Water Quality of Cisterns and Underground Dams in Semiarid Regions: Case Study of Afogados da Ingazeira, Pernambuco – Northeast Brazil

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Abstract

In semiarid regions water resources are limited and irregularly distributed over space and time. As a result, water scarcity is a reality emphasized by the high evaporation rate recorded in these regions (2000 mm per year). In consequence, the management of water use is a subject that requires priority, especially in the regions where water is a scarce resource. There should be orientation towards its rational use through storage in appropriate places – as cisterns, and underground dams. Additionally, these techniques represent an advantage since they have low costs and can be developed and maintained by individual or community programmes. The social mobilization that occurs with families involved on the construction and maintenance of these structures guaranty the sustainability of these techniques. Although several local populations continued to use water without any treatment, is essential to promote the sanitary security of those waters, which must achieve the human consumption standards, defined on Brazilian legislations. The main goals of this work are: (i) to analyze the maintenance of these structures and the facilities of their implementation; (ii) to calculate the costs involved; (iii) and finally to discuss the importance of improve water quality in cisterns and groundwater dams.

Keywords: cisterns, semiarid regions, undergrounds dams, water quality.

INTRODUCTION

The northeast of Brazil occupies 18.2% of the nation's territory and is almost characterized by semiarid conditions. Recent figures indicate that the population of the region is 28.58% of the total national with a density of 24.49 inhabitants per km^2 (IBGE 2010). The Brazilian semiarid region is characterized by a lack of water resources irregularly distributed over space and time. As a result, water scarcity is a reality, emphasized by high temperatures, low precipitation (between 340 mm a 800 mm per year) and high evaporation rates (2000 mm per year) (Branco *et al.*, 2005). Soils occupy a fine layer, not permitting water retention with a consequent high superficial flow during the wet period. The annual fluctuations of superficial flow with drastic droughts and floods are typical hydrological phenomena that define semiarid systems (Vieira and Filho, 2006; Rosado and Morais, 2010). The lack of water resources is a real problem in semiarid regions, where there is not enough water to sustain agricultural production for rural population (e.g. Mvungi *et al.,* 2005). The scarcity of water difficult the access to safe drinking water, becoming even more complicate during droughts, where only the urban population (or most part of it) is connected to the public water supply system (Hauschild and Döll, 2000). Regions with dry climates have long-standing water conservation customs, which are being maintained by management practices (UN, 2006). To follow increasing demands, water resource managements are applying techniques that augmenting the limited natural water supply, such as, rainwater harvesting and sustainable use of groundwater (UN, 2006).

The adoption of cisterns as a method of collecting rainwater is an ancient practice. According to Portela (2003), in northeast Brazil, the construction of cisterns was a practice utilized in older habitations. Today, the construction of cisterns has been encouraged by NGOs. The "One Million Rainwater Harvesting Programme - P1MC" was launched by civil groups in the region, whose target were rural families without a secure drinking water source. The objective of P1MC was to

construct one million rainwater harvesting systems for decentralized access to drinking water to one million families, or about five million people in total. The programme is carried out by ASA, a forum of about 750 NGOs constituted by agricultural labor unions and farmers' associations, to cooperatives, churches, and organizations for local and regional development. The Brazilian government and ASA jointly finance the programme. Furthermore, they are very simple to be constructed and the transfer of this technology is also simple.

Recent studies undertaken in semiarid zones in northeast Brazil, points out to the need of store water mainly in the subsoil, making use of ancient techniques utilized by small farmers (Silva and Porto, 1982). Underground dams are constructed on the beds of river, in the alluvium. They are built perpendicular to the riverbed with the purpose of intercept the groundwater flow for storage. The function is to leave the soil wet in a way that increases the agricultural productivity of the region and makes agricultural exploitation by small and medium-sized rural properties viable, particularly for those that do not have water at their disposal for use in irrigation (Silva and Porto, 1982). The principal advantages are: (i) accumulation of water with lower levels of evaporation; (ii) lower risk of salinization when well exploited; (iii) non-occupation of agricultural areas that are normally covered by water in reservoirs collecting surface water (Brito *et al*., 1989). Successive dams can be constructed in a more intensive form. They comprise a series of walls made of masonry and/or stone constructed one after the other, obstructing the bed of the river or stream. The water stored by a dam stretches back to the wall of the previous dam, increasing the quantity of water accumulated.

