Chapter 150

Efficiency of rural reservoirs in the storage and use of rainwater

10.56238/tfisdwv1-150

Thiago Igor de Medeiros
Civil Engineering Student, Academic Unit of Environmental Sciences and Technology - UACTA, CCTA, UFCG, Pombal, PB
E-mail: thiago.igor@estudante.ufcg.edu.br

Rosinete Batista dos Santos Ribeiro
PhD in Natural Resources, Advisor and Professor of the Academic Unit of Environmental Sciences and Technology - UACTA, CCTA UFCG, Campina Grande, PB
E-mail: rosinete.santos@ccta.ufcg.edu.br

ABSTRACT

Brazil has the largest water reserve in the world, but several factors generate its poor distribution, resulting in water scarcity in parts of the semi-arid regions of the Northeast and Minas Gerais, where millions of inhabitants live with drought. The "Water for All" program was successful in combating the drought, providing access to water for millions of low-income families through the construction of cisterns for various purposes, such as human consumption and agricultural family production in small units. It is the result of a simple and low-cost technology, where rainwater is collected from the roof through gutters and stored in cisterns built with cement boards, allowing a family of up to five people to have water for consumption for up to 8 months, the possibility of contamination of these reservoirs is very high, which can generate numerous health problems for users. Thus, this study aims to analyze some rural reservoirs, verifying their use, water supply through the calculation of the yield of their contribution area and their accumulation capacity, possible physical and structural problems or arising from contaminating sources in their area of capture and risks to the health of users, helping to study and implement alternatives to improve water storage and use conditions, as well as alleviate the effects of drought.

Keywords: Cisterns, quali-quantitative analysis, efficiency.

1 INTRODUCTION

Brasil has the world's largest water reserve, but geographical, demographic and political issues promote the poor distribution of this resource in its geographical space. The reactions and measures implemented by several governments since then have proved to be lentas and ineffective, initially focused exclusively on the construction of large public dams, which despite great impact on the environment and the life of the beautiful communities did not present significant results for most of the population.

Subsequently, family care actions also emerged, but only at the end of the 20th century were more effective measures implemented to improve coexistence with prolonged periods of drought, promoting the permanence of populations in the backcountry and encouraging agricultural production, especially family agriculture (LIMA; MAGELLAN, 2018).

Acting on two fronts, called "First Water" and "Second Water" promoted the construction of cisterns of 16,000 liters of capacity for human consumption and 52,000 liters in small units of family agricultural production, respectively, and in this aspect achieved an undeniable success in improving the quality of life of these populations (MINISTRY OF NATIONAL INTEGRATION, 2015).

However, with regard to human consumption, a more careful assessment of the impacts that direct consumption of rainwater can have on the health of consumers is necessary, after all, as the result of a simple and low-cost technology, where rainwater is captured from the roof by means of gutters and stored in cisterns built with cement plates allowing a family of up to five people to have water for consumption for up to 8 months (PLANTIER, 2014), the possibility of contamination is very high and can generate numerous health problems.

In view of the above, the study aimed to analyze some rural reservoirs (cisterns), verifying their use, water supply through the calculation of income of their contribution area, be it a roof or an area waterproofed known as "boardwalk", accumulation capacity, possible physical, structural or resulting from contaminant sources in its catchment area and the health risks of users, assisting in the study and implementation of alternatives to improve storage conditions and use of water, as well as mitigate the effects of drought.

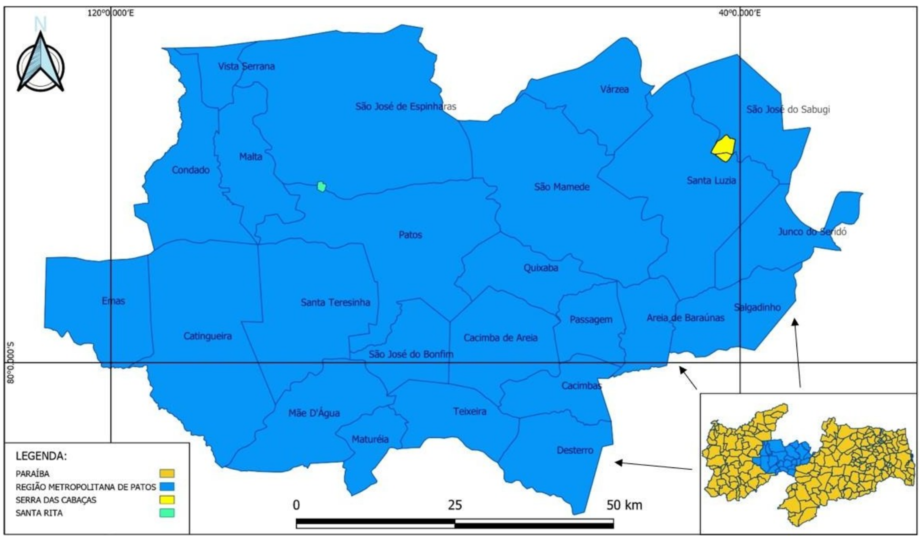
2 MATERIALS AND METHODS

The methodological stages of this study consisted of: data collection, diagnosis of cisterns regarding sanitary conditions and the impacts of water use on the health of the population and indicate alternatives that minimize any problems Existing. For this purpose, the physical situation of the existing reservoirs, their use and their quali-quantitative parameters was analyzed, generating a diagnosis about their situation and possible interventions to improve the quality and quantity of water available to families.

In-lo co visits weremade to raise the profile of resident families, as well as cisterns, both for their dimensions, their physical conditions, presence of pathologies, sources of contamination and others.

- Area of Study

Figure 1.Study development areas.



Source: Author, 2021

The study was carried out in two large areas in the Metropolitan Region of Patos: Sítio Santa Rita and the Serra das Cabaças Community.

