Chapter 277

Proposal for water treatment to promote access to safe supply in a small community

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ABSTRACT

Universal access to water is already recognized as a human right, but your fulfillment is still a challenge in some regions of Brazil. In regions further away from urban centers, access to a water supply system is non-existent or ineffective. The population of these regions is forced to quest for alternative supplies to achieve quality home access. The residential condominium Solar de Maricá I, in the municipality of Maricá, has a water supply from individual wells, but it does not serve all the residents. This work presents a project for sizing the water supply system, in addition to a proposal for the reuse of gray waters as an alternative to preserving water resources. To do that a previous study was carried out to improve knowledge about the local reality in terms of access to water through visits to nearby condominiums with surveys on the technology used for treatment and quality of available water. Furthermore, water collections were carried out in the study condominium to establish the adequacy of the proposed system with the water quality of the place. The water purifying station operates for 16 hours daily, serving a projected population of 30 years, and consists of 2 filters in parallel with zeolite and sand as filter media, disinfection with sodium hydrochloride, two reservoirs of treated water, and a chemical house. The reuse water treatment is composed of a bio-disc reactor, equalization tank, decantation tank, accumulation tank, pressure sand filter, and disinfection system and presents itself as an effective alternative in reducing water consumption, thus preserving the resource local water resources.

Keywords: Water treatment, Groundwater, Local supply, Reuse.

1 INTRODUCTION

Three out of ten people in the world do not have access to safe drinking water. The first global assessment of safely managed drinking water and sanitation services concludes that especially in areas far from urban centers, the population needs these basic services (UNICEF, 2017).

In addition to quantity, the quality of water consumed is also a factor of extreme importance to the health of the population. Outside the parameters of adequacy for human consumption (intake, food production, and personal hygiene), determined by the World Health Organization (WHO), water can transmit numerous infectious diseases in the short, medium, and long term (PAHO, 2001).

As a result of the recognition of the human right to water, Goal 6 of sustainable development, elaborated in 2015 by the United Nations Summit for Sustainable Development, contemplates the search for the availability and sustainable management of water and sanitation for all people. Improving the quality of water, the efficiency of its use, and being able to supply communities scarce with this resource are among the items to be achieved by the countries that have signed the action plan, with a total of 17 goals, by the year 2030 (UN, 2015).

However, among Brazilian households, only 66% have a connection to the sewage network, and the rest have pits not connected to the network or another form of sewage (IBGE, 2017b).

Aiming at the sustainability of the system, the alternative of reusing gray water, from washing and bathing, enters as a solution to combat scarcity, since the availability of the resource depends directly on the daily activities of man (Gonçalves, 2006).

According to data from the State Water and Sewage Company (CEDAE), only 28.8% of the population of the Municipality of Maricá was supplied by the drinking water distribution network in 2017 (IBGE, 2017a; CEDAE, 2017). This service gap generates the need to use alternatives to obtain drinking water.

The Solar de Maricá I condominium, located in the Municipality of Maricá, provides access to water from individual wells to 93% of its households, however, some households do not have any preliminary treatment for consumption. Locals still have caveats about the smell of water at certain times of the year.

In this scenario, the installation of a small treatment plant is beneficial to residents in general, since everyone would be guaranteed the supply of safe water. Therefore, the objective of this work is to carry out a previous study that provides technical subsidies for planning and decision-making regarding the adequacy of the system with the quality of the water available to residents, dimensioning a small treatment plant to meet the supply of the condominium, also presenting an alternative to reduce consumption through the reuse of gray water.

The final intention of the implementation of the project is to ensure the human right to quality water for the residents of the condominium. Among the points covered in such a guarantee are piped water supplied to the dwellings, uninterrupted water supply, quantity greater than the minimum necessary for their basic needs, and water quality according to potability standards (Heller; Padua, 2010, p. 72).