In this context, in Brazil northeast region, cisterns and underground dams have been focus of governmental and nongovernmental projects, from the perspective of community participation and sustainable development. The social mobilization, encouraging families to construct and maintained theses structures, is a guaranty of the sustainability of these low-cost techniques. Cisterns and groundwater dams permit to collect rainwater for different uses, such as human supply, agriculture and animals. Although is important to consider the quality of the stored water (Horak *et al.,* 2010). In Brazil like in many countries, the stored water is utilized without any treatment, being urgent to implement sanitary security measures in order to have water that accomplishes the requirements for human consumption.

The main goals of this work are: (i) to analyze the maintenance of these structures and the facilities of their implementation; (ii) to calculate the costs involved; (iii) and finally to discuss the importance of improve water quality in cisterns and groundwater dams. With these goals Afogados da Ingazeira municipality was select as a case study.

AFOGADOS DA INGAZEIRA MUNICIPALITY (PERNAMBUCO STATE)
Localization
The Afogados da Ingazeira municipality is located in Pernambuco state in northeast Brazil (South 07°45'03" and West 37°38'21"; Figure 1). It covers an area of de 377.86 km², in *sertão* interland. The annual precipitation is about 413.8 mm, not well distributed over the year. The winter rains arrive in December or January and diminish in May, with the heaviest precipitation occurring from February to April. The region is characterized by the *caatinga* type of vegetation, covering a soft and wavy relief with presence of narrow valleys. The average altitude is 514m above sea level, with an average natural slope of 0.3% in the line of the valley.
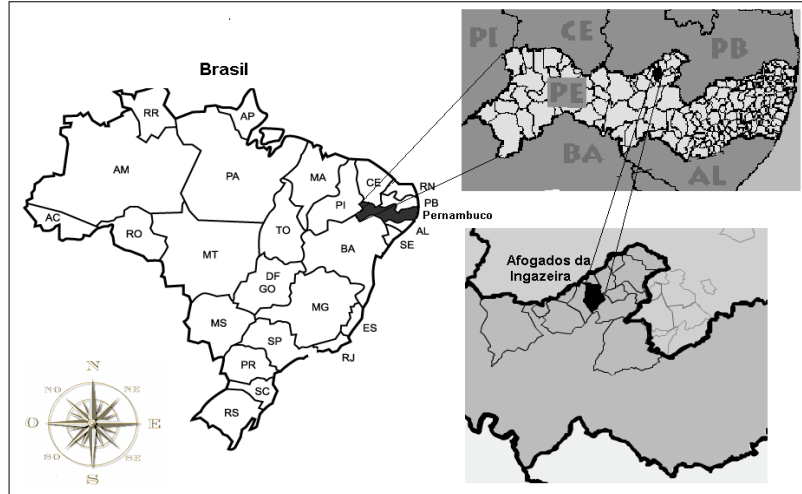
Figura 1 – Localization of Afogados da Ingazeira municipality in Pernambuco state, Brazil.

Rainwater harvesting and sustainable use of groundwater

Such climate variability has always been considered the major constraint to economic development as well as the principal cause of the rural poverty that afflicts northeast population (Tundisi, 2005; Morais *et al.*, 2009). The rural economy of Afogados da Ingazeira municipality is based primarily on subsistence crops such as permanent farming products (banana, orange, lemon and sleeve); temporary farming (potato candy, onion, beans, cassava, maize and tomato) and cattle (cows, sheep, goats, chickens). When the yield is high, rural households sell the surplus of their crops. Although, low local market prices make it difficult due to the absence of an effective policy to assure commercialization of the cultivated crops (Branco *et al.,* 2005).