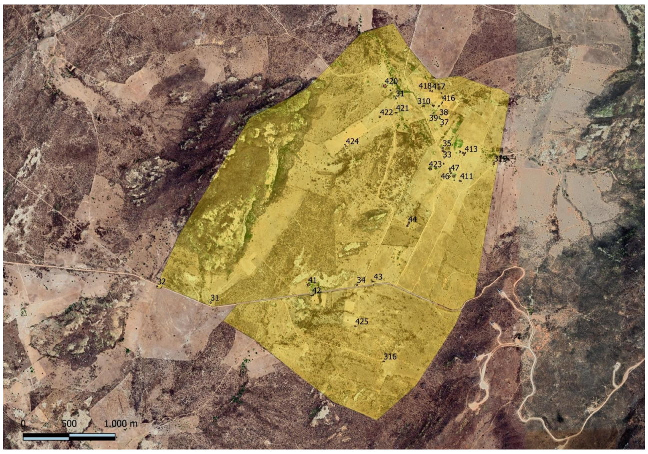
The first area of the study is located in the rural area of the municipality of Patos, district of Santa Gertrudes and the municipality of São José do Espinharas. Sitio Santa Rita is a rural community of 172.08 hectares, divided among 21 families, 19 of which residein the locality, with a permanently resident population of 74 individuals.

Figure 2. Location of the improvements in Sítio Santa Rita.

Source: Author, 2021

The second, represented in Figure 3, occupies an area of 970.8 hectares between the municipalities of Santa Luzia and São José do Sabugi, is home to 32 families, with 14 of them permanently residing in the territory, totaling 144 residents.

Figure 3. Location of improvements in the Serra das Cabaças Community.



Source: Author, 2021

Aiming to analyze the flow generation capacity for tank supply, the water recharge capacity of the localities was verified through the annual rainfall average and the surface flow coefficient of the catchment basin, in this case the roof of the residences.

Because there was no meteorological station in the localities with sufficiently accurate data for the development of the study, we opted for the analysis of official hydrological data and cálculos of average precipitations, such as the Isoietas and Thiessen Method.

It was found that for Sítio Santa Rita, the average annual rainfall is 805.4 mm/year, while for the Serra das Cabaças Community the average annual rainfall is approximately 510 mm/year.

In both localities, the climate is characterized as hot semi-arid, with average annual temperatures fluctuating between 21°C and 27°C, and daily thermal amplitudes of 10°C. The rains are predominantly of convective-concentrated in a humid season that usually runs from February to May with an irregular historical average.

- Rainwater catchment and storage capacity

In possession of local rainfall information, contribution basins and local storage systems were analyzed.

For the analysis of the water availability of a cistern, the contribution basin is the roof area of existing buildings, or the waterproofed area for the case of boardwalk-type cisterns All buildings are covered by ceramic tiles, therefore, the Runoff coefficient used for the calculations was 0.85.

Rainwater is captured from the flow of water to gutters, where filters are installed to eliminate impurities from the liquid and separate the water itself consumption that cannot be reused. The water considered good is destined for a cistern, where chlorine is added. Using the Software QGis and Google Earth was calculated the contribution area of the roofs, then possession of the data collected with the average precipitation calculated by thiessen method, the value of the Surface Deflúvium Coefficient tabled and applying all data in Microsoft Office

Excel, it was determined the volume that each roof is able to generate annually.

- Collection and storage structures

The choice of the cistern will depend on the need of each family, as well as the availability of physical resources, such as the space for installation of the reservoir, the catchment area, water availability, in addition to the financial resources for the execution of the project.

The following table typifies each of the main types of reservoirs built by social programs in rural areas of the semi-arid.

Table 2. Main types of booking systems.

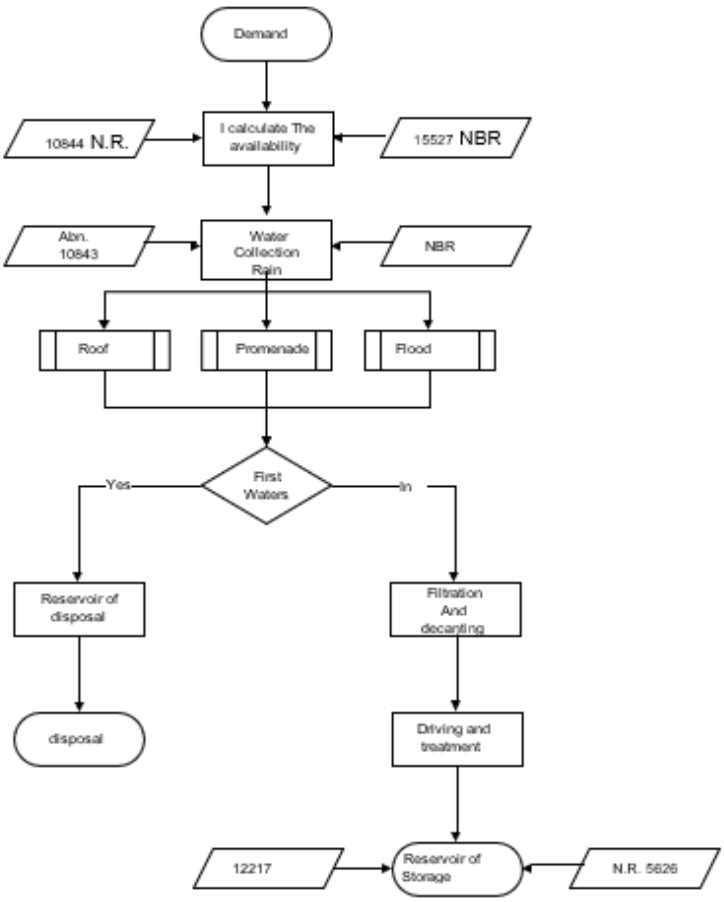
Cistern	Capacity (L)	Features
Domestic plates	16,000	Capture and storage of rainwater through its flow on the roofs of houses, using zinc or PVC gutters. Because it is semi-buried, they present difficulties in identifying leaks and the capture depends entirely on the roof area contemplated by the gutters, not having large storage capacity;

Polyethylene	16,000	Variation of the domestic plate cistern without the need for excavation or construction of the reservoir. Easier installation and hygiene;
Promenade	52,000	Capture is carried out on a boardwalk of 200 m², made from the union of concrete plates of 1 m² each, with unevenconcentrating the deflúvium in a decanter
Roofing	52,000	The capture of rainwater through a roof of 100 m², in the form of a shed. The roof picks up rainwater and through a system of gutters and pipes takes it to the cistern. Indicated for properties with less area available, because shed can be used with tool storage, breeding, among others. With an area smaller than the boardhouse cistern and lower flow coefficient due to the material, its flow generation capacity is lower;
Flood	52,000	Collection and decanting system of floods and a reservoir covered and buried in the ground, in which the cylindrical reservoir is buried in the soil and covered, with an internal diameter of 6.20 m and a depth of 1.8 m, collecting rainwater directly on the flood shaft. Ideal for agricultural production, it needs more excavation work and its interior needs to be cleaned periodically;
Rotomolded Plastic	600, 800 and 1000	Ideal for small spaces because it has compact structure, with easy installation and handling, do not require excavation, and can be connected directly in the gutter.