2 METHODOLOGY

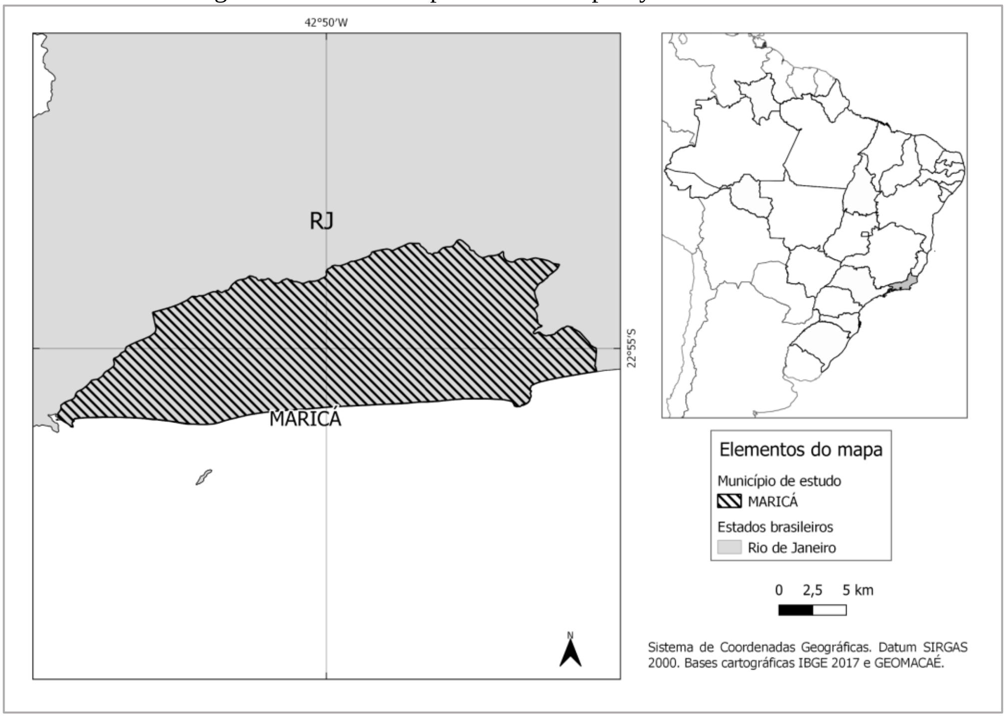
2.1 RECOGNITION OF THE AREA OF STUDY

The Solar de Maricá I condominium is located in the neighborhood of São José do Imbassaí, a district of the city of Maricá, near the main lagoon and is subdivided into 3 locations. Founded in 1992, it comprises 191 lots, of which 171 are occupied, with some of the houses spanning more than one lot and others still under construction. After the zoning of the city, the condominium was classified as an urban area and single-family residential zone 2 (ZR2u) (Maricá, 1998b).

The municipality of Maricá is part of the metropolitan region of the State of Rio de Janeiro (Figure 1) and has a hot and humid climate, with a maximum temperature of 37 and a minimum of 18 °C (Pereira, 2005). The mountainous topography provides precipitation due to increased air turbulence (MMA, 2006), leading to an annual volume of rainfall of about 1,200 mm, with a season of greater precipitation during the summer (SNIRH, 2006).

In 2007 the Complementary Law No. 157 was sanctioned, which classifies the municipality into urban, rural, and urban expansion areas and their subdivisions (Maricá, 2007).

Figure 1: Location map of the municipality of Maricá- RJ.



2.2 PRELIMINARY STUDY OF THE SIZING AND SURVEY OF DATA IN THE FIELD

To improve knowledge about the local reality in the context of access to water supply, visits are made to nearby condominiums to survey the technology used for treatment and its results.

The visits were carried out in condominiums in the same study region, which are not served by CEDAE's water supply network and which have some local alternative solutions. The aspects consulted included: demand, treatment, and level of urbanization, among others.

Among the interviews conducted, those responsible for the condominiums and for the measurements of chlorine and pH at the exit of the treatment were contacted.

To know the quality of the water that reaches the residents of the Solar de Maricá I condominium, samples were collected in 3 wells of its domain. For the collection, sterile bags with wire closures were used for sampling and the collection occurred about 4 hours before the samples were delivered to the laboratory. The procedure adopted was to turn on the pump and open the tap or register, letting the water from the good drain for 2 minutes, and after that time fill the container to the mark of 100 ml and submitted to microbiological and physicochemical analysis.

