revista tecnologia e sociedade

Revista Tecnologia e Sociedade
ISSN: 1984-3526

https://periodicos.utfpr.edu.br/rts

Sustainability of rain water supply technologies: a methodology applied to Belém county islands

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ABSTRACT

In the Grande and Murutucu islands, county of Belém, Pará state, lack of drinking water is the major challenge to improve the quality of life of river bank inhabitants, because they use the rivers as main source for water consumption without any treatment. This was a key fact for caring out studies that lead to the deployment and implementation in 2011, of two Rain Water Utilization Systems (RWUS), one in each island previously mentioned. Therefore, this study aimed to evaluate the sustainability of these supply technologies, adapting the Barometer of Sustainability tool, through the definition of 5 dimensions and their respective topics and indicators, allowing to identify that the RWUS

KEYWORDS: Drinking water. Rain. Utilization. Barometer of Sustainability. Island.

INTRODUCTION

Social and environmental problems resulting from socioeconomic integration between the world societies are not easily mitigated. This is due to the fact that human society, as a complex system, must understand the dynamics of this system in order to achieve sustainable development, by adopting appropriate criteria to monitor the changes brought about by intervention processes in the environment, and to minimize harmful practices (MENDES et al., 2012; TAYRA; RIBEIRO, 2006; FENZL; MACHADO, 2009).

Water management could be considered one the most important human intervention processes in order to establish a more balanced relationship between society and the environment, mainly because it grants population access to a basic quality water supply service. This could be a major aspect if one considers that various regions of the world are experiencing a steady decline in water quality offer.

The importance of water management, as well as, the need to avoid a merely discursive sustainable development debate, were decisive factors for conducting research in rural and peri-urban areas of the Amazonian cities, for example, the Grande and Murutucu islands, located 12,2 Km and 9,29 km south of Belém (State of Pará), namely, which are the focus of this research.

Since 2008, the Research Group of Rainwater Utilization, Sanitation and Environment in the Amazon (GPAC-Amazon, at Federal University of Pará), has been targeting the use of rainwater utilization as main strategy for the region's water resources management, by understanding the importance of the rational use of natural resources and also the need to preserve them. This concept led to the development and implementation, in 2011, of two Rainwater Harvesting Systems (SAAC), one on each in aforementioned islands.

However, Hardi et al. (1997), Van Bellen (2002) and Miranda e Teixeira (2004) emphasized the need to use criteria that point out the degree of sustainability of such intervention measures, in order to enable a proper analysis of social technology. Therefore, this article aims to present results from the application of an evaluation method, adapted with the *Barometer of Sustainability* tool, in order to enable comparisons and reflections on socioeconomic, political-institutional and environmental aspects, which eventually contributed to the implementation of the two SAACs or that were caused by their implementation.

SUSTAINABILITY INDICATORS

The launch of the sustainable development concept in the 1980's, and its popularization after the United Nations Conference on Environment and Development (Rio-92), highlighted the need to define development standards, which consider environmental, economic, social, ethical and cultural aspects (TAYRA; RIBEIRO, 2006; RAULI; ARAÚJO; WIENS, 2008).

The paradigm shift made the adoption of indicators for human intervention in the environment possible. Thus, reflecting on development goals progress and preventing harmful practices continuation (MENDES, 2005).

The adoption of these indicators constitutes a systematic and also synthetic way to gather and transmit technical and scientific information. Thereby preserving the essence of the original data, and also facilitating periodic monitoring and assessment of conditions and trends by gathering and comparisons. Therefore, these indicators should be constructed based on consistent measurement methodology, whether they are quantitative or qualitative ones.

Fenzl and Machado (2009) warn that in order to develop operational instruments of intervention in biological systems, ecosystems, sociosystems or towards problems related to sustainable development, one must analyze constituent parts and inter relations, as well as the relations between a whole set of parts and the environment.

According to this systemic approach, also adopted in this article, the objective here is the construction of a set of indicators, which show binding and/or synergistic tendencies. According to Tayra and Ribeiro (2006), this could be explained because analysis of variables may show the main trends, tensions and causes of sustainability's problems, and, therefore, play the role of revealing complex processes of simpler and more representative information, in a way to provide foundation to future decision making.

At the present, despite numerous initiatives and a large existing literature on the subject, there is no specific science that considers sustainable development of society as its main unique target. Hence, there is a need to create theoretical and methodological bases capable of building scientific instruments to transform our societies and make them more sustainable (FENZL; MACHADO, 2009).

