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Full Length Research Paper

Rondon project: Addressing water issues in socio-economically disadvantaged communities in Brazil

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The northeastern region of Brazil has embattled a severe drought for centuries making it almost impossible to supply the local communities with adequate drinking water. As part of their outreach program the university of Zumbi dos Palmares was contracted by the Ministry of Defense to provide the necessary technical expertise to build a water cistern in the town of Maranhao. One of the project requirements was that the cistern has to be built with minimal inputs so as to allow duplication in limited resource communities throughout the country. The aim of this paper is to describe the socio-economic aspect of this construction project. The entire project was conceived around the framework of sustainability which includes not only the methods and procedures used but also economic responsibilities and guidelines for the cistern long term care and maintenance. The "projeto Rondon" has proven to be a viable alternative in sync with the built-in environment.

Key words: Water resources, water availability, rainwater storage, low cost cisterns, and sustainability.

INTRODUCTION

Historically, the northeastern region of Brazil has had difficulty supplying water to its population. This has been a challenging problem in the hinterland, which is an area known for its droughts. The constant lack of water is frequently debated in a political, social and economic sphere. Despite the fact the weather conditions cause a lack of water; the volume of the surface water is small, which does not convey confidence. The alternative method of using tankers has a high financial cost associated with it. There is also evidence that the underground water is highly brackish. The use of such a mechanism would require a considerable investment to become feasible. The search for sustainable alternatives can help improve the situation of water supply, use and reuse of water, community involvement, and can contribute to the welfare of the population. A plausible alternative would be the capture and storage of rainwater. The rainwater tanks are of vital importance to capture and store water which can supply household consumption, or be used for irrigation of crops and plantations. However, the high costs involved, not to mention counterproductive geographical conditions, require tremendous investment to find technological solutions which are financially viable and adequate for the local economy, without harming the environment. As part of their outreach activities, the Faculdade Zumbi dos Palmares was offered the opportunity to conduct a project called "projeto Rondon." This project was financed by the Federal Government and coordinated by the Ministry of Defense. The aim of this activity was to build a water cistern which would provide employment and teach local construction methodology, which will enable the transfer of technology. This paper aims to describe the construction of a low cost cistern in the state of Maranhão (Anajatuba city) in Figure 1 with an eco-socioeconomic perspective. The geographical region in which the city is located has a semiarid climate with a specific period of rainfall. There is a six month period of high precipitation, a six month period of low rainfall. During those months, there are also long intervals of droughts.

According to INPE (Special Research National Institute) the precipitations volume in the region where the city is located ranges from 1,200 to 2,000 mm per

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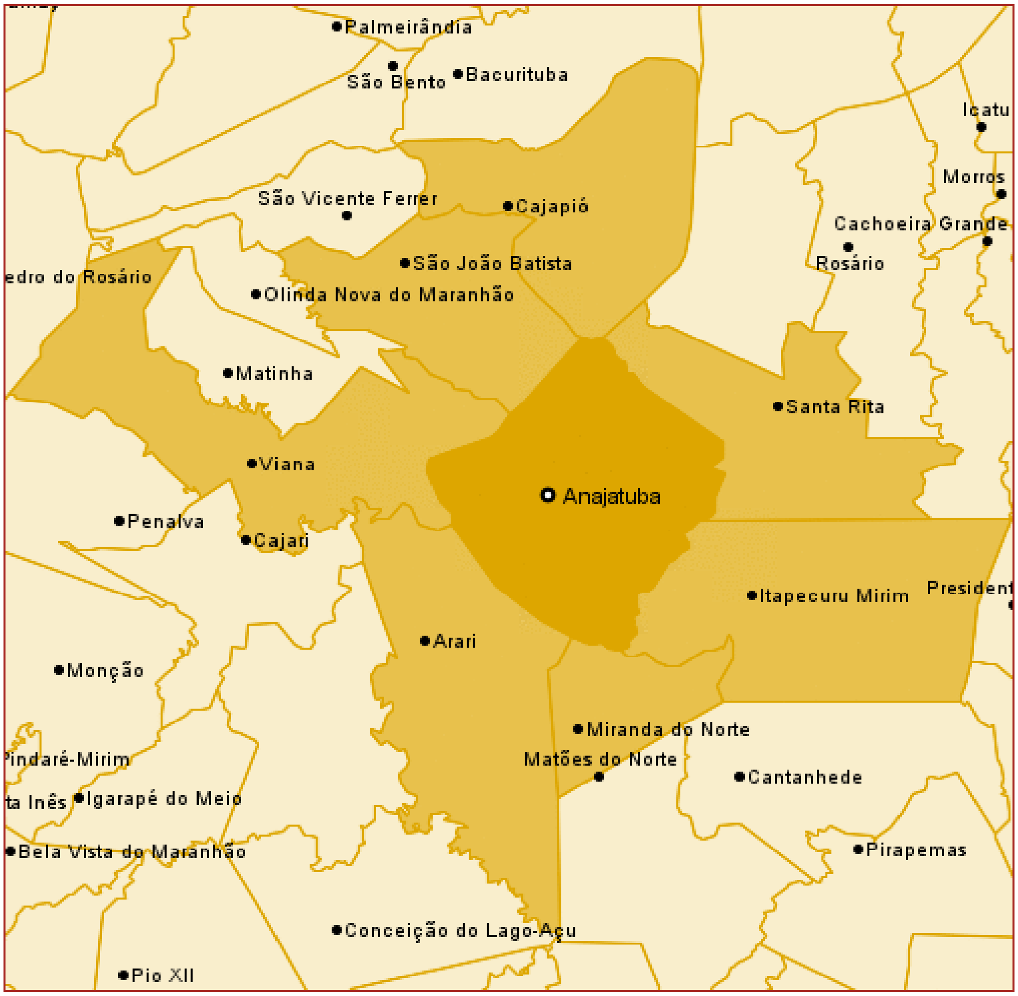