The analyses were performed by the Miguelote Viana State Laboratory, located in the Vital Brasil neighborhood, in Niterói. The methodologies followed were, respectively, of the enzymatic substrate with Aquateste Coli kit and photometric system in the Spectroquant Nova 60 apparatus.

In addition, in collaboration with the Laboratory of Environmental and Mineral Analysis of the Federal University of Rio de Janeiro, the concentrations of Iron (Fe), manganese (Mn), and the conductivity of the samples were obtained. The conduct meter used is PinPoint American Marine Inc.com range of action up to 2000μS. To obtain the concentration of Iron and Manganese, the method adopted was atomic absorption in a compact spectrometer of atomic absorption, the contraAA® 300 - Analytik Jena.

The classification of the samples, according to the definition by CONAMA (Brasil, 2005), was calculated through the relation of conductivity and salinity given by Tchobanoglous, Burton, and Stensel (1991). The methodology classifies the samples into fresh water (salinity equal to or less than 0.5‰), brackish water (salinity greater than 0.5‰ and less than 30‰), and saline water (salinity greater than 30‰).

2.3 CONSIDERATIONS FOR SIZING

From the research of theoretical reference on water treatment and the data of the analyzes carried out, the calculations for correction of concentration of the elements outside the organoleptic standard were defined.

The dependencies of the common areas of the condominium that also use water were included, as well as a concierge with a kitchen and bathroom for the employees. For the place of disposition of the supply system, two large common areas were considered. The first common area features tall vegetation for most of its length and contains some children's toys and a soccer field. The other is on high ground about the rest of the condominium, largely wooded and with a trimmed lawn.

Currently, about 500 people are living in the condominium, including summer residents. The discrepancy between the residences stands out in the place, some with size and grandiose structures, while others are simple and smaller.

From IBGE data (2017b), it was possible to make population projections using as a basis a method of indirect quantification of ratio and correlation, in which it is assumed that the population of the place of study presents the same behavior as the physical or political region in which it is located (Heller; Padua, 2010).

The methods chosen for the projection were the geometric growth method because it is a population of fewer than 20,000 inhabitants, and the method of decreasing growth rate, because this has as its premise a future saturation of the population, that is, as the population grows, its growth rate decreases.

The average *per capita* consumption of water in the municipality of Maricá in 2016 and the one considered in the dimensioning was 129.5 l/inhab./day (Cidades, 2016).

In this project, we opted for the upstream reservoir, which allows the storage of treated water and its distribution efficiently. For the calculation of the necessary capacity of the reservoir, the treated flow is considered directed to the reserve and the operating time of the station.

3 RESULTS AND DISCUSSION

3.1 RECOGNITION OF THE AREA OF STUDY

In the stage of recognition of the study area, it was to know the reality of the region in the scope of the supply and access of the local population to water. Muehe and Valentini (1998) include the municipality in the region of the lakes of the state of Rio de Janeiro, a region socioeconomically focused on tourism and summer that has grown in recent years with the production of the Pre-Salt and the receipt of *royalties* (Pizzol; Ferraz, 2017). This growth is evidenced by the increase of 47.1% in the municipal human development index of Maricá between the years 1991 and 2010 with the city reaching the number 6 position in the state with an index of 0.765 (IBGE, 2010).

With a value of 1,021.70 m³/inhabitants per year, the availability of water resources in this section of the Southeast Atlantic is in a state of stress (MMA, 2006), a situation consistent with the forecasts of the National Water Agency (2006) due to the high population density of the region and the health problems encountered.

The distribution of water and sanitary sewage in the municipality is the responsibility of CEDAE. Although 98.54% of households are on urbanized roads (IBGE, 2017a), only 1% of the population is served by the sewage network (ANA, 2013), with some condominiums in the region having their sewage treatment plants. The municipality determines that "every building, in places without a sewage collection network, will have a septic tank, built according to technical standards that ensure its good performance" (Maricá, 1990, Art. 249, p.52).

