A pós-graduação e a sustentabilidade do abastecimento de comunidades ribeirinhas na Amazônia por meio de água de chuva: da concepção à ação

Postgraduate education and the sustainability of rainwater supply to riparian communities in the Amazon: from conception to action

El posgrado y la sostenibilidad del abastecimiento de comunidades ribereñas en la Amazonía por medio del agua de la lluvia: de la concepción a la acción

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Resumo

Apesar de a Amazônia ser rica em recursos hídricos, sua população tem dificuldade no acesso à água potável. O abastecimento de água nas ilhas de Belém (PA) é deficitário. Alternativas locais que garantam o acesso à água em quantidade e qualidade adequadas são grandes desafios. O objetivo deste artigo é apresentar uma experiência integradora de dois programas de pós-graduação na implementação de alternativas de aproveitamento da água de chuva para fins potáveis a fim de contribuir com a sustentabilidade do abastecimento local. A caracterização socioeconômica e o diagnóstico do abastecimento de água subsidiaram a implantação dos sistemas. Verificou-se a sustentabilidade por meio da aceitabilidade e do acesso ao sistema, dos impactos financeiros e dos padrões qualitativos da água. De forma geral, são modelos positivos de abastecimento de água para populações ribeirinhas da Amazônia.

Palavras-chave: Água da Chuva. Abastecimento de Água. Desenvolvimento Local. Belém. Amazônia.

Abstract

In spite of the wealth of water resources in the Amazon, access to drinking water is still difficult for its population. Water supply in the islands of Belém (PA) is deficient. Local alternatives to guarantee access to water in adequate quantity and quality are a major challenge. The objective of this paper is to present an experience integrating two postgraduate programmes to implement the alternative use of rainwater for drinking purposes in order to improve the sustainability of local water supply. Socioeconomic characterisation and a water supply diagnosis subsidised the implementation of the systems. Sustainability was ascertained by means of the acceptance of and access to the system, financial impacts and water quality standards. In general, these are positive water supply models for riparian populations in the Amazon.

Keywords: Rainwater. Water Supply. Local Development. Belém. The Amazon.

Resumen

A pesar de la Amazonía ser rica en recursos hídricos, su población tiene dificultades en el acceso al agua potable. El abastecimiento de agua en las islas de Belém (PA) es deficiente. Alternativas locales que garanticen el acceso al agua en cantidad y calidad adecuadas son los principales retos. El objetivo de este trabajo es presentar uma experiencia de integración de dos programas de posgrado en la puesta en práctica de alternativas para el aprovechamiento del agua de la lluvia como agua potable con el fin de contribuir a la sostenibilidad del abastecimiento local. La caracterización socioeconómica y el diagnóstico del abastecimiento de agua apoyaron la implementación de los sistemas. Se verificó la sostenibilidad por medio de la aceptabilidad y del acceso al sistema, de los impactos financieros y de las normas de calidad del agua. En general, son modelos positivos del abastecimento de agua para las poblaciones ribereñas de la Amazonía.

Palabras clave: Agua de Lluvia. Abastecimiento de Agua. Desarrollo Local. Belém. Amazonía.

Introduction

Water is listed as a basic human need. It is also a natural resource of economic, social and environmental significance, and in the case of the Amazon of cultural and social reproduction significance. Water is a determining factor for sustainable development and for this reason it is one of the great challenges faced in Brazil, where there are 12% of surface water resources, but where distribution and quality are mired in adverse conditions.

United Nations data indicates that the world has reached the Millennium Development Goal (MDG) on drinking water ahead of plan, in 2010. However, 1.2 billion people still suffer from lack of access to treated water (UN, 2010).

Although the Amazon area is widely recognised as having the largest water reserves on the planet, it is ironic that some of its areas are still hostages to drinking water shortage. According to Brazil's National Water Agency (ANA, 2011), approximately 70% of the population in the Northern region is devoid of access to treated water. When analysing GDP per capita growth in Legal Amazon states and access to water and sewage systems in households from 2002 to 2009, Giatti and Cutolo (2012) affirmed that Pará showed little progress in the offer of water and sanitation services.

With approximately 1,000 inhabitants, the Grande and Murutucu islands located in the south of Belém have no water supply system. The demand for this resource is being met inadequately. Having no alternative, many riverside dwellers purchase water or extract it from wells of dubious quality. Direct consumption from highly degraded springs has also been reported, with risks of disease and further complication to already precarious health services (VELOSO, 2012).

Faced with this scenario and based on the interaction of two postgraduate programmes – the professional master's degree Postgraduate Programme in Natural Resources Management and Local Development in the Amazon (PPGEDAM) at the Centre for the Environment (NUMA); and the academic master's degree Postgraduate Programme in Civil Engineering (PPGEC) at the Institute of Technology (ITEC) – the Federal University of Pará (UFPA) is conducting applied research targeted to finding alternative supply models to ensure access to quality drinking water by riparian communities in the state, and in particular, in Belém.

The alliance between a professional master's degree and an academic programme has proven useful in the performance of one of the many university roles, which is to contribute to the development of its surrounding area, whether on the regional spectrum or the community level. Additionally, the union of both master's degree programmes is seen as an interdisciplinarity practice, since both programmes come from different areas of knowledge. The multidisciplinary and interdisciplinary approaches that water resource management requires have enabled programmes to share methodologies and exchange theories that help advance the frontiers of science and technology, as advocated by the National Postgraduate Plan – PNPG 2011-2020 (BRAZIL, 2010).