Source: Cisterns Program, adapted

Despite the different types of collection and storage, all follow the same operating principle. The following flowchart represents the process of capturing and storing rainwater and all the standards that can assist in the design of the different systems.

Figure 4. Sizing systems from collection e storage from water.



Source: Author, 2021

The reservoir or cistern, in turn, can be concrete or polyethylene plates, which are made in factories and driven to the destination where it can or cannot be buried.

Plate tanks are molded on site, usually containing 16 or 52,000 liters of maximum storage volume, and 16,000 liters areused for consumption, being connected to the gutters present on the roof of the residences. Cisterns of 52,000 liters are used for food production or animal desedation, their catchment surface usually takes place on a boardwalk of concrete plates, an attached roof or in a flood stream bed , necessitating decanting processes before storage.

- Sizing of rainwater reservoirs

The methods presented in NBR 15527/2007 of ABNT are: Azevedo Neto, Rippl, Practical German, English And The Australian Practical, being the firstmost used in Brazil, due to its reliability and approximation to the results obtained in national territory, carrying out what will be treated here.

The annual rainfall volume that can be stored is expressed by the Ripple Equation, expressed below:

$$V = P * A * C$$

In which:
V = Annual volume of rainwater (m^3); P = Average annual precipitation (mm);
A = Roof area (m^2); C = Runoff coefficient.

According to the calculation procedure proposed by Azevedo Neto who, unlike the others, takes into account not only the average annual precipitation but also the months of little precipitation or drought, and the capacity of the reservoir is obtained from the product between the annual precipitation, the number of months of little precipitation or drought, and also, the projected collection area , as presented in the equation:

$$V = 0{,}042 * P * A * T$$

Where:
V is the estimated useful volume for the reservoir, in liters P is the annual precipitation, in mm;
A is the collection area in projection, in m^2;
T represents the numerical value of the number of months of low rain or drought.

As mentioned earlier, the rainy season of the region comprises the months of February to May, so 8 dry months should be considered. The equations were applied in the form of an algorithm in the Microsoft Excel software, the volume produced by each cover over the course of a year and the appropriate volume of the reservoirs for storage of the available resource are found.

In the study area, the consumption of water is solely for domestic use and in order to obtain the daily consumption of each family unit were collected, on site, information on forms of use, being them, the use for personal cleaning, for drinking and cooking, use in bathrooms and washing of home and clothes, such information when applied to the spreadsheet resulted in the daily consumption values of each family unit, in turn generating quantitative parameters to verify the availability of each reservoir.

3 DEVELOPMENT

- Survey

The surveys were carried out between 03 and 04 March 2021 at Sítio Santa Rita and between 02 and 4 July 2021 in the Serra das Cabaças Community, in these were observed the forms of capture used, the situation of the reservoirs, elementos constituents of the system, sources of contamination, treatments used, types of reserved water consumption, aspects of cistern maintenance and the socioeconomic situation of families.

Through the questionnaire applied, it was possible to subdivide the consumption of families in personal care (bathing and hygiene), human food, use in bathrooms, washing of homes and clothes and descation of animals, as well as identify the forms of water treatment and possible contaminant factors.

The results obtained served as the basis for the composition of the demand and supply calculations that followed .

- Data collected

The family units were categorized according to their location and presence, or not, of rainwater reservation systems in order to the table below.

Table 2. Identification of family units by location and type.

Identifier	Locality	Description
1.00	Santa Rita Site	Unit with reservation system
2.00	Santa Rita Site	Unit without reservation system
3.00	Gourds Mountains	Unit with reservation system
4.00	Gourds Mountains	Unit without reservation system

Source: Author, 2021

The data obtained were released in Microsoft Excel, then qualitative and quantitative analyses of the values were made. Tables 2 and 3 are shown the volumes stored in the tanks, in addition to the unused quantities, either because there is no storage system or the extravasation of the cisterns, as well as the cisterns that have greater difficulty in full supply due tothe reduced dimensions of its catchment basin (roof or boardwalk), which present with negative values.

The values with positive results in the last two columns indicate that this a system that can meet the needs of its residents, on the other hand, with negative values, are the systems unable to meet the demand, whose effect is the need for alternative sources, such as wells and refills of tanks by water tankers or adjustments.

Table 3. Sitio Santa Rita units with asystem for the use and storage of rainwater.

Identification	Coverage area (m²)	Residents	Reserved volumes (m³)
2.1	22.81	6	-9.80
2.2	75.30	4	4.40
2.3	199.27	0	38.00
2.4	47.21	3	-3.20
2.5	39.52	0	-5.30
2.6	86.30	2	7.40
2.7	284.16	4	60.90
2.8	67.20	4	2.20
2.9	24.47	7	-9.30
2.10	137.09	3	21.10
2.11	221.43	2	44.00
2.12	206.88	0	40.00
2.13	48.95	8	-2.70
2.14	33.80	1	-6.80
2.15	164.14	3	28.50
2.16	113.50	5	14.80
2.17	192.20	6	36.10

Source: Author, 2021

Table 4. Units of the Serra das Cabaças Community with rainwater use and storage system.

Identification	Coverage area (m²)	Residents	Reserved volumes (m³)
3.1	247.05	4	42.4
3.2	56.15	0	9.7
3.3	342.02	3	58.7
3.4	276.82	2	47.5
3.5	257.11	8	44.1
3.6	164.73	4	28.3
3.7	85.83	0	14.8
3.8	102.07	5	17.5
3.9	44.23	0	7.6
3.10	103.89	5	17.9
3.11	42.56	2	7.3
3.12	85.47	0	14.7
3.13	70.63	3	12.2
3.14	51.45	2	8.9
3.15	10.5	0	1.8
3.16	176.23	7	30.2
3.17	132.32	4	22.7
3.18	439.51	6	75.4

Source: Author, 2021

We also analyzed the volumes that could be obtained if the other buildings contained in the areas also had reservation systems to verify the local water availability, represented in the tables below, which correlate the consumption of families with the amount of water stored and then exposing its water situation.