Figure 1. Maranhão (Anajatuba city).

year (CPTEC, 2010). These weather conditions often affect water supply in the region, which is negatively impacted by the high rate of brackish water for almost the entire geographical area of the city. The pumps, which distribute water from the reservoir to the city, suffer damages from constant electrical power outages. These pumps frequently have to undergo corrective maintenance, which causes disruption in the water supply. Given these circumstances it was necessary to find alternate ways to keep the water supply constant and to minimize the conditions limiting domestic consumption. The construction of low cost cisterns is presented here as a viable and feasible alternative, as long as the socio economic situation of the city is taken into account. Although this construction project does not provide a guarantee of full supply, this technology can become an excellent strategy to avoid constant shortages. The project aim is to contribute to the improvement of the city's water supply by capturing rainwater through the construction of low cost cisterns and transfer this employment enabling technology to other communities. This paper will present a brief biographical review of subjects such as: 'sustainability' and 'eco-socioeconomy', a succinct presentation of 'projeto Rondon', a thorough description of the methodology used, as well as the theoretical framework in which it was based, and finally the results and discussion.

Sustainability

According to the World Bank (1992), the concept of sustainable development emerged in 1987 from the World Commission on Environment and Development, indicating that all today's human beings demands must be met, however, these conditions must preserve future generations. The concern for sustainable development represents also the possibility to guarantee socio-political changes that will not undermine ecological and social systems that sustain communities (Jacobi, 2003: 192). In addition, the concept of sustainability includes the combat of the misuse of available resources in our environment and the creation of mechanisms to avoid predation and degradation of planet Earth. This includes alternatives that take into account the preservation of human lives and natural resources. Nevertheless, sustainability is not a one dimensional concept; besides the environment it also includes economic, social, and cultural/educational dimensions. Environmental sustainability deals with nature preservations and rational use of natural resources. Economic sustainability refers to the preservation of resources such as the control of public spending and inflation, so as not to leave the bill to be paid by future generations. Social sustainability refers to human rights aspects, security, justice, equality, inclusion, and population diversity. Finally, "cultural and educational dimension" is concerned with creating conditions to train future generations, ensuring structures are eligible to transmit values, knowledge, and preparing them to act responsibly (Rede Nacional De Consumo Responsável).

In order to foster and guarantee sustainability, Constanza (1991) suggested the formation of auditors with ecological function of supervising public or private companies, and activities which could cause negative environmental impact. In addition, he further recommends that the World Bank be an agent of sustainability encouragement, adopting policies to grant credit that requires environment counterparts in the projects submitted for assessment, considering criteria such as the use of renewable resources, and waste generation. The author also recommends that governments should level fees for activities that do not comply with sustainability concepts and incentives for those who adhere to it.

Figure 2. Economy of materials phases.

