the section. The acoustic equipment has a limitation that is the velocity measurement at the bottom of the creek, where they are represented by the black cells, in which they are not used in the flow calculation, as they are interpolated by the software.

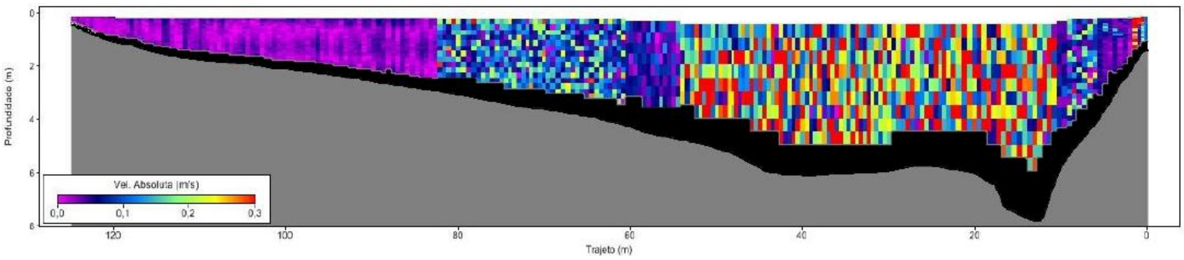

Fig. 3: Cross section profile of the first section.

The data collected by the equipment were processed by the software RiverSurveyorLive and they are presented with the summary of each crossing, according to Table 1. It is worth mentioning that the coefficient of variation of the total flow was 1.04%, ie, less than 5% as recommended by the NBR-13403, and having the average value of the flow found for the section was 1.55 m³/s.

According to Ibiapiana *et al.* (2003), the flow measurement data are indispensable for the studies of water resources planning, flood forecasting, watershed management, public supply, sanitation, irrigation, environment and many other studies of great scientific and socioeconomic importance.

1.7. Analysis of the water velocity of the reservoir:

In the analysis of the water velocity along with the depth, it was observed that the velocity has a different behavior in the transverse direction of the reservoir, with larger values in its right margin, in the main channel of the river basin, and with lower values of the center to the left margin. It was also possible to conclude that in the regions closer to the bus, the velocity was higher in the section of lower depth (60 to 80 meters), according to the Figure 4. The velocity in the longitudinal direction of the reservoir ranged from 0 to 0.09 m/s.

Table 1: Summary of the crossings.

Crossing	Start Margin	Surface Flow	Average Flow	Bottom Flow	Total Flow	Area (m²)
1	Left	0,031	1,112	0,418	1,561	491,634
2	Right	0,029	1,094	0,420	1,543	487,173
3	Left	0,032	1,107	0,441	1,560	490,679
4	Right	0,033	1,119	0,410	1,562	489,460
5	Left	0,033	1,087	0,424	1,544	489,975
6	Right	0,032	1,098	0,410	1,540	483,932
7	Left	0,031	1,099	0,410	1,540	487,134
8	Right	0,030	1,089	0,430	1,549	486,438
9	Left	0,031	1,107	0,390	1,528	485,810
10	Right	0,034	1,103	0,440	1,577	488,167
Average		0,032	1,102	0,4193	1,552	488,040
Standard Deviation		0,014	0,009	0,0146	0,016	2,272
Coefficient of Variation (%)		4,52	0,871	3,501	1,039	0,465