In Afogados da Imgazeira different organizations have shifted the attention to small-scale water harvesting systems at the farmer's field and pasture. The main focus is on the management of rural water using cisterns and underground dams, both for human purposes and for agriculture production. These initiatives are being canalized by ASA – the Brazilian Semiarid ONG Network into different programs, which take Rainwater Harvesting as integrated part of "Living in Harmony with the Semiarid Climate", including also climate change adaptation. Besides raising the consciousness of the population towards their right to water, these programs allow people to learn ways to manage scarce water resources and understand their rights as citizens. These projects also involve the families training about how to construct their own systems. This not only gives a sense of fulfillment to the beneficiary population, who are engaged in the construction, but can also provide them with a new source of income.

The conventional systems utilize the house roofs as surface area for rainwater harvesting, after canalized thought gutters or pipes to cisterns. Each cistern has an approximate capacity of 16 000liters with an estimated cost of US$740. This is sufficient for a family with five individuals during a period of 10–12 months (Portela, 2003).

The *calçadão* cisterns (Figure 3) have a constructed harvesting area of 200m^2, with a storage capacity of 52 000liters (Farias Júnior *et al.*, 2003) and an estimated total cost of US$ 3 750.

Figure 2 – Conventional cisterns. The rainwater is collected on a house roof and led through a gutter into a cistern. Afogados da Ingazeira municipality, Pernambuco state, Brazil.

Figure 3 - *Calçadão* cistern. The rainwater is collect on a constructed harvesting area and led to a cistern. Afogados da Ingazeira municipality, Pernambuco state, Brazil.

The stored water is used for families' needs, cattle, and irrigation of subsistence agriculture (Figure 4), which contributes for an increment of families' income, also permitting them to sell the surplus of their crops in next cities markets.

As previously referred, underground dams (Figure 6) are alternative techniques for harvesting water mainly with agricultural propose in small and mediums rural proprieties. These infrastructures permit a significant increase in agriculture productivity (Brito *et al.*, 1999; Silva *et al.,* 2006). Considering a study about underground dams in Pernambuco state, Cirilo *et al.* (2003), refer the different water uses: domestic (to wash clothes, cleanness, to cook); cattle; pastures for feed cattle; small irrigation with pomp; human consumption. Investment costs for subsurface dams depend on the size and may vary from US\$5000–10 000 for small dams and up to US\$10 000 for large dams with storage capacities of 100 000m^3 - 1 000 000 m^3. The investment cost per m^3 storage volume is about US\$0.499 –1.99/m^3.

Figure 4 – Subsistence agriculture. Afogados da Ingazeira municipality, Pernambuco state, Brazil.

Figure 6 - Underground dam, Afogados da Ingazeira municipality, Pernambuco state, Brazil.

QUALITY OF RAINWATER HARVESTING

The quality of rainwater used for human supply is of particular importance because in most cases it is directly used for drinking without any treatment. In the 1980's several studies indicated that rainwater supplies often do not meet WHO and other national drinking water standards, especially with respect to bacteriological conditions (Fujioka and Chinn 1991, Lye 2002, Krishna 1993). These data point to further investigations which focused on determining both the sources and implications of contaminations (Fujioka and Chinn 1991, Lye 2002, Krishna 1993, Gould. 1999). In a parallel development, drinking water quality guidelines more appropriate for rural conditions in developing countries were proposed (Ockwell 1986, Morgan 1990). These less exigent guidelines allowed water with mean *E.coli* counts of up to 10 per 100ml to be accepted for drinking, compared to the WHO recommended limit of 0 per 100ml (WHO 1993). When the quality of stored rainwater are analyzed according to this more realistic criterion, the number of rainwater supplies within acceptable limits for drinking greatly increased (Gould, 1999).

In Afogados da Ingazeira municipality the maintenance of water quality in cisterns and groundwater dams is essential because for almost families represents the only available water for human supply. In accordance with the Brazilian legislation (Ministério da Saúde, Brasil 2004) the water destined to human consumption must be in accordance with the established standard. Methods to protect or

improve rainwater quality include: appropriate system design; proper operation and maintenance systems; use of first flush devices; and treatment (Gould, 1999; Evans *et al.,* 2007). Treatment is mainly appropriate as a remedial action if contamination is suspected. First flush devices can be effective in reducing contamination if properly maintained. Good system design, operation and maintenance are generally the simplest and most effective means of protecting water quality. If the water is used for drinking purposes, the piping system towards the storage system must be equipped with first flush and filters, to prevent contamination from entering the storage system. A properly operated and maintained first flush is often sufficient to provide water of potable quality. In the storage facility, it is important that no light enters the system, because this could lead to bacterial growth. It should also be protected from people and animals entering the system (Gould, 1999).