Eco-socioeconomy

According to Constanza (1991) eco-socioeconomy is an interdisciplinary research area which studies the relationship between ecosystems and economic systems and is concerned with the development of management strategies, participatory, communitarian, and regional activities that take into account social responsibility and environmental preservation. Eco-socioeconomy emerges as an alternative to the current economic model, overly consumptive, called economy of materials based on a utilitarian or economic rationality. A summary of an economic model as well as its harmful consequences can be seen in a movie widely posted on the Internet called 'the story of stuff'. This movie reflects on how the widespread consumption is generated, its consequences over human beings, and the environment in which they live in. This is described in a linear chain of five phases (Figure 2), which begins with obtaining raw material to produce goods to be consumed and finishes in the disuse and disposal of them. Sampaio (2010) indicates that the current economic model generates social pathologies that are harmful to human beings and the environment, generating powerful organizational systems with high profitability, and concentrated income, however with the socialization of negative consequences to the population (environmental degradation for instance). Social pathologies can be sociopolitical, when there is power manipulation in favor of organizational interests, socioeconomic in the form of informal work, semi-slavery, or social exclusion of those who cannot follow strong appeal to consume, and finally, socio cultural pathologies which significantly alter people's lifestyles due to reach productive efficiency.

Eco-socioeconomy emerges as an alternative to current economic model and points to the decentralization of decision making power, giving more power to the people. The model proposed requires rationality in the management of regional ecosystems and highlight community creativity, seeking their autonomy and giving priority to the satisfaction of their demands and basic needs, without forgetting environment preservation (Constanza, 1991; Sampaio, 2010). Changing the current economic paradigm is an enormous challenge that will demand big effort, since each organization must be persuaded to abandon capital accumulation and labor exploitation (capital gain), then start to plan living with a sufficient level of profitability for her survival and sustainable development, sharing results with the community as social and environmental actions.

Rondon project

In 1907, Marshal Rondon, as he is popularly known, received the strategic task of demarcating the Brazilian territory and populate her borders. He was personally in charge of section “C” of Rondon Commission which dealt with the recognition of the hinterland, and the preparatory studies to trace the construction of a trunk telegraph line that culminated in the installation of 2,268 km of telegraph lines, 25 telegraph stations, building two bridges and a road in Indian territory, and the incorporation of 30,000 Indians and their territories to Brazil, all this in a peaceful manner (Bigio, 2000). This period was of vital importance to create communications infrastructure to foster the Midwest region of Brazil development. The Rondon project, an initiative from the Brazilian government at the request of The National Union of Students (UNE), was revived in 2004 with the creation of an inter-ministerial group which was launched again in 2005 in the city of Tabatinga AM, in the Amazon operation (Barreto, 2008). The integration of university students in the process of national development is among the objectives of the project. This will be accomplished through participatory activities concerning the country reality and encouraging them to produce local collective projects together with the community. Rondon project is coordinated by Ministry of Defense and the participation and collaboration of many other ministries. Taking part in the Rondon project is a single opportunity to put into practice what is learned in the classroom, benefiting a Brazilian municipality. Similar to Marshal Rondon, students map their needs and then open a channel of communication to regional development. The students themselves transmit necessary knowledge to generate local sustainable development, citizenship, and social welfare. Both professors and students taking part in this project are volunteers which foster this sort of work in Brazil.

The cost of transport to the place where it occurs is covered by the Ministry of Defense. The costs of accommodation, food, as well as local transport; with view to implementing the proposed actions is the responsibility of the municipality. The university can help with the donations of materials for training, team transport to and from the boarding place printing certificates, and more of what its volunteer vocation as the resources allow. Among other advantages, participating in the Rondon project enables professors and students to integrate local realities of this vast country within a global context. Since universities nationwide participate in the implementation, this project also allows people from all over Brazil to get acquainted with each other, experience diverse culture, and exchange experiences.

Theoretical reference

A cistern is a water tank, usually cylindrical, which aims to capture and store rainwater. Gnadlinger (2001) pointed out six different models of cisterns:

i) Concrete slab cistern;
ii) Wire mesh- cement cistern;
iii) Brick cistern;
iv) Iron cement cistern;
v) Lime cistern;
vi) Plastic cistern.