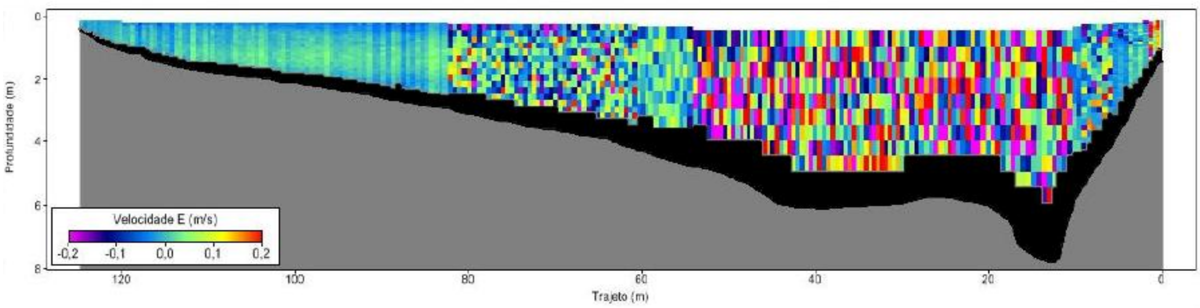

Fig. 4: Velocity of a transversal course carried out on 12/07/2017.

Gentil (2015), in a study in the reservoir of the hydroelectric plant of Caçu, state of Goiás, found speed values in the range of 0 to 0,8 m/s. The velocity has an important role in the conduction of the sediments, which are transported to the reservoir, and as this flow decreases some of the sediments are deposited at the bottom of the reservoir.

1.8. Characterization of sediments:

Taking as basis the sediment sample from the bottom of the collected reversal, which was later analyzed in the laboratory, it is possible to obtain the granulometric variation of the sample, and the specific mass value of the particle. The results of the analyzes are presented in Table 2.

Table 2: Results of the granulometric analysis

Point of Sampling	Clay (%)	Silte (%)	Thin Sand (%)	Average Sand (%)	Coarse Sande (%)	Especific Mass
1	51,5	41	4,5	1	2	2.723

The granulometric fraction of the sediments presents a large amount of soil with low granulometry, with clay and silt prevailing with approximately 93% of the total, and the percentage of sand, classified as fine, medium and coarse, was below 8, the value found for the specific mass of the particles was 2.72 g/cm3. In a study in the PCH Pipoca reservoir in the state of Minas Gerais. Minhoni (2013), it was found the approximate values of the specific mass, with an average of 2.66 g/cm3, with a low granulometry, with 89% of clay and silt and 11% of sand, which also characterizes the bottom sediments of the two reservoirs under study as silty clay.

The sediment sample has a large amount of clay and silt; the fraction prevailed in eleven points with more than 90%. The percentage of sand was below 5%, which can be observed in Figure 5.

According to Jesus *et al*. (2004), sediments have been considered as a compartment of accumulation of polluting species, in which the soils with high content of clay and silt are rich in binding sites, making it possible their use as a good indicator of environmental pollution. For Silva (2009), the contamination of the water body happens in three different phases: dissolved organic carbon, aqueous solution and in the sediment. As the hydrous body in which is located the public supply reservoir and its amount is located in an area surrounded by the monoculture of the soy being an activity of great concentration of application of pesticides, putting at risk the health of the population of the municipality and rural communities that use the reservoir water.