In this sense, promising attempts regarding the need to quantify and qualify the energy-material flows emerge, among of which it is possible to cite the PSR model (*Pressure-State-Response*). PSR is among the most popular models in terms of sustainable development measurement. In the late 1980's the first version of PSR model was developed by the Organization for Economic Cooperation and Development (OECD), and it was used in the elaboration and publication of one of the first reports on environment state (VAN BELLEN, 2002; KLIGERMAN et al., 2007; SIENA, 2008).

> "[The PSR model] (...)is based on a concept of causality: human activities exert pressures on the environment, modifying its quality and quantity of natural resources; the society, in its turn, responds to these changes through environmental, economic and sector policies" (KLIGERMAN et al., 2007, p.201).

In 1995, the United Nations Commission on Sustainable Development (CSD) adopted the method of evaluation *Driving Force-State-Response* (DSR), developed from the PSR system through the replacement item *Pressure* (P) by *Driving-Force* (D) to make it possible to incorporate social, economic and institutional sustainable development (VAN BELLEN, 2002). The system is well known because of its indicators are divided into four interrelated major categories: social, economic, environmental and institutional.

Over the years, the method adopted by the CSD has undergone several changes due to experts' criticism. First, it had to be organized into topics and subtopics, as it was also initiated the discussion on the division of indicators in essential and non-essential, given that indicators considered important in some regions are not to others. In 2003, alternatives were discussed to improve the DSR methodology regarding the aggregation of indicators; however, there were not many advances.

Siena (2008) reports that the latest version consolidates the essential indicators of division (40), non-essential (39) and other indicators (13) and although the methodology, in general, becomes more flexible and more comprehensive by user, issues related to aggregation of topics and subtopics remain open.

On the other hand, Van Bellen (2002) and Kronemberger et al. (2008) highlight the System Assessment Method (SAM) as an example of model, which improves the measurement of the multiple processes involving the encompassing concept of sustainable development. It is a systemic method, developed by various experts from World Conservation Union (IUCN) and International Development Research Centre (IDRC) institutes that make use of the *Barometer of Sustainability* (BS) as a tool, which is why the method is also known by this name.

To Prescott-Allen (2001), the BS is the only measurement tool designed so that an increase in environmental quality does not mask a decline in the well-being of society or vice versa.

In the BS, the indicators are selected by means of a hierarchical method, starting with the system definition and objectives, in order to reach the measurable indicators and their performance criteria. After the calculation of the indicators, these are combined to result two indexes - human well-being and the ecosystem indexes - which are presented in a two-dimensional chart that has relative scales ranging from 0 to 100, indicating a bad and good situation in relation to sustainability.

The performance criteria of the *Barometer of Sustainability* – desirable, acceptable, transitional, undesirable and unacceptable - defined for each indicator is illustrated in Table 1, allowing measurements of the indicators conversion through the BS scale.

Table 1 - Scales of the *Barometer of Sustainability*.

Sector	Interval	Definition
Sustainable	81-100	Desirable performance
Potentially Sustainable	61-80	Acceptable performance
Intermediate	41-60	Transition phase
Potentially unsustainable	21-40	Undesirable performance
Unsustainable	1-20	Unacceptable performance

Source: Adapted from Prescott-Allen (2001).

METHODOLOGY

This paper adopted the method based on the general concept behind the BS, using the general principles of sustainability considered by Sachs (1993) as theoretical background. Thus, the option was to consider the system consisting of dimensions, issues and indicators.

The dimensions were considered equally important and, because of this, it was decided to represent them by their respective indexes in radar charts, in order to show the sustainability assessment of SAACs and to promote reflection and debate about the crucial factors for the sustainability.

Therefore, five sustainability dimensions were defined (social, economic, technical-operational, environmental and political-institutional). These were subdivided into eight themes and their respective indicators (in total there are fourteen indicators), according to Table 2. The themes and indicators were selected so as to be representative for each dimension in order not to only assess the rainwater utilization system, but also the interaction processes that indicate the potential local use of this technology.

Table 2 - Scales of the *Barometer of Sustainability*.

Dimensions	Themes	Indicators
Environmental	Rain Water (Atmosphere)	pH
		Average rainfall
Social	Education	Population with 15 years or more of study
	Acceptability	Interest by SAAC
Economic	Investments and Benefits	Time of return of capital (TRC)
		Benefit / cost ratio (B/C)
Political-Institutional	Environmental legislation	Existence of environmental laws
	Social Organization	Representation of civil society in the Environment Council
		Existence of local social organizations
Technical-Operational	SAAC water volume	Provided water
	SAAC water quality	Total coliforms (drinking water)
		Escherichia coli
		pH (lower reservoir)
		Turbidity

Source: Prepared by the authors.