The proximity of both postgraduate programmes culminated in the deployment of rainwater use systems in the Grande and Murutucu islands. Rainwater use consists of a social water supply technology that uses the roofs of houses to collect the rainfall water in a reservoir and then distributes it by using gravity, without the need to use electricity.

Since the amount of rainfall in Belém is high, at about 2,800 mm per year (INMET, 2011), this modality is believed to be an alternative to the supply of drinking water, in view of the degradation of surface springs, especially near urban centres. In fact, the heavy rainfall in Belém favours this catchment modality, which can completely fulfil the demand for water use. Rainwater management is a form of water resource management that can contribute to settling economic, social and environmental conflicts as well as pending issues experienced by people who live alongside river banks, known as riparian residents, since most of Belém islands have suffered no significant interventions by the government in favour of water supply.

The design

The PPGEDAM was implemented in 2007 with the purpose of training professionals to work at public and private bodies as agents for environmental development and management. The PPGEDAM has resulted from the UFPA's Centre for the Environment experience, which acts primarily in training professionals to act in the area of sustainable conservation unit management and in the management of the multiple territories that shape the Amazon region, especially communities, municipalities, micro-regions and river basins. Understanding the need for the adequate management of natural resources with a view to helping the region's development from the perspective of its diversity has guided the programme proposal to seek development alternatives on the local level. In this context, the PPGEDAM also seeks to train professionals to transfer technology in both directions, i.e., from academia to the community and from the community to academia, and to manage water resource use on the local level.

The programme's general design follows the guidelines established by Capes for professional master's programmes. Among the PPGEDAM's basic assumptions are the understanding that sustainable development must be i) based on the adequate management of natural resources and ii) an endogenous change process that leads to improvement in the quality of life of local communities, respecting their culture and values. Local development is the product of a dynamic relationship involving all social actors, including local and government organisations, and communities acting under the concept of governance. Universities, as producers of knowledge, are important social actors to support the construction of a new society.

In view of these assumptions, the programme's objectives include: to discuss environmental management methods and models for the use of natural resources; and to equip participants to use innovation in the preparation of programmes, projects, methodologies, processes and products that can be made feasible to meet the demands of local communities.

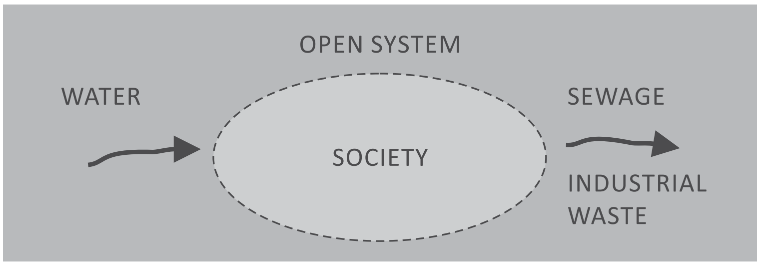
The PPGEC principle is sustainable development and environmental preservation in the region. Among the programme's areas of concentration are water resources and environmental sanitation systems as well as urban infrastructure. This line of research aims at developing advanced studies in Water Resource Engineering with an emphasis on studying water resources in their quantitative and qualitative aspects, their occurrence, propagation, distribution and use, in order to perfect the various uses of water, and therefore to ensure that present and future generations will have high quality standards as well as rational and integrated use, targeted to sustainable development and the prevention and protection against critical hydrological phenomena or improper use of natural resources.

While the PPGEC focuses on the constructive aspects of propagation, distribution and use of water resources, the PPGEDAM focuses on how new technologies can be deployed, owned and managed on the local community level. The programmes complement each other in so far as they each conduct research concerning the applicability of and catering for social and environmental demands of communities already identified by the government as needy, but that have not yet been included in certain sustainability public policies. If the PPGEC postgraduate training audience consists of engineers and related professionals, PPGEDAM's audience stems from interdisciplinary areas and is qualified to design integrated studies that contribute and/or promote local and community development.

Assumptions for water supply sustainability in rural Amazonian communities

The present work's assumptions to achieve its objectives are based on the basic fact that water supply systems for human populations must be sustainable. That is, they must meet the needs of users in all phases, from conception to use and maintenance.

As presented by Mendes (2005), Fenzl, Mendes and Fernandes (2010), Mendes and Fenzl (2011) and Mendes et al. (2012), supply systems are open social systems, which, due to their nature, not only change their surroundings but are also changed by them. In this systemic view, water supply is connected with the nutritional, housing and material well-being of societies. Such conditions are guaranteed by continuous flows of energy and matter from the natural environment, as shown in Figure 1.



Source: Mendes (2005).

Figure 1. Representation of the social system's interaction with water input and output.