Table 5. Sitio Santa Rita units without rainwater use and storage system.

Identification	Coverage area (m²)	Residents	Volume of possible reservation (m³)
1.1	473.30	5	128.10
1.2	21.37	0	5.80
1.3	25.25	0	6.90
1.4	20.00	0	5.50
1.5	139.55	2	37.80
1.6	107.23	4	29.10
1.7	56.56	1	15.40
1.8	33.06	0	9.00
1.9	27.49	0	7.50
1.10	115.79	0	31.40
1.11	44.12	0	12.00
1.12	121.85	4	33.00
1.13	38.13	0	10.40

Source: Author, 2021

Table 6. Units of the Serra das Cabaças Community without a system for the use and storage of rainwater.

Identification	Coverage area (m²)	Residents	Volume of possible reservation (m³)
4.1	351.83	0	44.3
4.2	245.94	2	26.2
4.3	54.72	0	-6.6
4.4	179.71	10	14.8
4.5	257.89	6	28.2
4.6	191.26	2	16.8
4.7	56.1	3	-6.3
4.8	25.37	7	-11.6
4.9	137.55	2	7.6
4.10	185.24	0	15.8
4.11	361.41	0	46
4.12	66.81	0	-4.5
4.13	237.05	8	24.7
4.14	200.71	5	18.4
4.15	159.93	8	11.5
4.16	114.59	6	3.7
4.17	51.22	3	-7.2
4.18	15.39	0	-13.3
4.19	24.81	0	-11.7
4.20	823.01	5	125.1
4.21	206.56	9	19.4
4.22	170.73	4	13.3

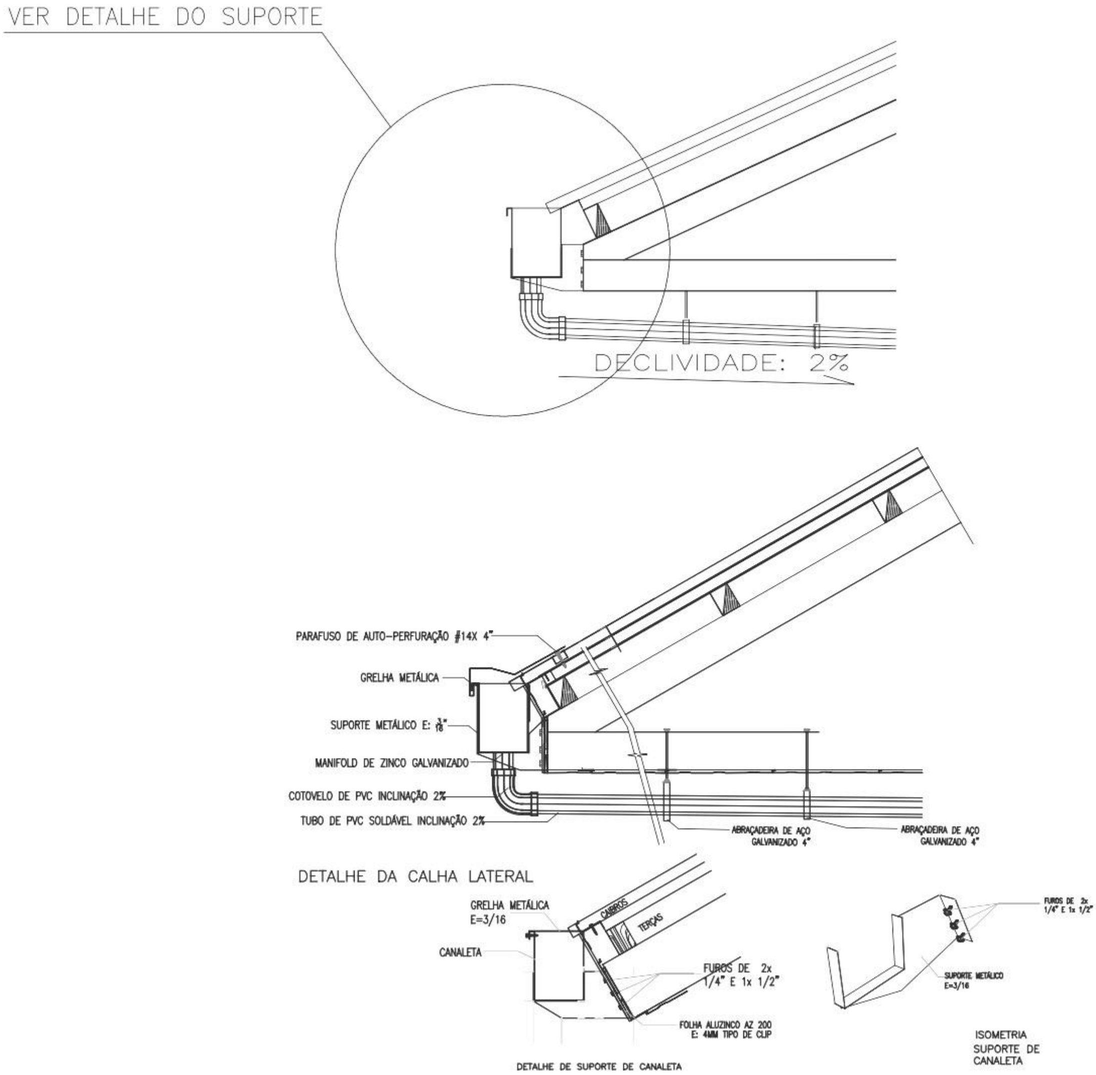
Source: Author, 2021

- Execution of the capture and storage project

The capture system is done by means of gutters attached to the roof rafters and pipes that connect the gutters and the cistern. At the entrance of the cistern , a strainer should be put in place to prevent dirt from entering the tank.

The main constituents of a rainwater collection system are represented below through gutters installed on a roof .

Figure 5. Detailing gutters and supports for collection systems.