Besides describing the manner of construction, related material lists, and costs for each model mentioned earlier, Gnadlinger (2001) also indicated the advantages and disadvantages of constructing each one of them. This project specifically discussed and described the ‘iron cement’ cistern model, as it is more appropriate to the geographical and economic conditions of the municipality of Anajatuba. According to Schistek (2005) the technology for constructing a cylindrical reservoir has become known for offering resistance and using low cost materials. In this construction principle, steel has been substituted with wire mesh, which simplifies the construction process. This substitution also reduces time to completion, material and workforce cost. The cistern constructed with wire mesh guaranteed necessary strength to withstand water pressure, and also offered security against leaks. Schistek (2005) indicated that a successful wire cement cistern construction depends essentially on a combination of three factors: simplicity of construction, high resistance, and low cost, which are in line with the advantages described in Table 1 by Gnadlinger (2001). The disadvantages described in Table 1 can be neutralized by the adoption of some specific precautionary measures. For instance, the issue of warming can be mitigated with an external white painting to reflect sun-ray. The issue of maintaining moisture for two weeks following construction can be solved by appointing someone to water the device daily. Finally the difficulty with water removal can be avoided by installing a water meter/tap or pump to drain the water.

According to Thomas (2001), analysis of the benefit which a family will receive by installing a domestic system for rainwater capture should be based on the interaction between rainfall, catchment area of the roof, cistern size, and finally the water consumption habits of the cistern users. Data collected in Brazil indicate that the amount of water per person per day for domestic purpose is 77 L as distributed in Table 2. For the calculations, illustrations, and specifications, we will use the values suggested by World Health Organization (WHO) and World Bank, shown in Table 3. Adopting a cistern as an alternative water supply requires the use of certain care and precaution measures both in relation to consumption habits as well as to conditions of hygiene in the collection and storage. The collection of rainwater done through the roof then transferred to the cisterns is generally made by a system of gutters. In order to avoid contamination and preserve water quality, it is of vital importance to constantly clean both roof and gutters (Gnadlinger, 2001). The use of rainwater for domestic purposes is only feasible if the rainwater undergoes a filtering process,

Table 1. Constructing a wire cement cistern.

Advantages	Disadvantages
The way of constructing a cement cistern is similar to building a mud house (very well known among the inhabitants).	Controlling the proportion of cement, water and sand according to specification.
Suitable for both small and big cistern construction projects.	Periodically wetting the walls during construction, and in the following two weeks.
Low construction time.	Easy water warming due to sun heat.
Reduced employment of materials.	Complexity for water removal.
Absence of heavy digging, since cistern is above the ground.	The work cannot be interrupted during construction; otherwise subsequent layers of plaster will not adhere sufficiently to each other.
Presents low leak probability.	
Easy to be fixed in case of leak.	

Adapted from Gnadlinger (2001).

which requires a filter installation between the cistern output and a mechanism which will direct the water for consumption purposes only.

The process of filtering and treating water collected from the rain will not be considered in this work. Therefore, without treatment, rainwater can only be used for purposes such as irrigation, flush, tile washing and etc.

METHODOLOGY

The following methodology describes the method used to construct a low cost cistern, providing guidelines for periodic cistern maintenance and care, sizing and pricing the materials needed for its construction, as well as providing capacity according to local need where the cistern will be built. The method used considered the construction of a 'pilot' iron cement cistern type, with some adjustments in the raw material used. Therefore, this cistern will be called 'wire mesh cement'. The site to construct the pilot cistern was defined by the Health Department of the city, which proposed to construct the cistern together with a Basic Health Unit (USB), in a small town that has had a critical history of water shortages. The water collected and stored in this cistern will be used to supply the UBS. This UBS has a catchment area (roof) of approximately 32 m^2, considering the lowest rainfall in the region (1,200 mm – INPE), the USB will provide an annual collection of 38,400 L. Even with the possibility of collecting 35,000 L of water per year, the cistern was sized for 16,000 liters for being a pilot project. A cistern with this capacity can supply a family of 4 for a 100 days, taking into account UN and World Bank recommendations (Table 2). However, it is worth repeating that the process of checking the feasibility to construct and design the cistern should consider rainfall in the region, catchment area of the roof, the size of the cistern, and finally the consumption purpose of the users, in order to obtain a better cost/benefit relationship.

A 16,000 L cistern can be constructed within a week by a construction worker and two assistants with the cost of R$ 2,294.50. Tables 4, 5 and 6 describe the materials, quantities, and local prices used in the cistern construction in Figure 3 describes its external dimensions.