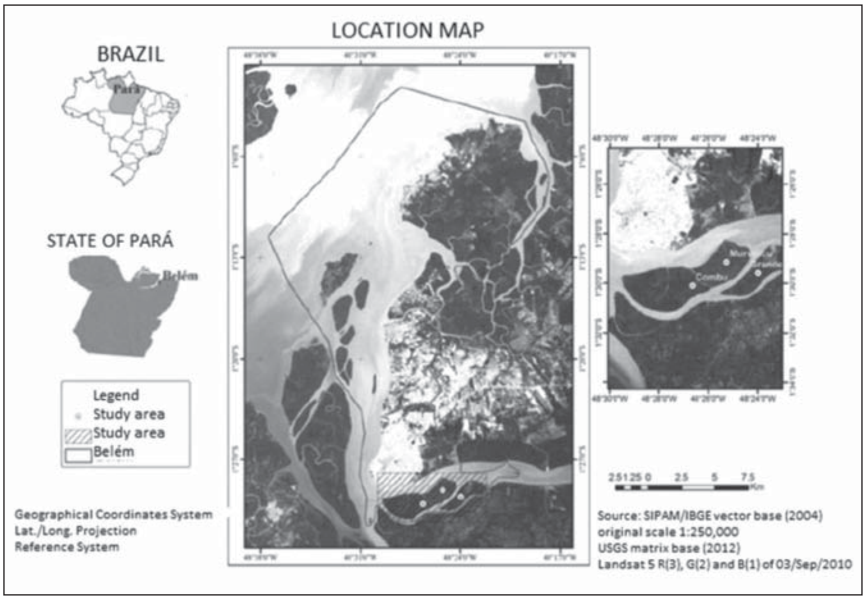
Therefore, in addition to the water and the physical structure, supply systems also consist of users (and forms of water use), the environment surrounding them and even the financial aspects for their installation and maintenance. Consequently, all these elements must be taken into consideration for the sustainability of a supply system. The sustainability of a water supply system is translated into user satisfaction in terms of: a) easy access to water; b) quantity that meets demand; c) quality within drinking standards; and d) price that is adequate to their payment possibilities (MENDES, 2005). All these elements are considered in this work.

The action: the research work and methodology

In 2012, two master's degree theses were concluded as part of the postgraduate programmes at UFPA, one in PPGEC and the other in PPGEDAM, both focusing on the implementation of rainwater systems as an alternative water supply system in the Grande and Murutucu islands: Use of rainwater to supply a rural area in the Amazon. Case Study: Great and Murutucu islands, Belém-PA; and Rainwater and local development: the case of water supply in the islands of Belém. The first thesis aimed at developing Rainwater Supply Systems (Saac) to cater for riparian communities; the second thesis aimed at evaluating the feasibility of the sustainable use of rainwater to supply drinking water in the Great and Murutucu islands.

The interdisciplinary work pursues the social applicability of science and the integration between two postgraduate study programmes. The Saacs were developed and deployed taking into account socioeconomic diagnoses and perception studies resulting from investigations conducted for the master's degree theses.

The study area is part of the municipality of Belém/ PA, more specifically its insular region, formed by islands with rural characteristics. The Grande Island (1°29'23.32" S / 48°24'18.39" W) and the Murutucu Island (1°29'27.80" S / 48°24'40.18" W) are located along the Guamá river, in the southern portion of the municipality, geographically arranged in opposition to one another, separated by the Bijoró river, at a distance of about 12 miles from the urban area of Pará's capital city, as shown in Figure 2. Together they have an area of 1,789.81 hectares and comprise a universe of 39 islands under the jurisdiction of Belém, representing 65% of the total municipal area (Belém, 2012).



Source: Guimarães (2012).

Figure 2. Study area location map.

The study provided subsidies to calculate the dimensions of rainwater management and the catchment system on both islands. Subsidies emerged from the construction of the socioeconomic profile of residents and the diagnosis of the drinking water supply. As a result, two prototypes were implemented and the impacts of using the model to local development were investigated by monitoring the systems' efficiency based on water quality and the monitoring of users.

The first field visits that took place between March and April 2011 were crucial for the visualisation of local sanitation conditions and for probing the acceptability of rainwater. The visits revealed that Grande Island had already experienced rainwater supply, and its community was willing to accept the proposed model. The choice of households that would receive the prototypes was based on three factors: interest of residents in having the system, number of users and roof area. House roofs had to be measured because of the last factor.

Project preparation and sizing followed parameters: contribution area; critical rainfall indicators for the site; and user demand. The definition of water availability was based on historical rainfall series obtained from the last climatological norms manual of the National Institute of Meteorology (INMET, 2011) for the period 1961-1990[1], station Belém, number 82191. The calculus of the per capita demand considered in the sizing was based on the average daily use for drinking and cooking activities during three consecutive days. The demand calculated corresponded to 5L /day/inhabitant. For the total volume, we used the number of systems users - 19 in Grande Island (five families) and 14 in Murutucu Island (three families).

The systems consist of a gutter pipe, conductors, self-cleaning devices, a storage reservoir, a sand filter and a reservoir for treated water. The Saacs sizing was based on technical standard NBR 10844 (ABNT, 1989), which deals with rainwater pipework installations in buildings. The reservoir calculation was based on the Rippl method contained in NBR 15527 (ABNT, 2007).

In order to ensure the drinking water standards required by Administrative Decree no. 2,914 /2011 of the Ministry of Health (BRAZIL, 2011), sand

[1] This period is the last cycle provided by Inmet. Normal climatological patterns are calculated for 30-consecutive-year periods. Historical data from 1991 to the present day are not available.

filters were developed with the same principles of traditional filters.

On Grande Island, the model has four self-cleaning reservoirs, two filters, a 500-litre upper water tank and a 310-litre lower water tank. The system built in Murutucu Island is smaller in size and has two self-cleaning reservoirs, a filter and two 310-litre water tanks, as shown in Figures 3a and 3b.

Source: Veloso (2012).

Figure 3a. System installed on Grande Island.

Source: Gonçalves (2012).

Figure 3b. System installed on Murutucu Island

The form used contained questions about socioeconomic aspects; the diagnosis of the water supply for the population; forms of water treatment; the acceptance of rainwater; interest in having the Saac system; the physical and building aspects of households; knowledge of the water use system; the science of sanitary conditions; accessibility; sharing the model; among others.

Two hundred and one households were visited. This total corresponds to 79% of the homes of Grande Island and approximately 88% of Murutucu Island. After data were collected, they were processed statistically through the Statistical Package for the Social Sciences (SPSS Data Editor version 13.0).