However, the condominium is not integrated into the sewage network of the concessionaire and does not have a unified treatment system, like some other condominiums in the region. Therefore, as determined by the Municipal Organic Law (Maricá, 1990), all residences have a septic tank with a biological filter.

Together, there is no water supply through the CEDAE network in the region, and it is the responsibility of each resident to provide water. All residents buy gallons of drinking water for consumption and food handling. For hygiene and maintenance activities. Of the occupied lots, 93% of residents have opted for drilling individual wells, while only 7% are supplied by water trucks.

3.2 DATA COLLECTION IN THE FIELD

In the field stage, the interviews indicated the problems regarding the quality of the water to which the residents of the condominium have access. The most reported by all interviewees was the high concentration of iron and manganese. With this step together with the research carried out in the condominiums on the margins of the study site, it was possible to identify the characteristics of management and maintenance of the respective supply systems (Table 1).

Table 1: Parameters of the stations of the condominiums visited

Unit visited	Type of treatment	Number of wells	Supply flow (1000) (L/day)	Number of employees	Station cost (1000) (R$)
Elisa	FAA, CL, AE, and DC	6	456	3	NU
Bosque de Itapeba	FZ, AR and CL	5	250	1	227
Beverly Hills	FZ and CL	2	10	*	121,6

Legend: Ascending filters of sand (FAA), chlorination (CL), aeration (AE), and decantation (DC), Filter with zeolite (FZ), softening with resin (AR). Unreported data (NI). Provision of service by the outsourced company (*).

Subsequently, the water samples that were collected and sent to the laboratory for analysis of their quality presented results such as the one presented in Table 2.

Table 2: Results of sample analysis

Parameters	Sample 1	Sample 2	Sample 3
Total coliforms	absent	absent	Presents
Escherichia coli	absent	absent	The user
Aspect	clear	clear	Impious L
Color (uH)	2	8	16
The residual chlorine (mg/L)	0,05	0,07	0,08
ph	8,5	8	8
Fe (mg/L)	0,16	0,026	0,069
Mn (mg/L)	0,81	0,66	0,32
Conductivity (µS/cm)	946	650	557

Sample 1: gatehouse well, depth of 15 meters; sample 2: residential deep well, depth of 98 meters; Sample 3: Residential shallow well, depth of 5.5 meters. Data from the Miguelote Viana Laboratory and the Environmental and Mineral Analysis Laboratory.

The classification of the samples according to salinity, as defined by CONAMA (Brasil, 2005), through the relation of conductivity and salinity given by Tchobanoglous, Burton, and Stensel (1991) is shown in Table 3.

Table 3: Classification of samples according to salinity

	Sample 1	Sample 2	Sample 3
Salinity (mg/L)	605,44	416	356,48
Classification	Brackish	sweet	sweet

Sample 1: gatehouse well, depth of 15 meters; sample 2: residential deep well, depth of 98 meters; Sample 3: Residential shallow well, depth of 5.5 meters. Data from the Miguelote Viana Laboratory and the Environmental and Mineral Analysis Laboratory (2018).

From the information on water quality available in the condominium and the treatment alternatives studied, the decision model was elaborated, contained in Table 4 are the parameters analyzed for the choice of filtration methodology. The decision-making parameters for the disinfection methodology are shown in Table 5.

Table 4: Decision model based on Filtration parameters for the type of system to be adopted in the dimensioning.

Parameters	Filtration				
Alternatives	Slow filtration	Activated carbon	Zeolites	Membrane	Ion Exchange Resin
Area	Big	Average	Average	Average	Average
Water quality	Not applicable	Not applicable	Reasonable	Exceptional	Exceptional
Allows regeneration of the filter media	No	Yes	Yes	Yes	Yes
The durability of the filter medium (months)	*	*	72	18	18 to 24
Cost of operation	*	*	Medium	Low	Medium
Degree of difficulty of the operation	Low	Low	Low	Low	Low
Implementation cost (x1000) (R$)	640	*	65	250	69

Data not informed (*).

Table 5: Decision-making model based on Disinfection parameters for the type of system to be adopted in the dimensioning.