Source: Author, 2021

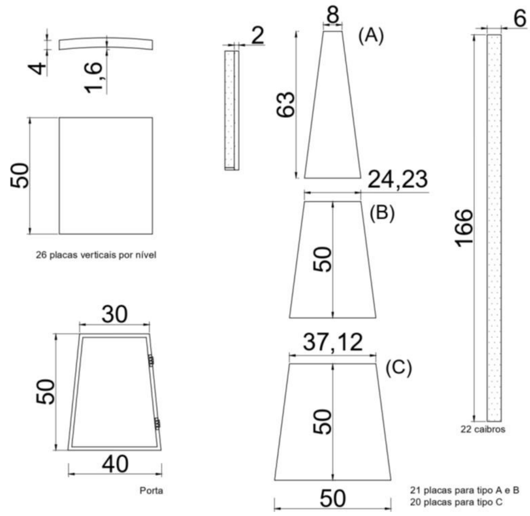
The reservoir, closed, partially buried and built near the family home, is protected from evaporation and contamination brought by air.

According to the Annex of OPERATIONAL INSTRUCTION SESAN No. 02, of August 8, 2017, the process of construction of the cistern takes place from the following main steps:

- Excavation, manufacture of plates;
- Manufacture of the rafters;
- Construction of the bottom slab and walls;
- Execution of the coverage;
- Placement of the capture system and automatic device to protect water quality;
- Retouches and finishes;
- Initial tank supply and,
- Automatic device installation for water quality protection

Based on the values indicated by the Cisterns Program, the constituent elements for detailing were defined, represented in Figure 6.

Figure 6. Elements of the structure of a domestic plate cistern.

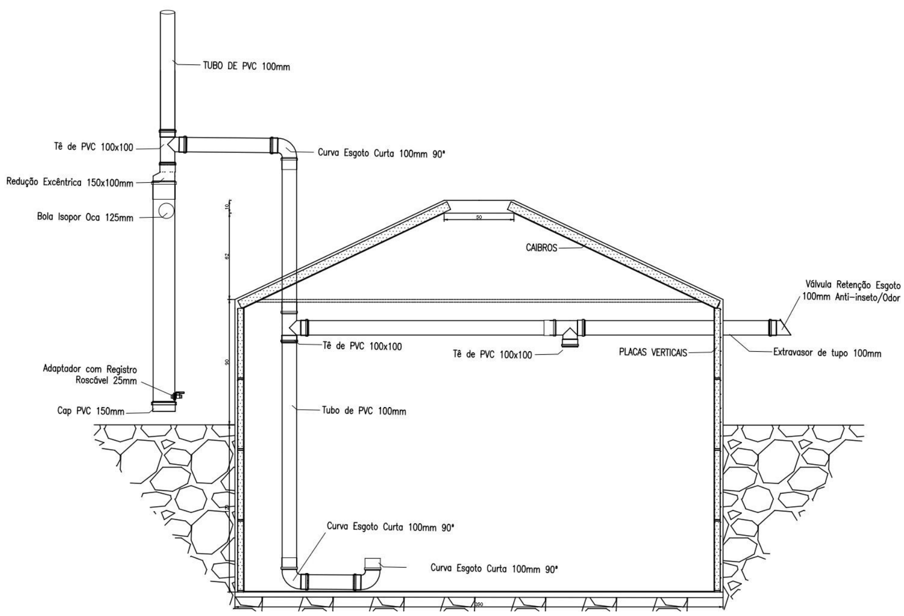


Source: Author, 2021

With the constituent materials of the reservoir structure and the capture system, the elements corresponding to the pipes and connections that connect the gutters to the reservoir are analysis, in addition to the water quality preservation system.

According to the specifications of the Annex of THE SESAN Operational Instruction No. 02 of the Cisterns Program and the Thematic Booklets: Hydroenvironmental Technology and Practices for Coexistence with the Semiarid of the Secretariat of Rich Water Resourcesof the State of Ceará, a cross-sectional representation was elaborated of a cistern, with all the main elements identified, explained in the figure below.

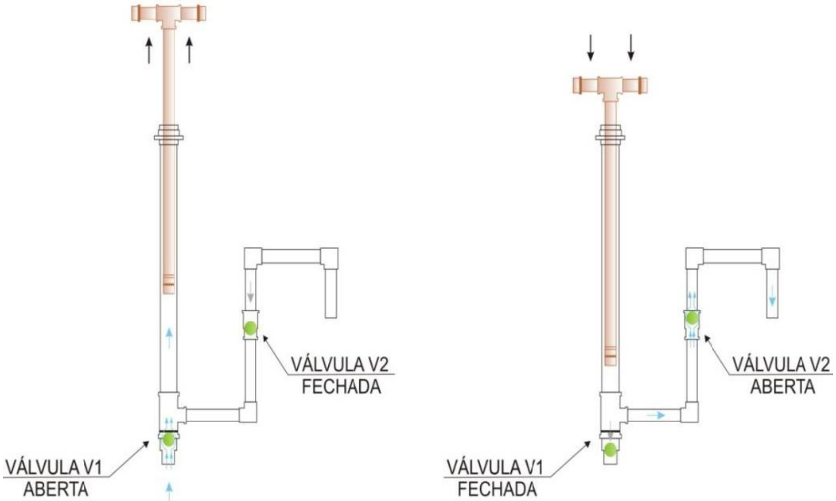
Figure 7. Elements of the structure of a domestic plate cistern.



Source: Author, 2021

It is also indicated the need to build a simple manual pumping system with free water outlet to avoid contamination of the stored resource. Easy to assemble, the pump consists of PVC pipes of different diameters, valves and connections, as shown in Figure 8.

Figure 8. Elements of the structure of a domestic plate cistern.



Source: Author, 2021

- Budgeting and implementation of the system

Listing all the constitutive elements of a system with capture, conduction, preservation of water quality and storage, it became possible to quantify the material and execution of this project.

For this, the National System of Research of Costs and Indices of Civil Construction (SINAPI) was used, updated monthly by caixa Econômica Federal and the Brazilian Institute of Geography and Statistics (IBGE), in which prices and costs assist in the preparation, analysis and evaluation of contractual proposals, while the indexes allow the updating of expenditure amounts in contracts and budgets.

According to the model elaborated and the material relationships available in the Annex to OPERATIONAL INSTRUCTION SESAN No. 02 of the Cisterns Program, the necessary supplies were arranged for execution in three tabelas, presented below.

Table 7 presents the necessary supplies for the execution of a 16,000-liter family plate reservoir.