Health and environmental education initiatives were accomplished after a meeting with the residents at São José School on Grande Island, attended by two health agents who work in the community.

The Saacs were monitored through physicochemical and bacteriological analyses made along the catchment, treatment and storage system, especially on the gutters and the self-cleaning and storage reservoirs (after filtration). Samples collected from the atmosphere were also analysed.

Fifteen water quality analyses were made throughout the months of January and April 2012. The preservation of the samples and the method used in the physicochemical and bacteriological analyses of the water collected were in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WPCF, 1980). The physicochemical analyses of the samples were conducted by the Multi-User Water Treatability Laboratory and the bacteriological samples were sent to the Microbiology Laboratory of the Institute of Biological Sciences, both at the Federal University of Pará.

Understanding the impacts generated took place after a general screening of the context. The quantitative and qualitative results of the survey were used as a reference to point out impacts on the sustainability of Saacs and local development reach. The propositions seek to subsidise water supply management in insular regions.

Results of surveys, of the integration between the postgraduate programmes and of community development

This section focuses on showing the results of the surveys; of the integration between the PPGEDAM and PPGEC; and of the contribution of Saacs to community development. Initially, comments will be made about the socioeconomic characterisation of the islands' residents and the diagnosis of water supply on the islands. It also presents an assessment of the systems' sustainability according to three criteria: (1) acceptability and access to the proposed system; (2) financial analysis and impacts on residents' income; and (3) assessment of qualitative water standards. These comments connect the two theses.

1. Socioeconomic profile of residents and diagnosis of supply for drinking purposes

In order to characterise the social context of the islands' riparian residents, information was collected regarding population size, stratification by gender, number of persons per household, respective schooling levels and also family income.

The Grande Island comprises 89 households that hold 288 people, of which 53.1% are males. The Murutucu Island has 149 households and a population of 529 people, men also being predominant at 52.1% of the island's total population. Both islands have a significant percentage of children (residents aged less than 12): 33% in Grande Island and 32% in Murutucu Island. The data collected indicated 3.23 and 3.55 persons per residence in the Great and Murutucu islands, respectively. This profile of the islands' population showed how much a Saac could contribute to improve the quality of life of local residents.

As for education, the survey results showed that the residents of both islands have low levels of schooling. In fact, 10.7% and 9.8% of the inhabitants of Great and Murutucu Islands, respectively, have never attended school; and 33.6% of the inhabitants of Great Island and 30% of the inhabitants of Murutucu Island have not even finished the 4th grade in elementary school. These numbers are for age group 21-50 years old.

Of the families interviewed, 60% of their members are engaged in paid employment. Income composition in rural areas does not consist only of declared income. When dealing with island populations with peculiar economic dynamics, residents have particular working activities that ensure family livelihood, such as plant and animal extractivism. The pursuit of these activities is an important part of family income, and is theoretically not accounted for by residents. In fact, there is a real difficulty in measuring effective monthly family income. The objective of the family income survey was to ascertain whether the population had financial sustainability to implement and maintain the rainwater use system. Therefore, we used salary ranges only as income indicators, as shown in Table 1.

Table 1. Monthly family Income per island

Family Income	Grande Island		Murucutu Island	
	Percentage (%)	Accumulated percentage	Percentage (%)	Accumulated percentage
Less than 1 MW	44,3	44,3	65,6	65,6
Between 1 and 1.5 MW	35,7	80,0	21,4	87,0
Between 2 anbd 3 MW	14,3	94,3	6,1	93,1
Above 3 MW	4,3	98,6	4,6	97,7
NS/NI	1,4	100,0	2,3 1	00,0
Total	**100,0**		**100,0**	

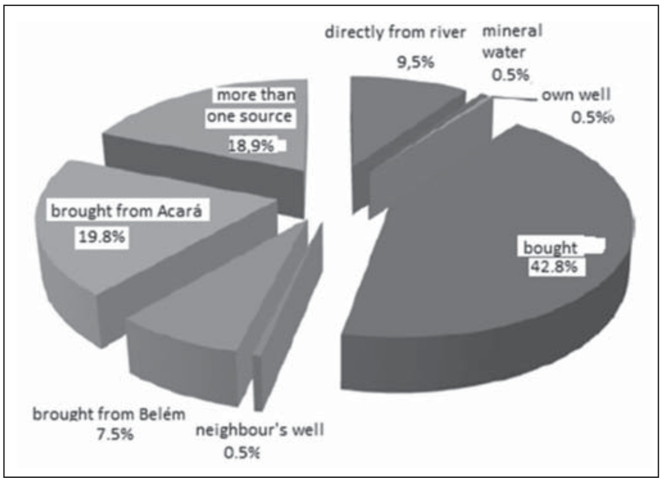
MW: minimum wage (R$545.00 in 2011). NS: not known. NI: not informed.
Source: Veloso (2012).

On Grande Island, 80% of the population declared monthly earnings up to 1.5 times the minimum wage. But in Murutucu Island, approximately two-thirds of residents are paid less than one minimum wage. The data reveal that the residents of both islands have difficulty maintaining the financial sustainability of the system.

In order to diagnose water supply categories, the following data were collected: origin of the water used; type of water treatment used by residents; perception of the quality of the water used by residents; and information reflecting the health conditions of residents regarding waterborne diseases.

The investigation revealed the following ways of obtaining water to meet the residents' needs for drinking and cooking water: direct collection from rivers, either manual or with a pump; purchase of mineral water; extraction from a well in the family's property or in a neighbour's; collection from nearby places, such as urban Belém or the municipality of Acará; finally, purchasing water.