Parameters	Disinfection		
Alternatives	Hypochlorite	Chlorine lozenge	UV
Area	Small	Small	Small
Water quality	Great	Great	Great
Degree of difficulty of the operation	Low	Low	Low
Cost of operation	Low	Low	Low
Implementation cost (x1000) (R$)	5	4	12

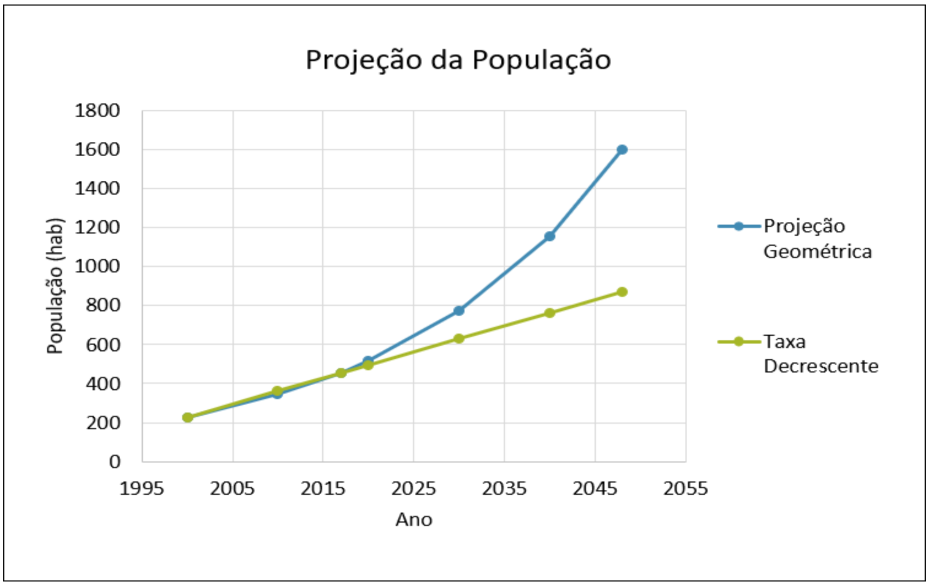
3.3 CONSIDERATIONS FOR THE SIZING OF THE WATER SUPPLY SYSTEM

The project to be developed deals with an alternative solution to water supply for human consumption (Ordinance MS no. 518/2004). Its definition explains that it is a collective modality that includes as a source of water, among others, community wells and also covers horizontal condominium facilities (Brasil, 2005).

In the sizing stage, the slope of the condominium land was considered. The location indicated for the location of the system is in the highest part, protecting it from possible flooding and favoring the pressure of the distribution network.

Using the method of least squares, which estimates which procedure is closer to the curve of the Census, resulted in the method of the Decreasing Rate being found as the best prediction. However, once the condominium has a consolidated water supply system and Maricá has been among the five cities that generated the most jobs in the last 12 months (CAGED, 2018), it is expected that the attractiveness of the condominium and municipality will grow. For these reasons, we chose to use the largest number of inhabitants, found by the Geometric Projection method (Figure 1).

Figure 1: Graph with projections of the population of the condominium



From the initial considerations, the methodologies for the sizing calculations were selected, as shown in Table 5.

Table 5: Considerations and methodologies are chosen for the design of the water supply system.

Considerations for sizing	Methodology	Findings	Unit
Current population estimate	Stipulation by households (IBGE, 2017b).	456	Hab.
Population projection (30 years)	Geometric Growth and Decreasing Rate (Heller and Padua, 2010)	1602 and 807	Hab.
Daily water consumption	The average *per capita consumption of 129.5 Lhab./day (CIDADES, 2016).*	2,40	L/s
Coefficient of maximum daily flow	(ABNT, 1986)	1,2	
Operating period (n)	(Heller and Padua, 2010).	16	h/day
Consumption in ETA	(Heller and Padua, 2010).	2,00	%
Capture flow rate (Q1)	(Tsutiya, 2006)	4,41	L/s
The flow of treated water destined for the reserve (Q2)	Q1-consumption in ETA	4,32	L/s
Adduction pipe diameters	ForchHeimer-Bresse formula (NBR 5626)	0,078	m
Reserve volume (Vres)		248,83	m³
Lower reservoir volume (VRI)	NBR 5626	167	m³
Upper reservoir volume (VRS)		83	m³

The adduction is composed of two sections: adduction of the catchment to the ETA and adduction of the ETA to the reserve. The first stretch is equivalent to the flow of raw water captured, Q1. The stretch to the reservation excludes the demand reserved for the consumption of the station itself. It is then calculated by the equation.