Procedure

The procedure to construct a wire mesh cement cistern with the capacity to collect and store 16,000 L began with ground cleaning and digging a 3.5 m trench in diameter and 40 cm in height. 20 cm of trench space was filled with rock and then an iron frame was inserted with proper mooring of the trusses, which will form the base to fix the iron frame. Soon after the wire mesh was fixed, it was wrapped in two layers of trusses. In order to start slab construction, a slab foundation was concreted in each of the trusses, as well as another one in the center to serve as a level reference, so then the rest of the trench was filled with concrete continuously. After drying the slab, it was moistened and covered with banana leaves to avoid drying out and cracks caused by sunlight. The next day, two 3/16 iron bars were fixed, uniting the four trusses, one on the top and the other in the middle so that all trusses stay together by the bars. Onion bags were then sewn into wire mesh with plastic ribbons and fixed in a single layer. From there began the task of placing the first mortar on the outer of the frame. After 12 h the first inner mortar layer was applied. Once finished, the second outer mortar layer

Table 2. Water consumption per person.

Use of water for domestic use	Consumption (L/hab.day)
Ingestion	2
Food and cooking	6
Washing utensils	9
Bath	30
Laundry	15
Sanitary appliances	10
Other uses	5
Total	77

Source: NUCASE (2009).

Table 3. Water consumption per person (WB).

Use of water for domestic use	Consumption (L/hab.day)
Ingestion	2.5
Bath	15
Food and cooking	10
Sanitary appliances	12.5
Total	40

Source: NUCASE (2009).

Table 4. Local costs of materials used in the cistern construction.

Material	Unit	Quantity	Supplier A	Supplier B	A	B
Cement	50 kg	20	25.00	24.00	500.00	480.00
Gravel	m³	2	150.00	145.00	300.00	290.00
Sand	m³	3	75.00	45.00	225.00	135.00
Hen house wire (h = 1.7 m)	Ml	30	11.00	7.00	330.00	210.00
Ribbon	Roll	1	7.00	7.00	7.00	7.00
Onion bag	Unit	25	0.30	0.30	7.50	7.50
Lime	5 kg	4	4.00	3.50	16.00	14.00
Iron 3/16	Bar 1.5	5	20.00	20.00	100.00	100.00
Trusses 3/16	Bar 2	3	20.00	20.00	60.00	60.00
PVC pipe (40 mm)	M	0,5	10.00	10.00	5.00	5.00
Meter (40 mm)	Unit	1	26.00	8.00	26.00	8.00
Annealed wire	Kg	1	12.00	8.00	12.00	8.00
				R$ 1.588.50	R$ 1.324.50	

Table 5. Peripherals cost.

Description	Quantity	Price
Filter	1	R$ 250.00
Submerged pump anauger Mod 900	1	R$ 250.00
Eletric wire	1	R$ 20.00
	Total	R$ 520.00

was applied. At that time also began to frame the roof. After 24 h of the first inner part being applied, the second inner component was applied. Finally the ceiling was built taking into account the mobile part with plenty of space for a person to pass through for the maintenance and inner cleaning of the cistern. Remember that the systematic of the ceiling construction was the same as the cistern,

Table 6. Labor cost.

Description	Unit cost	Quantity	Total per day	Days	Workforce cost
Construction worker	R$ 40.00	1	R$ 40.00	5	R$ 200.00
Assistant	R$ 25.00	2	R$ 50.00	5	R$ 250.00
				Total	R$ 450.00