According to locals, water can be purchased in two ways: by paying a boatman R$2.00 for every 20 litres delivered door-to-door in containers; or by paying R$3.00 every month to one of four residents associations in the municipality of Acará – Itancuã, Guajará, Boa Vista or Santa Maria – which charge outside residents for access to community wells. Figure 4 shows percentages per supply modality practiced on the islands.



Source: Veloso (2012).

Figure 4. Water supply modalities practiced on the islands.

According to Figure 4, the modalities that stand out the most are 'bought' and 'brought from Acará'. Also, 10% of the population uses river water only. When analysing river water use in comparison with other categories – when riverside residents declared the use of more than one source of water – the percentage doubles. This means that 20% of households use spring water for drinking purposes, either exclusively or combined with other modalities. The table demonstrates the want of access to water by the surveyed islands' inhabitants, since none of the categories offer safe origin regarding water quality with the exception of purchasing mineral water.

The survey revealed that 44.3% of the Grande Island population interviewed do not treat water for ingestion in any way; in other words, these are residents who, regardless of the source of water (mineral, bought, brought from Acará or Belém or extracted from neighbours' wells), do not subject the water they use for drinking and cooking to any kind of special treatment. The remainder of residents (55.7 %) declared they treat the water reserved for these purposes in one or more ways. On Murutucu Island, of the 131 families interviewed, 39 (29.8 %) did not treat water in any way. The high number of families on both islands who do not treat water in any way points to a worrying impact on the health of residents due to the probable use of contaminated water.

With the intention of relating the influence of population schooling levels with the provision of water treatment, the data were given statistical treatment, shown in Table 2. With this information in hand, it was possible to check that paradoxically, the part of the population which theoretically had less access to education had a healthier behaviour towards water treatment. A significant part of the people who had higher levels of education (finished primary school, unfinished secondary school, and even graduates) did not treat water properly. This draws attention to the need for action by health agents on health education related to water use.

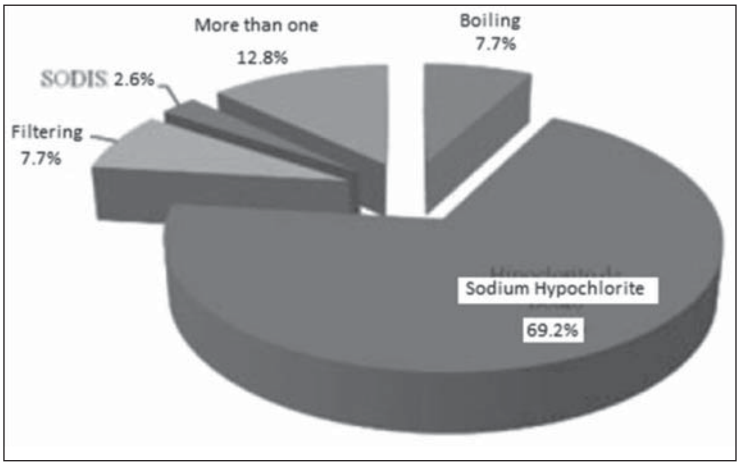
Table 2. Relationship between population schooling and water

treatment.

Schooling	Treatment	
	Yes	No
Never attended school	69,6%	30,4%
Incomplete elementary school up to 4th grade	76,2%	23,8%
Complete elementary school up to 4th grade	73,9%	26,1%
Incomplete elementary school 5th to 8th grade	59,3%	40,7%
Complete basic education	28,6%	71,4%
Incomplete secondary education	43,7%	56,3%
Complete secondary education	63,6%	36,4%
Complete higher education	66,7%	33,3%
Post-graduated	0,0%	100,0%
Total	**65,2%**	**34,8%**

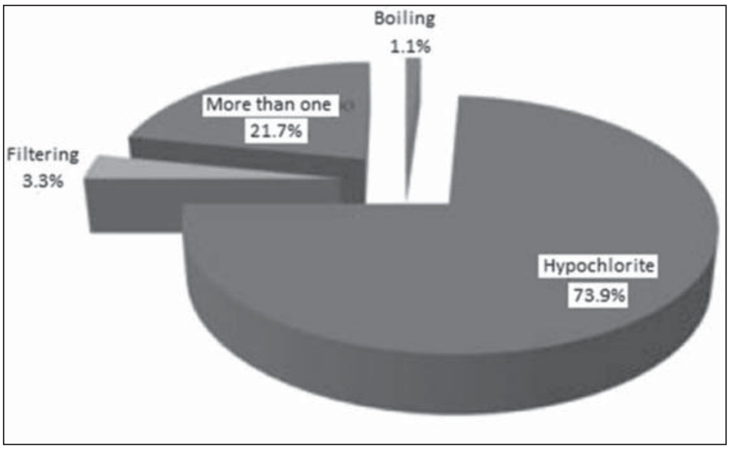
Source: Veloso (2012).

Water treatment options emphasised in the survey were: boiling, filtering, adding sodium hypochlorite or aluminium sulphate, exposure to ultraviolet rays by solar radiation (Sodis), and a combination of two or more treatments. The water treatment profiles of the Grande Island and of the Murutucu Island households are shown in Figures 5a and 5b, from which it is possible to identify more clearly the reality experienced by the islands' inhabitants. The most usual water treatment method was the use of sodium hypochlorite.



Source: Veloso (2012).

Figure 5a. Characterisation of water treatment type on Grande Island.



Source: Veloso (2012).