Commercially, for PVC pipe, the diameter found that meets the calculated value is 85 mm in diameter, with a gauge of 3", meeting a suction flow of up to 32 m³/h (Pool Shop, 2013).

It is chosen, therefore, for sufficient storage to meet 250 m³. It is indicated that reservoirs with a capacity greater than 1 m³, such should be compartmentalized so that there is no interruption of distribution during a cleaning operation. The recommended division is between upper and lower reservoirs, the first with 40% of the total volume and the second with the remaining 60%. For storage greater than the daily consumption, this surplus must be stored in the lower reservoir.

The commercial reservoirs selected by the company Stock Caixas ([n.d.]) were the CTU 881, with a capacity of 88,000 l a diameter of 2.50 m, and a height of 18.00 m, with a cost of R$ 61,300.00, and the CTU 1801, with a capacity of 180,000 l with a diameter of 3.50 m and a height of 18.80 m, with a cost of R$ 101,424.00. Its material is carbon steel, which provides high mechanical resistance and exposure to weather conditions, including ultraviolet rays, being 100% non-toxic and hygienic.

3.4 ZEOLITE FILTER SIZING

Due to the contamination characteristics of the water collected in the wells of the condominium, the type of zeolite 'ZF' is indicated for the removal of iron and manganese. Zeolites should be used at a pH higher than 6,5 (EPEX, [n.d.]), a value consistent with the water analyzed.

Commercial filters are sold according to the flow rate to be treated, in liters per hour. For the case of this work, the flow rate is 15 876 L/h. As a precautionary measure for possible failures, it is suggested the use of a parallel system of two or three filters (ABNT, 1992b). Table 6 contains some of the business models that are appropriate for the project.

Table 6: Commercial Filter Templates

Enterprise	Flow (L/h)	Model	Quantity	Price (R$)	Reference
MEKA	9.000	MAPI-24	2	5.450	MEKA, [n.d.]a
MEKA	6.000	MAPI-20	3	4.400	MEKA, [n.d.]b
SNATURAL	9.000	SN-AC 60	2	*	SNATURAL ([n.d.])
EPEX	10.000	F10000	2	*	EPEX ([n.d.])

Data not informed (*). Values related to orphans made by companies.

Some of the suppliers did not provide values, equipment dimensions or required filter media load. In all models presented, the use of a lower layer of sand is indicated. The use of two 9,000 L filters in parallel is preferable in this case, as it reduces the maintenance and operation costs of the station.

According to EPEX ([n.d.]), for a flow of 9,000 L/h 216 kg of sand and 405 kg of zeolites are required. Backwashing should be done daily, to maintain quality standards, with an average time of 5 minutes (SNATURAL, [n.d.]) and bed expansion of 20 to 30% (ABNT, 1992a). Regeneration of the medium is required every 7 days. The washing water can be reused and must be kept in a separate reservoir from the treated one.

3.5 SIZING OF TOOLS FOR DISINFECTION

For the sizing of the product for the disinfection of treated water, regardless of the sizing method chosen, it is necessary to know the dose applied, the residual disinfectant, and the exposure time. As the models are equations of experimental phenomena, any variation of the test conditions is sufficient to make it impossible to be safe to use them. Models are then used for sizing, but one must pay attention to the loss of efficiency and the limitations of this, increasing dose and contact time to enable an adjustment to the real conditions, which also vary with time (Daniel, 2001).

It is important to consider PRC n° 5 (Brasil, 2017), which indicates 0.5 mg/L of free residual chlorine at the treatment exit and maintenance of at least 0.2 mg/L at any point in the distribution network.