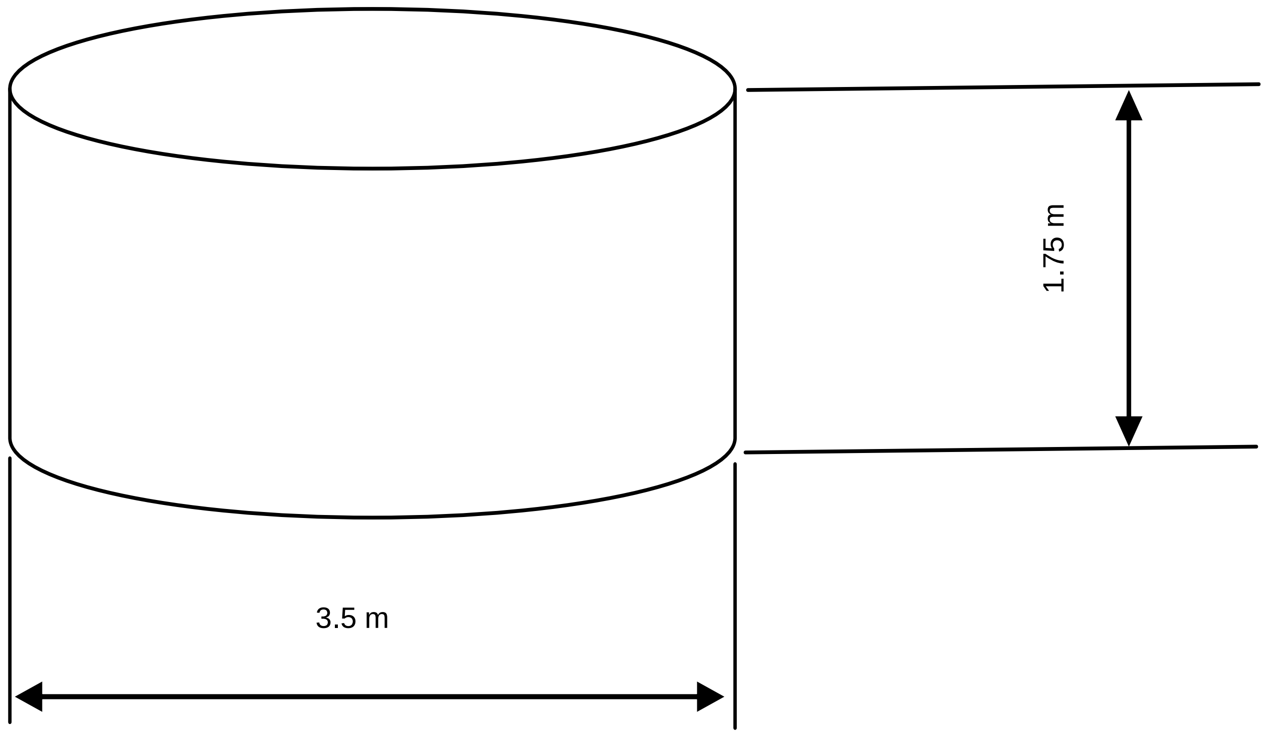

Figure 3. Cistern external dimention sketch.

where wire mesh, onion bag, and concrete were applied.

As far as the exterior finish is concerned, two thin coats of whitewash were applied to cover the base of the cistern to reflect sun ray and helping to prevent water evaporation. There are two methods by which the stored water could reach the people. The first method is to install a simple water tap in the lower part of cistern. This would allow the people to acquire water with buckets and carry it for use. The second method is by pushing the water to the house tank, usually installed up the roof, by the submerged pump indicated in Table 5. The first method is more economical than the second one but requires additional physical effort. As a method for assuring the water is fit for human consumption, the water could be treated by the simple system shown in Figure 4. Within this system, the water is first pushed from the cistern by the pump to a tank. As this water is being pushed, it is being mixed with 80 ml of chlorine ($NaClO$). After a half an hour, the water is ready to pass through a filter to remove the chlorine excess and the solid particles. The water is then ready for human consumption.

RESULTS

The construction of an iron cement cistern as presented in this paper, not only contributed to minimizing the water shortage problem at the UBS health care center, it also enabled local workforce that actively participated in all the phases of the process to receive guidance from the 'Rondon project' team. It should also be noticed that the construction process is simple, fast, and low cost, using regional materials easily found in the municipality. The project of constructing cisterns was presented to local authorities, who apparently were motivated with this alternative, demonstrating interest by seeking funds to implement a policy of building more cisterns in the city. The water stored in the cistern should be subjected to a treatment before being utilized in your household. A low-cost treatment unit (approximately R$ 1,500.00) has the capacity to treat 2,000 L of water per hour and can be installed to treat water from several cisterns simultaneously.