Development of performance indicators scales

Kronemberger; Carvalho; Clevelario Junior (2004) claim that performance scales can be used to evaluate the indicator situation in relation to the objective, standard or pattern for different periods, detecting advances or drawbacks. The use of performance scales - one of the fundamental characteristics of the BS - allows combining different indicators coherently from a common unit so that there is no distortion (PRESCOTT-ALLEN, 2001; VAN BELLEN, 2002; SIENA, 2008).

Therefore, and in a manner analogous to the scale of the Barometer of Sustainability (BS), a Performance Indicator Scales (EDLx) here implemented were divided into five intervals set by values representing the varying conditions from sustainable to untenable level.

Since the boundaries of the EDL ranges for each indicator were defined based on standards or official standards established at national or local level or were arbitrarily defined or where there are targets or standards determined and are presented in summary form in Table 3.

Therefore, by establishing the reference values shown in Table 3, it was possible to define the limits of the EDLx intervals for each indicator, which correspond to the interval values of the BS, as observed in Table 4.

According to Kronemberger; Carvalho; Clevelario Junior (2004), the definition of these limits in EDLx seeks to interpret the concept of integrated and sustainable local development (DLIS). For this reason, Table 4 shows that some indicators have the limits of all EDLx intervals. For instance, the indicator Population with 15 years or more of study, whereas others do not have all the EDLx ranges. This actually happened, for example, with the *Escherichia coli* and *Fecal Coliforms* indicators, because they do not represent amounts considered outside the context of DLIS, and it was just not possible to admit intermediate values rather than the ones established by normative health standards.

Table 3 - Themes, indicators and reference values for the EDLx elaboration.

Theme	Indicator	Reference Values for the Performance Scale
Rain water	pH (Atmosphere rainwater)	"[...]is considered normal when it is equal to or greater than 5.6, slightly acid of 5 to 5.6 or acid when its value is smaller than 5" (CUNHA et al, 2009, p.341)
	Average rainfall (mm)	Values below 77 mm on Murutucu Island and 68 mm on Grande Island are unsustainable (GONÇALVES, 2012). And considering the historical data of the National Institute of Meteorology (INMET), the 6 months with the lowest rainfall (125-177mm) were classified as potentially sustainable and the months of the rainy season as sustainable (values ≥ 239 mm).
Education	Population with 15 years or more of study (%)	Data from the Brazilian Institute of Geography and Statistics (2012), therefore, the value of the best case at the national level - Federal District (24,6%) – was divided into five approximate intervals.
Acceptability	Interest for SAAC (%)	The residents of the Grande and Murutucu Islands had great interest in acquiring, 83% and 74%, respectively (VELOSO, 2012). Therefore, interest above 80% was taken as sustainable.
Investments and Benefits	Time of Return of Investment (TRC) (months)	According to Dias, Athayde Junior, Gadelha (2007), the undiscounted TRC corresponds to the time required to return the initial investment, disregarding the increase in monetary quantities during the analysis of the project. Since the systems were installed in August 2011, the useful life of 76 months was considered, so this value was divided into approximate intervals.
	Benefit / Cost Ratio (B/C)	According to Dias, Athayde Junior and Gadelha (2007), the SAACs were analyzed by comparing the costs necessary for the installation of the systems and the tangible benefits related to savings with the purchase of water for 12 months.

Theme	Indicator	Reference Values for the Performance Scale
ENVIRONMENTAL LEGISLATION	Existence of environmental laws	Based on the analysis of environmental laws instituted in the city of Belém, was defined as the sustainable existence of laws that encourage the implementation of SAACs (equivalent to 100).
SOCIAL ORGANIZATION	Representation of Civil Society in the Environment Council (CMMA) (%)	In this study, it was considered a new form of environmental management with greater involvement of civil society. Therefore, the percentage of 50% or more representation in the municipal council was defined as sustainable.
	Existence of local social organizations	Based on Silva (2010), the existence of local social organizations was taken as sustainable condition (equivalent to 100). Since the absence of such organizations represent an unsustainable situation (value of 0).
SAAC WATER VOLUME	Water Supply (L per capita / day for drinking and cooking)	Based on Gonçalves (2012), the authors considered the average daily consumption of local people for drinking, washing and cooking food (5L). The daily supply equal to or higher than 5L was taken as sustainable.
WATER QUALITY OF SAAC	Total Coliforms (%)	It adopted as the sustainable in the absence of total coliforms in 100% of the samples with respect Brazil (2011).
	Escherichia coli (E. Coli)	The absence of Escherichia coli in 100% of the samples was adopted as sustainable, in ways that respect Brazil (2011).
	pH	It was defined as the sustainable range from 6.0 to 9.5, in ways that respect Brazil (2011).
	Turbidity (UT)	Values equal to or less than 1.0 TU were considered sustainable, respecting Brazil (2011).