Studies have shown that rainwater quality stored in cisterns accomplished the physicist-chemistries standards requirements. The potential health risk comes from identifying the presence of specific pathogens microorganisms, which compromise its use for human consumption (Andrade Neto, 2004; Amorim and Porto, 2001). In accordance with Blackburn *et al.* (2003) microbiological contamination in cisterns are due to: (1) presence of animals inside cisterns; (2) inadequate preservation of pips to conduct water; (3) other facilities for water store, namely trucks (*carros pipas*) where water present poor quality and causes a series of illnesses to those who drink it; (4) utilization of first rainwater or inadequate discarding of these waters.

Considering this scenario some measures must be taken, such as, clean and disinfect roofs, gutters and cisterns, as well as, install sanitary barriers throughout all the store system to reject first rains. Complementarily, control and monitoring programs for stored water must be implemented in order to improve water quality to human consumption.

Regarding water quality in groundwater dams, salinization problems in land surrounding dams has been observed in some regions, mainly due to the water in temporary streams. In this sense, beyond monitoring parameters related to human supply, other parameters must be considerate, such as the level of salts concentration in water and also in the plantation areas of groundwater dams (Oliveira *et al.*, 2007). The evaluation of water quality in some Brazilian groundwater dams, provided a number of key issues for successful dam construction: (1) proper site selection to ensure sufficient storage potential; (2) assurance that there is sufficient depth to reach relatively impermeable bedrock; (3) availability of a soil type with sufficient infiltration capacity; avoidance of a soil type that could lead to groundwater salinization; (4) proper design and construction to avoid low-yielding abstraction wells; (5) address the landownership issue. In Afogados da Ingazeira municipality, this accompaniment is essential since it is localized in a region where the annual average evaporation is of 2 000mm and annual total precipitation is about 413,8 mm.

CONCLUSIONS

Cisterns and underground dams represent important systems for collect and store water in the semiarid region of Pernambuco state, contributing for increases familiar income and life quality for many agricultural communities. The technology used is not new but its efficiency in storing water for a rational use, suitability for a participatory approach and relative simplicity, has recently revived interest. They represent important mitigation measure toward the scarcity of water in the Brazilian semiarid region, providing an insight about the impact and usefulness of a mitigation measure initially proposed by civil society and then supported by governmental institutions. This is emphasized by the partnership between governments and civil groups in regards to the development and implementation of effective mitigation measures to live in "Harmony with the Semiarid Climate". The main goals these projects and actions are to contribute, through an educational process, to a social transformation in the region. Through the provision of water and the

empowerment of the most vulnerable population, all these actions expect to introduce new patterns of social relations distinct from the old patron-client relations between the poor and the wealthy, which have characterized the semiarid region for a long time. Thus all these activities consider the preservation, access to and management of water as a right and an obligation of every citizen. However, it is necessary to guarantee that the water stored for human supplying fulfills the norms of quality stipulated in Brazilian legislation. In this context is necessary to implement adequate monitoring programmes. In the case of underground dams the programmes must include the control of salts level in water and soil, stimulatingly with training courses and educational activities about the risks and benefits of this technique in order to promote the sustainability of populations in equilibrium with environment.

In the future, there will be a shift in water management and storage, ranging from the surface (dams) to the subsurface (cisterns and subsurface dams) increasing the efficient use of the irregular rainfall, where it falls. Especially in semiarid regions, as northeast Brazil, the ongoing development programs like biodiesel, irrigation of sugar cane and transferring water from São Francisco River, should be questioned under the aspects of climate change, land and water management and of "*living in harmony with the semiarid climate*"

ACKNOWLEDGMENTS

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