DISCUSSION

It is possible to create low cost alternatives to attend

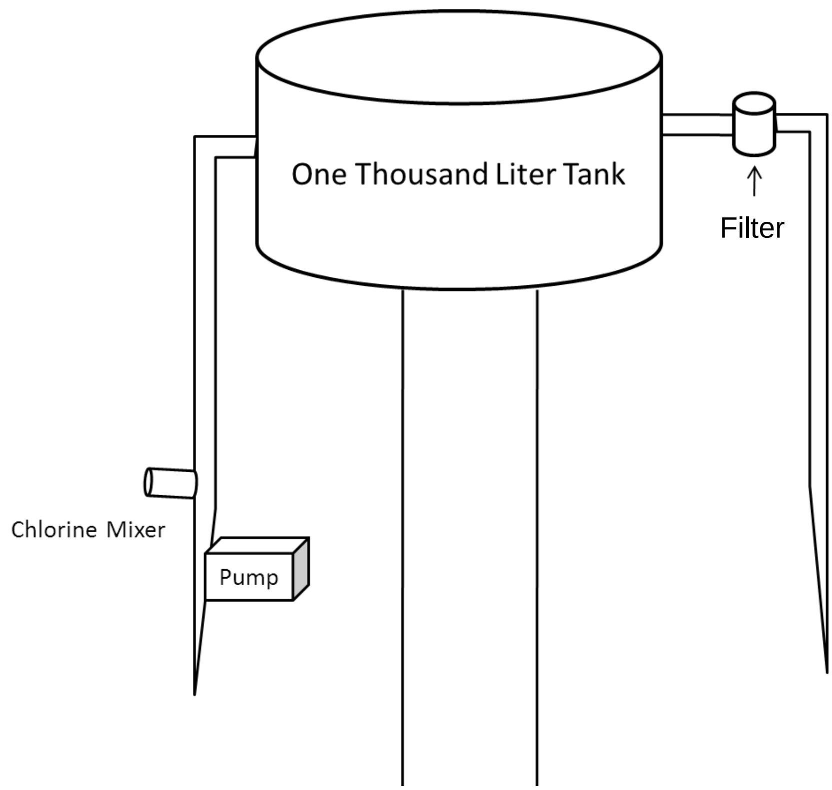

Figure 4. Water treatment system.

regional needs, promote income generation, be sustainable and not to harm the environment, be economically viable, and can be shared with the community. Adopting the strategy of constructing low cost cisterns to reduce the problem of water supply is within the context of eco-socioeconomy; as long as it generates income to local workforce, and to business owners who sell necessary raw material to implement it, without concentrating the construction on big companies, and also without harming the environment. Additionally, filtering and making available rainwater to domestic consumption contributes to disease reduction. Another feature that associates this method with eco-socioeconomy premises is the popular participation in deciding the places that will benefit from the construction of a cistern. As a cistern like the one described in this paper has a capacity to assist a four people family for 100 days, to supply a whole city of Anajatuba that has 25,000 citizens, a 6,000 unit cistern would have to be constructed. That is not the target. The target is just to find an alternative way to supply water in the dry season for limited resource people with a low cost. The more well-endowed people can pay to dig deep water wells and get clean water or buy a water tank truck. It is noteworthy, that the interest and good political will, not to mention the courage of some politicians to break the status quo, are essential factors to run a project based on an economic paradigm, different from the current one. Calling the population to take part in the decision making process has determined who is eligible as a constructor and raw material suppliers.

The municipal government also must demonstrate the motivation to find resources for financing the project, while the government provides subsidies for the construction. This paper showed that it is possible to create alternatives, low cost and affordable social sustainable technologies that can comply with demands of a given region, without harming the environment, promoting income generation, and community participation. It is hoped that this paper may contribute to other researchers who care about water issues to use this approach as a starting point for generating their own improvement, as well as, the search for complementary low cost alternatives such as filtering and treatment of rainwater for domestic use. Although the process of filtering and treating water collected from the rain was not thoroughly considered in this work, the inclusion of a more preventative approach for improving the quality of drinking water based on the evaluation of risk to contamination from the source water to the tap through a risk assessment approach will be the next step in our studies. This will be initiated by conducting an up to date review of both chemical and microbiological parameters to include standard methods for monitoring, sampling and analysis that pays special attention to small water supply systems, which are now known to be those at higher risk globally and to introduce criteria for construction products in contact with drinking water. The WHO recommend water safety pans (WSPs) as the most effective approach for consistently ensuring the safety of a drinking-water supply, because this approach manages the risk from the catchment or water sources to the consumer's tap (WHO, 2008; Bartram et al., 2009; Ainsworth, 2004).

The risk assessment of the complete water system (catchment to tap), included in the WSP, should provide a better understanding of the risks of contamination by pathogens at each step along the system. Then preventative strategies should be designed (a multi-barrier protection) in order to correctly manage these risks to efficiently and effectively protect public health. Furthermore, the recognition in this modification that small water supplies are at the highest risk, and the introduction of measures to control these supplies more efficiently will contribute to the expected improvement.

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