According to NBR 12216 (ABNT, 1992a), "the consumption of chlorine required for water disinfection is estimated at 5 mg/l, with a minimum of 1 mg/L." Considering the volume of 254 016 L daily to be treated, the amount of chlorine required is 1,270.08 g. Using sodium hypochlorite of 12% concentration with a specific mass of 1.2 kg/L, 144 g of active chlorine per liter of hypochlorite solution is obtained. The daily amount of solution required is therefore 9 liters.

As chlorination should be performed at pH below 8.0, if a higher value is charged in the test after the water passes through the filter, a correction should be made to adjust the value. The minimum contact time indicated is 30 min.

3.6 PROPOSAL FOR REUSE OF GRAY WATER

Simultaneously, to the sizing of the water treatment and supply system, this project aims at a proposal for the reuse of gray water. According to Santos (2002), a gray water reuse system is constituted by a wastewater collection subsystem, a water conduction subsystem, which can be composed of extensions, fall pipes and conductors, a treatment unit with operations such as grating, decantation, filtration and disinfection, an accumulation reservoir and also, if necessary, a remediation system, an upper reservoir, and a distribution network.

In his work, May (2009) proposes an aerobic biological treatment, using a biological contact reactor, popularly known as a biodisk, along with an equalization tank, settling reservoir, accumulation tank, pressure sand filter and disinfection system.

Waters from 3 collection points were taken to the equalization reservoir, where an agitator had the role of preventing the sedimentation of possibly present solids. The degradation of organic matter occurred in the biodisk, fed with a flow rate of 500 L/day. Pre-treatment storage was a maximum of 24 hours. After the sedimentation of the sludge in the decanter, the water went to the fast downflow pressure filter, with a filter medium composed of sand. Without the addition of coagulants, the last step consisted of disinfection with the addition of sodium hypochlorite. About 54g of biomass was generated for every 500 l treated.

It was possible to observe that all the parameters analyzed fit the requirements of at least one of the sources, according to May (2009). Thus attesting to the functionality of the suggested treatment. Based on this functional example, it is suggested that the gray water treatment planning for use in a residence follow the operations listed in the bibliography, adapting to the desired water volume.

As a way of comparing the effectiveness of the proposed treatment, we used the parameters presented by SindusCon (2005), which presents characteristics required for post-treatment verification.

It is recommended a study of the implementation of a biodigester for biogas production from the use of the sludge produced in the gray water reuse process. According to Lima (2015), biogas is a gaseous mixture product of anaerobic digestion of sewage sludge, domestic organic waste, animal waste, agricultural waste and others. It can be used as fuel after purification, its burning does not produce toxic gases and generates biofertilizer as a substrate. The possibility of reusing waste produced by the residents of the condominium, with the sludge produced in the biodisc of the gray water treatment, brings a great environmental benefit.

4 CONCLUSIONS

From the physicochemical and microbiological analyses carried out and comparing them with the standard of portability, the appropriate treatments were defined to ensure the quality of the water for supply. For the case study, the correction of manganese concentration and chlorination is necessary to adjust the amount of residual chlorine. With the data collected, the most appropriate treatment system for the quality of the water available to the residents was chosen. It was taken into consideration for the selection of the alternative objectification of community management of easy operation, not requiring a specialized technician for operation and maintenance. The chosen ones were filters with zeolite as filter medium and disinfection by sodium hypochlorite solution, the sizing of the system

For the sizing of the system, we used the project population of 30 years, through methodologies that best suited the local growth. The sizing stages followed the technical range of building installations and the cost of the equipment used for water treatment was budgeted. Thus, the sizing project proved to be more faithful to the reality of the condominium, thus affecting the possible implementation of the project. The results were presented to fit the qualitative parameters presented in the literature.

As a solution to reduce the demand for drinking water, the reuse of gray water harvested in a residence was proposed. Its implementation will require analysis of these wastewaters to adjust the parameters of the treatment system. According to the presented, the proposal would be efficient to reduce water consumption in the condominium. The implementation of the project presents itself as an effective alternative for the sustainable use of local water resources.

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