Table 7. Materials used in the construction process of the cistern 16,000 liters

SINAPI	Materials	Quant.	Pcs.
32	CA-50 1/4" steel (6.35 mm)	20	Kg
337	Recooked wire 18 BWG - 1.25 mm - 9.60 G/M	1	Kg
342	Galvanized wire 12 BWG - 2.60 mm - 48.00 G/M	16	Kg
366	Fine Sand	2	m3
367	Coarse Sand	1	m3
4721	Crushed Stone N. 1 or 19 mm	0.5	m3
5090	Chrome Brass Padlock H = 25 mm	1	Pcs.
7325	Waterproofing for Concrete and Mortar Type Vedacit or Equivalent Brand	3.6	Kg
9837	PVC Pipe For Building Sewage DN 75 mm	12	m
---	Portland Cement Composite CP II-32 50 kg	16	sack

11061	Flat Galvanized Sheet 30 gsg 0.399 mm 3,204 kg/m²	26	Kg
11161	Hydrated Lime For Painting	10	Kg
12910	Weldable PVC Cap For Building Sewage DN 75 mm	1	Pcs.
20150	Knee PVC Serie R P/ Sewage Building 45 g DN 75 mm	3	Pcs.
20177	Te PVC Serie R P/ Sewage Building 75 X 75 mm	1	Pcs.
---	Nylon Screen for Filter Well Coating	0.5	m

Source: Adapted Cisterns Program, 2021

Table 8. shows the ingredients used in the manufacture of the manual pump and water quality protection devices.

SINAPI	Manual pump materials and protective devices	Quant.	Pcs.
9875	Weldable PVC Pipe Eb-892 P/Cold Water Building DN 50 mm	2.52	m
9868	Weldable PVC Pipe Eb-892 P/Cold Water Building DN 25 mm	3	m
9867	Weldable PVC Pipe Eb-892 P/Cold Water Building DN 20 mm	2.73	m
9869	Weldable PVC Pipe Eb-892 P/Cold Water Building DN 32 mm	0.4	m
1189	Weldable PVC Cap For Cold Water Building 32 Mm	1	un.
1191	Weldable PVC Cap For Cold Water Building 20 Mm	3	un.
1185	Weldable PVC Cap For Cold Water Building 25 Mm	2	un.
820	Bushing Reduction PVC Weldable Long W / Cold Water Building 50 mm X 32 mm	2	un.
829	Short Welded PVC Reduction Bushing W/ Building Cold Water 32 mm X 25 mm	1	un.
828	Short Welded PVC Reduction Bushing W/ Building Cold Water 25 mm X 20 mm	2	un.
3501	Weldable PVC Knee 45 g W/ Building Cold Water 32 Mm	1	un.
7098	Te PVC C/Rosca 90 g W/ Cold Water Building 1 /2"	1	un.
7130	Reduction PVC Soldable 90 g W / Cold Water Building 50 Mm X 32 Mm	1	un.
3860	Weldable PVC Glove / Cold Water Screw Building 32 mm X 1"	1	un.

Source: Adapted Cisterns Program, 2021

Finally, based on the type residence model, with the same construction pattern and average coverage area, a survey of materials needed to perform the collection system was elaborated

Table 9. Materials used in the preparation of the collection and conduction system

SINAPI	Trough materials up to 10 metres	Quant.	Pcs.
1108	American frame trough galvanized steel sheet in a 26, cut 33 cm	10	m
12626	Metal support for raingutter, zinc plated, folded, diameter between 119 and 170 mm, for building drainage	4	un.
12614	PVC nozzle, for rain gutter, outlet diameter between 80 and 100 mm, for building drainage	1	un.
12616	Headboard or left, pvc, for rain gutter, diameter between 119 and 170 mm, for building drainage	1	un.
38423	PVC curve , 90 degrees , R series , DN 100 mm, for sewage or rainwater	1	un.
9836	Pvc pipe normal series, dn 100 mm, for building sewage (NBR 5688)	5	m
117	Adhesive P/ PVC Bisnaga C/ 17 g	1	un.

Source: Author, 2021

4 RESULTS AND DISCUSSIONS

- Analysis of collected data

To make the correct analysis, it is necessary to initially understand the meaning of the results obtained after data processing.

Tables 10 and 12 represent the volumes available for consumption in the family units at Sítio Santa Rita and in the Serra das Cabaças Community, while tables 11 and 13 represent the theoretical volumes that could be obtained if the structures or unidades in question have capture and storage systems.

The amount of water available in the family tanks during one year - Reserved volumes (m^3) - is positivewhen the system can replenish the reserved volume, and there may be extravasation. However, negative values indicate that the catchment area is not able to promote the replenishment of the reserveriver.

The ratio between volume reserved for the volume consumed - Vreservado X Vconsumed - defines the maximum consumption that a family unit will have for one year, taking into account the volumes reserved to evaluate the annual water balance.

In this relationship, positive values are found in units where the reservoir can supply the demand of families and negative values are obtained when there is not enough volume for the supply, representing the maximum volume that should be acquired by the fam from other sources, be they pumping water from wells or supply by water tankers.

In the following table, the values obtained at the Santa Rita Site are presented, where it can be observed that in 35% of the homes the volume captured cannot reset the total volume of the cisterns and 76% of the units the volume annually is not able to meet the demand of residents, presenting a water deficit in the total volume of 100.82 m^3.

Table 10. Units of Sítio Santa Rita with rainwater use and storage system.

Identification	Reserved volumes (m^3)	Vreservado X Vconsumed
2.1	-9.80	-31.76
2.2	4.40	-10.24
2.3	38.00	38.00
2.4	-3.20	-36.14
2.5	-5.30	-5.30
2.6	7.40	-14.56
2.7	60.90	46.26
2.8	2.20	-12.44
2.9	-9.30	-34.92
2.10	21.10	-11.84
2.11	44.00	31.80
2.12	40.00	40.00
2.13	-2.70	-31.98
2.14	-6.80	-29.98
2.15	28.50	-33.72
2.16	14.80	-3.50
2.17	36.10	-0.50

Source: Author, 2021

As presented below, for the units in Sítio Santa Rita without use systems, it was observed that 62% of the buildings would have their volume captured not being able to re-reset the total volume of the cisterns, while in 69% of the units the annual reserved volume would not be able to meet the residents ' demand, but with a positive water balance of 65.34 m³.

Table 11. Units of Sítio Santa Rita without rainwater use and storage system.