Figure 5b. Characterisation of water treatment type on Murutucu Island.

In fact, the characterisation of the type of water treatment practiced on each island revealed a coincidence regarding the use of sodium hypochlorite. This may have occurred due to easy access to it, which is periodically distributed by local health agents. This is a strong indicator of institutional efficiency in the municipality of Belém with regard to the proportional distribution of this substance through island locations.

On Grande Island, the survey indicated that 41.4% of the residents interviewed admitted to having had a household member affected by typical symptoms of water-borne diseases over the previous six months: stomach pain, diarrhoea, dark urine, itching. Of this total, 75% said that these had occurred from one to three times in the previous six months.

The same survey showed that on Murutucu Island, 39.7% of residents said that a household member had had some of the water-borne disease symptoms over the previous six months. Of this total, approximately 70% said that the symptoms had occurred one to three times in the previous six months. It is noteworthy that 21.1% of respondents said that diseases bearing the characteristic symptoms of contaminated water use appeared seven or more times in their family members.

However, this information is controversial. The symptoms occurred in opposition to what 70% of the Murutucu Island respondents say regarding water treatment. Either way, it can be inferred that the treatment given to water is either inadequate or insufficient[2]. The questions that come up are: how can there be so many cases of disease in families that treat their water? Why is the sodium hypochlorite treatment not being effective?

2. The sustainability of Saacs on Grande Island and Murutucu Island

The analysis of Saacs sustainability took into consideration the acceptance of and access to the system proposed, the financial evaluation of the systems, their impact on the residents' income and the monitoring of water quality standards. These were considered key aspects in the research for the success of the water supply model in relation to management and sustainability.

With regard to acceptance, the research revealed that 61.4% of Grande Island residents are in favour of rainwater use; on Murutucu Island, 50.4% of respondents already use or would accept using rainwater. Most people on both islands accept using rainwater for drinking purposes. The rate of acceptance on Grande Island was higher, which can be explained by the experience had by a large part of inhabitants, in particular those who had the system. When investigating the reason for not accepting rainwater for use, the most frequent responses were displeasing taste (38.9 %), colour (14.4 %) and smell (7.8 %).

An analysis of access as perceived by the residents showed that they understood it as the water supply modality's ability to be or to become easily accessible through continuous supply, low catchment time and practical collection procedures. For 31.4% of Grande Island residents, using rainwater is the most affordable way to ensure safe drinking water for the local reality. The second most cited form of collecting drinking water was to retrieve it from rivers with the aid of a pump and subsequent treatment (28.6 %).

There was a different opinion on Murutucu Island regarding access to drinking water. Residents considered it easier to pump the water out of a river and subsequently treat it (41.2 %). Alternatives were also evidenced,

[2] This shows the need to analyse data contributed by community health agents and local health centres. Unfortunately, the data are not available.

such as: relying on a rainwater use system (26.7 %), continuing to buy water with no defined origin (14.5 %) or obtaining it themselves from a nearby location (7.6 %).

An analysis of these results combined with field observations helps to understand the local context regarding access to water supply. Islands' inhabitants report being concerned that the volume of rainfall in the Amazonian summer will not suffice for the entire demand for drinking water and therefore do not consider it to be the most sustainable option in terms of quantity.

As for the families that use rainwater supply systems, direct access is imminent since the installation of Saacs brought water supplied to their taps. Residents no longer worry about carrying water in heavy containers for tens or hundreds of metres.

In order to assess the financial sustainability of Saacs, it was necessary to investigate the local context and to estimate the impacts that the proposed rainwater model would bring to the population's monthly income. The focus of the exam was on the system's cost analysis and its financial impact on families.

According to Gonçalves (2012), the total cost of the Grande Island system was R$ 2,110.58, whereas the cost of the Murutucu Island system was R$ 1,638.88. As said previously, the most frequent monthly income in both islands is one minimum wage. The model's costs render it incompatible with its acquisition in a single down payment.

As much as 86.4% of riparian residents interested in the system were in favour of sharing it with other families and 52.6% of the respondents interested in the system already had a reservoir at home, which would reduce costs (MAY, 2004). Another way to reduce the system's cost when sharing it would be to erect it in collective spaces such as schools, community centres, churches, associations, and others. This alternative should be considered in collective supply.

In order to determine drinking water use, a demand of 5 litres/resident/day (GONÇALVES, 2012) was adopted. From this estimate, a family of four members receiving the above-mentioned amount will use a total of 20 litres a day, which adds up to a monthly need for 600 litres. With the purchasing price at R$ 2.00 per 20 litres, there will be an expense of R$ 60.0/month on water. This is equivalent to 11% of the minimum wage at the time of the survey. Therefore, a considerable percentage of their income is being spent on a resource that has no proven quality.

In a hypothetical situation in which the inhabitants of the islands would buy water every day to meet the same demand for water as used in sizing the systems (95l/day in Grande Island, with 19 users, and 70l/day on Murutucu Island, with 14 users), the expenditures would be far higher than the cost of erecting a Saac. Table 3 illustrates the characteristics of the example formulated.

Table 3. Daily, monthly and yearly expenditures on water, considering the system's design flow on each island.

Location	Water demand litres/day	N° of users catered for	Daily cost of purchasing water (R$)	Monthly cost of purchasing water (R$)	Yerly cost of purchasing water (R$)	Cost to erect the system (R$)
Ilha Grande	95	19	9,50	285,00	3.467,50	2.110,58
Ilha Murutucu	70	14	7,00	210,00	2.555,50	1.638,88

Source: Gonçalves (2012).