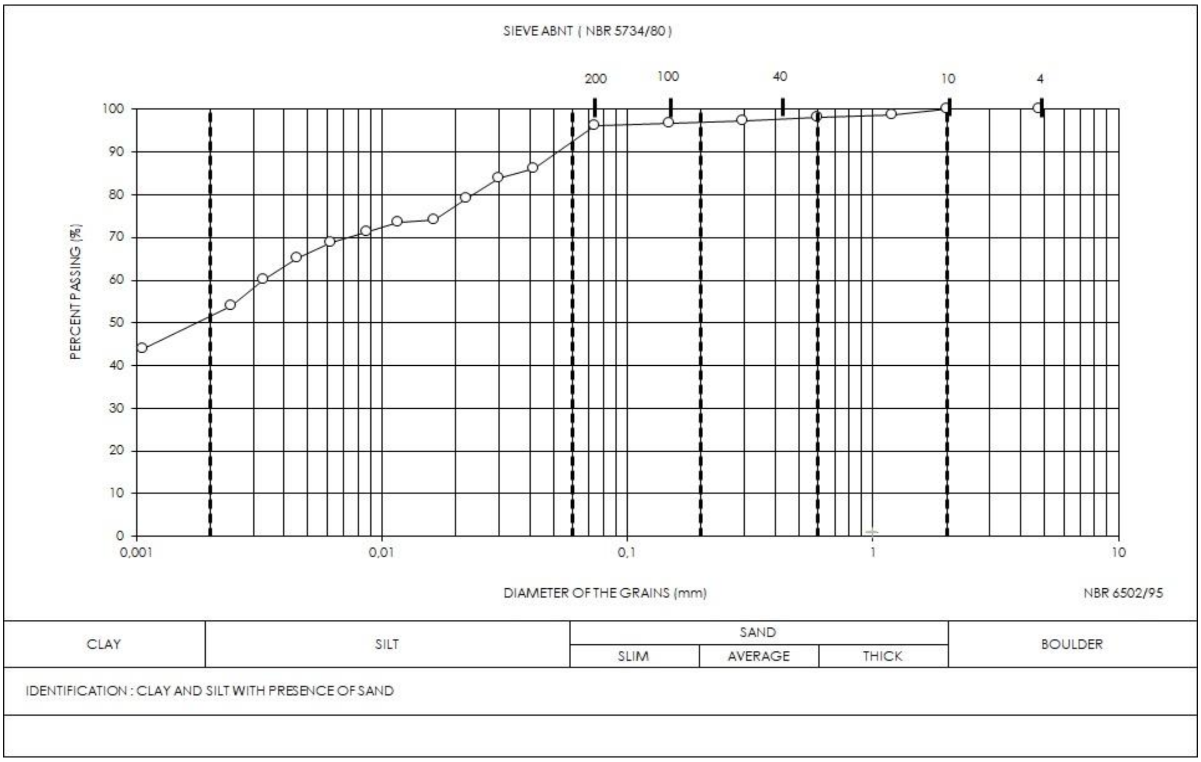

Fig. 5: Granulometric distribution curve.

Conclusion:

As the economic activities and population increase, many regions reach scarcity conditions or find limitations in their development, which makes them a concern both in the quality of water for public supply and in quantity.

The bathymetric survey performed by the Doppler acoustic meter made it possible to choose the appropriate sediment collection point for its characterization, as well as data such as reservoir area, depth, flow and water velocity.

The public supply reservoir has an area of approximately 488.04 m², 127.29 meters from one margin to another, and with a greater depth of 7.84 meters in its main channel. The flow measurement method was accurate according to NBR-13403, in which the average flow rate was 1.55 m³/s in the amount of the reservoir.

The velocity of the water flow, where it was carried out during the transition period (drought/rainy), presented values ranging from 0 to 0.9 m/s, with the highest velocity at the entrance of the reservoir and decreasing as the depth increased, width and distance traveled.

The characterization of the bottom sediment was extremely important, because it will enable a better management of this water resource regarding the management process. The granulometric fraction characterized the bottom sediments of the reservoir under study is silty clay, with 93% of its totality.

Considering the advance of agriculture in the area of the supply reservoir, and consequently the removal of soil cover and exposure to bad weather, it will result in the production of sediments that will affect the operation of the reservoir and will favor the chemical and physical pollution of the water, thus harming the quality for human consumption. As the bottom sediment is made of silty clay, there is some concern for monitoring agrochemicals generated by agriculture, because they can be absorbed on the floating sediment or the one located at the bottom of the water, and if detached from the sediment or ingested by a biota organism, it will consequently enter the food chain and endanger the health of the population.

Therefore, we can conclude that the results indicate that preventive and preservation measures should be adopted in the management of the reservoir, such as monitoring the daily water quality in the reservoir, dredging of the sedimented material and daily verification of the level of the reservoir through linimetric rules. With these initial measures it will be possible to perform a monitoring of both quality and quantity of water for the purpose of increasing the capture time in the reservoir.

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