Identification	Volume of possible reservation (m³)	Vreservado X Vconsumed
1.1	128.10	109.80
1.2	5.80	-10.20
1.3	6.90	6.90
1.4	5.50	5.50
1.5	37.80	30.48
1.6	29.10	14.46

Source: Author, 2021

Next, the values of the Serra das Cabaças Community are presented, where it can be observed that, due to the larger areas on the roof summation surfaces of the residences, all the volumes captured were able to reset the total volume of the cisterns, still presenting 28% of the units with the volume reserved annually not being able to meet the demand of residents, presenting a positive water balance of 96.92 m³.

Table 12. Units of the Serra das Cabaças Community with rainwater use and storage system.

Identification	Reserved volumes (m³)	Vreservado X Vconsumed
3.1	26.4	11.76
3.2	-6.3	-6.3
3.3	42.7	31.72
3.4	31.5	24.18
3.5	28.1	-1.18
3.6	12.3	-2.34
3.7	-1.2	-1.2
3.8	1.5	-29
3.9	-8.4	-8.4
3.10	1.9	-53
3.11	-8.7	-55.06
3.12	-1.3	-1.3
3.13	-3.8	-51.38
3.14	-7.1	-53.46
3.15	-14.2	-14.2
3.16	14.2	-11.42
3.17	6.7	-7.94
3.18	59.4	37.44

Source: Author, 2021

Finally, it is verified in the table below that in 32% of the buildings that do not have a system of use, their volume captured could not resum the total volume of the cisterns, while in 56% of the units the volume reserved annually would not be able to meet the demand of the residents, but with a positive water balance of 81.16 m³.

Table 13. Units of the Serra das Cabaças Community without a system for the use and storage of rainwater.

Identification	Volume of possible reservation (m³)	Vreservado X Vconsumed
4.1	44.3	44.3
4.2	26.2	18.88
4.3	-6.6	-6.6
4.4	14.8	-21.8
4.5	28.2	6.24
4.6	16.8	9.48
4.7	-6.3	-17.28
4.8	-11.6	-37.22
4.9	7.6	0.28
4.10	15.8	15.8
4.11	46	46
4.12	-4.5	-4.5
4.13	24.7	-4.58
4.14	18.4	0.1
4.15	11.5	-17.78
4.16	3.7	-18.26
4.17	-7.2	-18.18
4.18	-13.3	-13.3
4.19	-11.7	-11.7
4.20	125.1	106.8
4.21	19.4	-13.54
4.22	13.3	-1.34
4.23	43.3	28.66
4.24	-3.6	-10.92
4.25	12.6	1.62

Source: Author, 2021

It is worth remembering that, the volume considered is the volume of a standard family tank of 16,000 liters, all the values obtained took into account the reference volume, carrying the closer to 0 m³, the lower the amount of waste by extravasamento, to positive values, or incompetence of the replenishment or supply of family needs, in case of negative values.

Finally, summarized in the summary table below, the total values representing the lostvolums and those necessary for replenishment of the family units were grouped.

Table 14. Total volumes lost by extravasation and necessary for replacement of reservoirs and supply of the needs of families.

Location		Gourds Mountains	Santa Rita
Total volumes of capturing units	Lost by Extravasation	258.82	156.06
	Necessary for replenishment	-161.9	-256.88
Total target volumes of non-capturing units	Lost by Extravasation	278.16	126.04
	Necessary for replenishment	-197	-60.7
Balance of capturing units		**96.92**	**-100.82**
Balance of non-capturing units		**81.16**	**65.34**

Source: Author, 2021

It is noted that, in none of the regions studied, the volumes captured by the units where there is a system of use are able to meet the community's demand, but in the Serra das Cabaças Community, by adding more capture systems in the other buildings where there is no presenceof the system, the becomes positive, indicating that the simple expansion of the program with the sharing of resources by the community would make it self-sufficient, with a theoretical surplus of 178.08 m³.

However, the simple expansion of the program to the other units where it was not implemented would not solve the deficit of sítio Santa Rita, still requiring a volume around 35.48 m³, in this case being an additional amount isrequired , and may be the construction of a community cistern of the type of boardwalk, roofing or flood, ensuring the continuous supply of the community.

- Implementation costs

By placating the values obtained from the last Sinapi survey in the State of Paraíba, corresponding to the month of July 2021, it was possible to budget the system.

The value for implementing the system is composed of four constituent parts: The execution of the trough and conduits, water quality storage devices, the manual pump and the plate tank. In the table below were

Table 15. Summary table of the budget of a domestic rainwater collection and storage system with a reservoir of 16,000 liters.

Constituent step	Value (R$)
Device for water quality protection	312.7779
Manual Pump	179.0892
Trough up to 10 meters	541.98
16,000-liter plate cistern	2237.87
Total value	3271.717

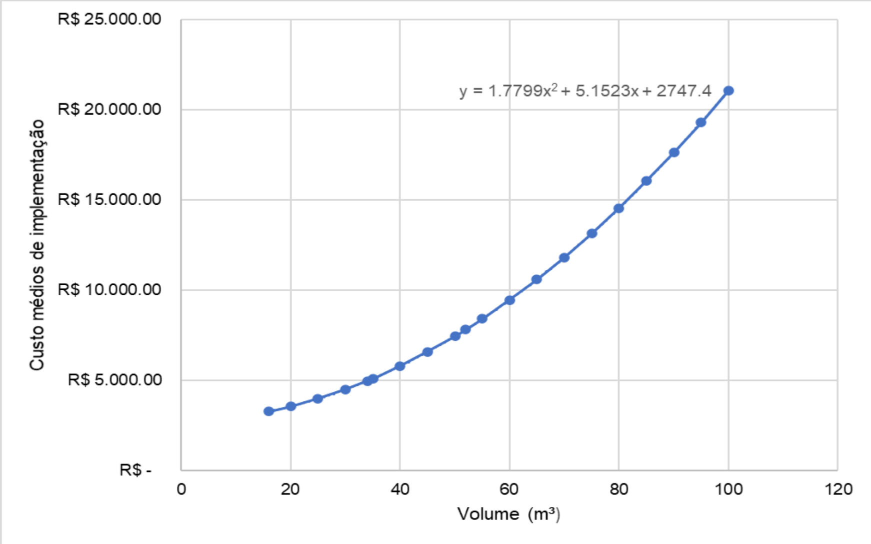
Source: Author, 2021

Similarly, a system composed of a plate cistern with capture using a boardwalk was budgeted, and execution is obtained at a cost of approximately R$ 7,789.55.