If locals gathered to save money for one year, in addition to erecting the systems they would have a balance of R$ 1,356.92 on Grande Island and R$ 916.62 on Murutucu Island in relation to the money spent on purchasing water for a period of 12 months. The residents of Grande Island that spend R$ 285,00/month on the purchase of water could install the Saac in just 7.4 months; and the inhabitants of Murutucu Island, in 7.8 months. Considering the context, it would obviously be a better institutional solution in which the government could donate or finance Saacs.

With regard to water quality sustainability, the investigation was targeted to the physicochemical and bacteriological analysis of rainwater samples collected directly from the atmosphere and from various points in the systems – gutter, point of discharge, upper reservoir and lower reservoir. The physicochemical parameters investigated were: apparent colour, turbidity, pH and temperature. The biological parameters investigated were: total coliforms and Escherichia Coli.

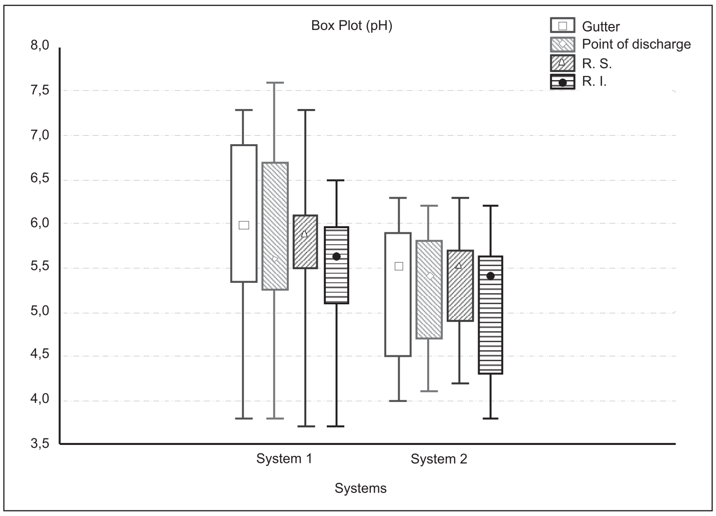
The temperature of the rainwater collected directly from the atmosphere varied between 18.5 and 23.4°C, with an average of 20.8°C. Table 4 displays the characterisation of rainwater in the systems, addressing main temperature figures such as maximum, minimum, average, standard deviation and coefficient of variation.

Table 4. Temperature: maximum, minimum, average, standard deviation and coefficient of variation in the islands' systems, in °C.

	Temperture in the Grande Island system in °C				Temperature in the Murucutu Island system in °C			
Points	**Gutter**	**Point of discharge**	**Upper Reservoir**	**Lower Reservoir**	**Gutter**	**Point of discharge**	**Upper Reservoir**	**Lower Reservoir**
Maximum	25,3	25,2	25	25,1	24,5	24,9	24,7	24,5
Minimum	18,1	18,3	18	17,3	18,1	18,5	18,1	17,8
Average	21,77	21,57	21,59	21,59	21,35	21,49	21,49	21,75
SD	2,35	2,35	2,39	2,58	2,15	2,1	2,26	2,13
CV	0,11	0,11	0,11	0,12	0,1	0,1	0,11	0,1

Source: Gonçalves (2012).

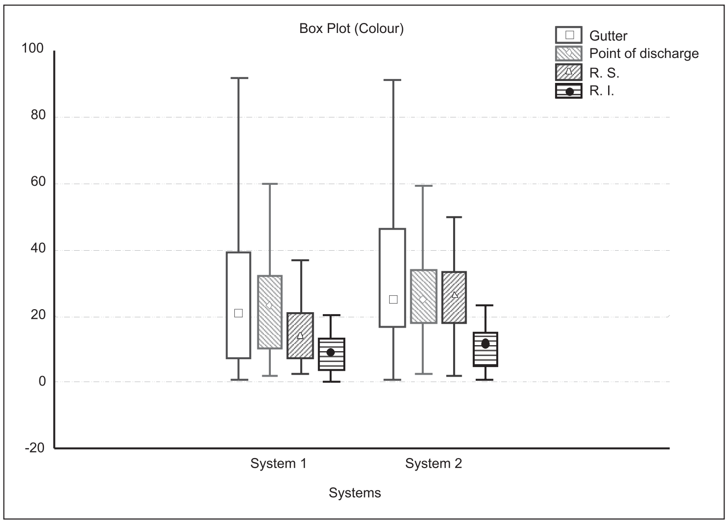
The pH of the rainwater samples collected without having passed over the roofs, i.e., directly from the atmosphere, was acid, with a minimum of 3.9 and a maximum of 6.6. However, in 53.33% of the samples analysed, the pH remained above 5.0. Figure 6 illustrates pH values at the four points analysed in the Grande Island system (System 1) and in the Murutucu Island system (System 2) consecutively, enabling the visualisation of the relationship between the data from the points shown.



Source: Gonçalves (2012).

Figure 6. Box plot of parameter pH in the systems.

In 92.86% of the water samples collected directly from the atmosphere, the apparent colour exhibited values equal to or smaller than 15 C.U., according to the standard stipulated by Decree no. 2914/2011 of the Ministry of Health. Figure 7 illustrates apparent colour values at four points analysed in the systems.

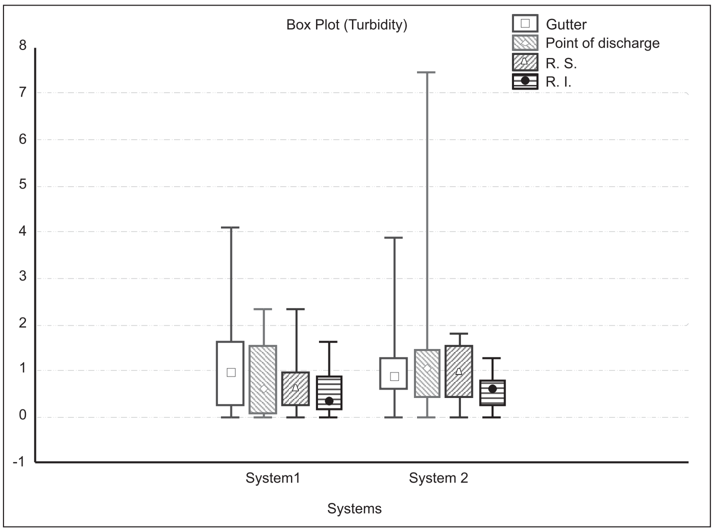


Source: Gonçalves (2012).

Figure 7. Box plot of parameter colour in the systems, in C.U.

The filter proposed for use in this work does not fall into the rapid filtration category or in the slow filtration category; even so, turbidity values will be evaluated in accordance with the VMP for slow filtration, i.e. 1 UT, as per Decree no. 2914/2011 of the Ministry of Health.

Of the water samples collected directly from the atmosphere, 73.33% were below the value recommended in the standards, with a minimum value of 0 TU, a maximum value of 3.26 TU and an average value of 0.9 TU. Figure 8 presents turbidity data in both systems.



Source: Gonçalves (2012).

Figure 8. Box plot of parameter turbidity in the systems, in TU.

Saacs proved to be efficient in removing turbidity in both systems; however, high figures were detected in the first system points. Turbidity in the system 1 gutter ranged between 0 and 4.12 TU; in system 2 it ranged between 0 and 3.86 TU. At the point of discharge, the maximum figure fell by almost half in system 1 (2.32 TU). System 2 did not behaved in the same way: there was an increase in turbidity (7.47 TU), which can be attributed to the conditions of that particular roof, where impurities ran through the gutter and were subsequently deposited in the points of discharge. In both systems, the upper reservoirs exhibited less turbidity in relation to the previous point, and in the last point of collection in the systems (lower reservoir or post-filter) almost all of the turbidity was removed, with only one sample remaining from each system with turbidity above 1.0 TU. Turbidity behaviour at all points in the systems can be seen in Table 5. The filter's efficiency in removing turbidity from both systems was 93.33 %.

Table 5. Minimum, maximum and average turbidity figures in the systems, in TU.

Point	Gutter			P. of discharge			Upper Res.			Lower Res.		
Medida	Min.	Max	Aver.	Min.	Max	Aver.	Min.	Max	Aver.	Min.	Max	Aver.
Grande	I. 0	4,12	1,28	0	2,32	0,85	0	2,32	0,66	0	1,63	0,47
Murutucu	I. 0	3,86	1,04	0	7,47	1,38	0	1,8	1,01	0	1,29	0,5

Source: Gonçalves (2012).

Of the 14 water samples collected directly from the atmosphere, 13 were found to have total coliforms and seven, E. coli. Two hypotheses are being considered: the water was probably contaminated during the collection process, since the recipient was exposed to the weather for some 30 to 40 minutes; or the contaminants existed naturally in the atmosphere.

Table 6 displays the bacteriological quality results of the 15 samples from the systems' points. All samples from the gutters, points of discharge and upper reservoirs in both systems had total coliforms. Fourteen samples from system 1 and 15 samples from system 2 had total coliforms in the lower reservoir.

Table 6. Result of the presence of total coliforms and E. coli in systems.

Parâmetro	N° of samples containing microorganisms at each collection point in system 1 (Grande Island)				N° of samples containing microorganisms at each collection point in system 2 (Murutucu Islant)			
	Gutter	Point of discharge	Upper Res.	Lower Res.	Gutter	Point of discharge	Upper Res.	Lower Res.
Total califorms	15	15	15	14	15	15	15	15
E. Coli	15	15	14	6	15	15	13	12

Source: Modified from Gonçalves (2012).

We identified the presence of E. coli in all gutter, discharge points and upper reservoir samples, with the exception of one sample which resulted negative for E. coli in the upper reservoir of system 2. In the lower reservoir, six samples from system 1 and 12 samples from system

2 resulted positive for coliforms. One can infer that the proposed sand filter has little efficiency in the removal of E. Coli.

In general, the physicochemical parameters are within drinking water standards. However, bacteriology still demonstrates the need for improvement, revealing the need to disinfect water – for the time being, sodium hypochlorite is being added by users.

Conclusions

As observed, the interaction of the postgraduate programmes revealed to be a way of bringing supplementary knowledge together to respond to a specific scientific and social demand by Amazonian populations.

In the context of the studies, using rainwater is related with the sustainable development of Belém's islands because it makes it possible to carry out integrated actions within the communities to meet the need for drinking water. The system's sustainability assessment took into consideration quantity, access, cost and quality aspects of the water supplied through Saacs.

The systems have been proved feasible in terms of quantity, facilitated access and cost, with great possibilities of being purchased. However, improvements are expected in terms of water quality, especially with the introduction of more efficient disinfection than the use of sodium hypochlorite.

In general, the contributions by PPGEDAM and PPGEC demonstrate that rainwater management meets local needs, establishes rational water management, decreases risks to human health and facilitates access to safe drinking water. This contributes to human development and the improvement of living conditions among riparian communities, and can certainly be used as a model for other Amazonian populations under similar conditions.

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