As a result, we sought to verify a correlation between the stored volume and the base cost of application of the systems to optimize the choice of the best alternatives of storage systems for each family unit.

For this, an average value was defined between the costs of implementing a system using a capture surface on a roof and on a boardwalk for reservoirs of 16, 52 and for the median volumes 34 and 35 thousand liters. Thus, it was verified that the values follow a pattern d andpolynomial growth, as can be observed in the following graph that correlates the volume in cubic meters and the average cost of execution.

Figure 8. Average cost graph of implementation by stored volume.



Source: Author, 2021

Based on the graph, it is evident that reservoirs with volumes greater than 52,000 liters would be exponentially more costly than the same volume divided into smaller reservoirs.

As an example, the cost of building two 52 mil liter systems would be around R$ 15,659.99, but the cost of a single reservoir of 104,000 liters may exceed R$ 22,533.04, i.e ., a value 30.5% higher.

In turn, tanks of 16,000 liters are not the most suitable for large volumes of reserve. Its construction is the most costly when compared to its reserve volume. To exemplify, the same volume stored in the previous example, if divided between cisterns of 16 m³, would result in a cost of approximately R$ 23,020.95.

Orthe highlight point is the initial value of the curve being R $ 2.747,40. This value corresponds to the basal elements for the construction of any collection and reservation system, so it is the minimum value for the construction of a new system composed of coleta and cistern of concrete plates, regardless of volume, and the maximum value for revitalization of any other pre-existing, including reforms, improvements and adjustments.

5 CONCLUSION

Studies aimed at improving the quality of life of the inhabitants are essential for the economic, environmental and social development of populations.

Through this, it was found that the expansion of social programs for the dissemination of collection technologies, improvement of quality and storage of water and water can be an applicable solution for combating drought, provided that these are well sized and implemented, taking into account the specificities of each family unit.

Buildings not incorporated into the programs, such as corrals, barns and buildings attached to the residences can be of fundamental importance for the expansion of water supply to resident families, as well as the correct distribution of gutters throughout the lower perimeter of the waters roofs, avoiding waste.

It has also become noticeable that the standardization of 16,000-liter plate cisterns in family units is not all beneficial, because it generates waste resources in buildings with a larger roof area, in addition to loss of quality and cost generation extras for refueling through water trucks, in this case, the sizing of the cistern by the methods described in ABNT NBR 15527/2007 would make the reservoir more efficient, thus avoiding waste or refueling difficulties.

Given the discrepancy between the volumes stored by each of the units and the verification that although many cannot replenish their reservoirs, i.e. undersized systems, the study areas usually apres there is a positive water balance, where there is more water being extracted than the annual needs of residents, so a logical solution for increasing the availability of resources would be the construction of community cisterns, using the pris-existing structures not contemplated by water access programs or new structures of simple technology, such as boardwalk cisterns, roofing and flood , correctly sized to contemplate all its users.

Different solutions can be applied to increase the water supply of reservoirs in family units. Through the calculations and simulations developed, problems and practical solutions were elaborated for them, listed in the table abstract to follow.

Table 16. Summary table of possible solutions to different problem situations for undersized reservation systems.

Situation	Solution
Family units with very undersized reservation systems that retain less water than their maximum capacity	Expansion of the catchment area or the construction of a second capture system using an attached roof
Family units with very undersized reservation systems that do not meet family demand	Expansion of the catchment area or the construction of a second capture and reservation system using an attached roof, roofing or a boardwalk
Family units with undersized reservation systems with the presence of extravasation	Expansion of the reserved volume with the acquisition of rotomolded plastic tanks installed in series on the conductive tube or the construction of a second reservoir in series after the extravasor

Source: Author, 2021

The use of technologies to improve the quality of life of the inhabitants should guide the development of research and extension work, and the application of the best engineering solutions ensures this improvement and access to resources essential for human and regional development.

REFERENCES

- ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). ABNT NBR 15527:2007. Água de chuva - Aproveitamento de coberturas em áreas urbanas para fins não potáveis, Rio de Janeiro, 24 set. 2007. Disponível em: http://licenciadorambiental.com.br/wp- content/uploads/2015/01/NBR-15.527-Aproveitamento-%C3%A1gua-da-chuva.pdf. Acesso em: 28 jun. 2020.

- BRASIL. Portal Brasil. Ministério da Integração Nacional (Ed.). Água para todos garante abastecimento a 5 milhões no semiárido, 2015. Disponível em: <http://www.brasil.gov.br/noticias/infraestrutura/2015/04/agua-para-todos-garante- abastecimento-a-5-milhoes-no-semiarido-1>. Acesso em 27 de junho de 2020.

- IBGE (Instituto Brasileiro de Geografia e Estatísticas). Censo Populacional 2010 . Disponível em: < https://censo2010.ibge.gov.br/sinopse/webservice/frm_hom_mul.php?codigo=251210>. Acesso em: 02 jan. 2021

- LIMA, J. R.; MAGALHÃES, A. R. Secas no Nordeste: registros históricos das catástrofes econômicas e humanas do século 16 ao século 21. Brasília, 2018. Disponível em: http://seer.cgee.org.br/index.php/parcerias_estrategicas/article/viewFile/896/814. Acesso em: 19 jun. 2020.

- ONU, Organização das Nações Unidas. Até 2030 planeta pode enfrentar déficit de água de até 40%, alerta relatório da ONU. 2015. Disponível em: <https://nacoesunidas.org/ate-2030- planeta-pode-enfrentar-deficit-de-agua-de-ate-40-alerta-relatorio-da-onu/>. Acesso em: 02 jan. 2021

- PENA, Rodolfo Alves. Escassez de água no Brasil. [S. l.]: Brasil Escola, 2015. Disponível em: https://brasilescola.uol.com.br/geografia/escassez-agua-no-brasil.htm. Acesso em: 28 jun. 2020.

- PLANTIER, Renato Duarte. Programa Água para Todos: Características Gerais. São Paulo, 2014. Disponível em: http://meioambiente.culturamix.com/gestao- ambiental/programa-agua-para-todos-caracteristicas-gerais. Acesso em 27 de junho de 2020.