Source: Prepared by the authors.

Table 4 – Local Performance Scale (EDL) of each indicator and its association with the Scale of Barometer of Sustainability (EBS).

Sustainable Development Indicators (IDS)	Scale of Barometer of Sustainability (EDS)				
	0 – 20	21 – 40	41 – 60	61 – 80	81 - 100
	IN	PI	INT	PS	SU
	Local Performance Indicators Scale (EDL)				
pH (Atmosphere rainwater)	<5,0	-	-	5,0 - 5,5	≥ 5,6
Average rainfall (mm)	<77* <68**	-	-	125-177	≥ 239
Population with 15 years or more of study (%)	1 - 5,4	5,5 - 9,9	10 - 14,4	14,5-18,9	≥19-24,6
Interest for SAAC (%)	0– 20	21 – 40	41– 60	61– 80	81 –100

Sustainable Development Indicators (IDS)	Scale of Barometer of Sustainability (EDS) 0 – 20 IN	21 – 40 PI	41 – 60 INT	61 – 80 PS	81 - 100 SU
	Local Performance Indicators Scale (EDL)				
Time of Return on Investment (TRC) (months)	≥77	76-58	57-39	38-20	19-1
Benefit / Cost Ratio (B/C)	0 – 20	21 – 40	41 – 60	61 – 80	81 -100
Existence of environmental laws	0	-	-	-	100
Representation of Civil Society in CMMA (%)	<50,0	-	-	-	≥50,0
Existence of local social organizations	0	-	-	-	100
Water Supply (L per capita / day for drinking and cooking)	0 - 4,0	-	-	-	≥5,0
Total Coliforms (%)	≥1	-	-	-	0
Escherichia coli (E. Coli)	≥1	-	-	-	0
pH	<6	-	-	-	≥6 - 9,5
Turbidity (UT)	-	-	-	1,63 - 1,1	1,0 – 0,0

IN – Unsustainable; PI- Potentially Unsustainable; INT- Intermediate; PS – Potentially sustainable; SU – Sustainable
* Value for Island Grande; ** Value for Island Murutucu

Source: Prepared by the authors

Assignment of degree to local indicator on BS scale

By defining the local performance scales (EDLx) it was possible to set each numerical values of local indicators (DLx) into EDLx. However, the process demanded a local scale harmonization, since the variability in terms of the BS is high, ranging from o to 100 for sustainability characterization. The scale transposition was then achieved by a simple linear interpolation between Dlx and BSx, which led to the degrees of the local indicators (Table 5). For these cases, Figure 1 illustrates the transposition of scales and the relationship between DLx and BSx, weather EDL is increasing or decreasing.

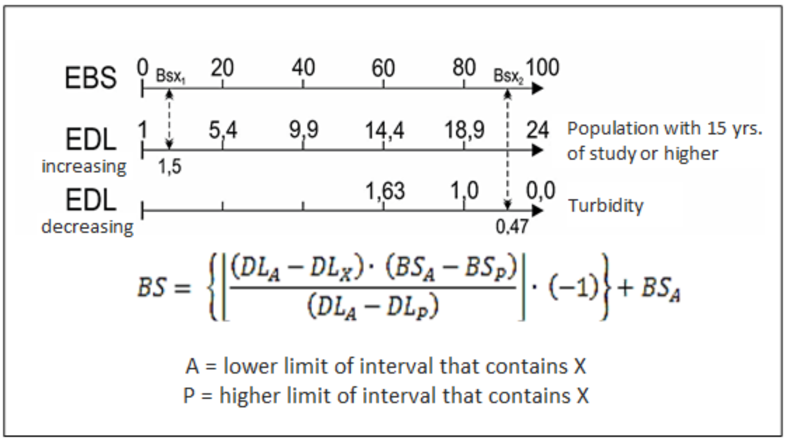
Table 5 - Numeric values of local indicators.

Sustainable development indicators (IDS)	Island Grande IDS (local)	Island Grande DEGREE IDS (BS)	Island Murutucu IDS (local)	Island Murutucu DEGREE IDS (BS)
pH (atmosphere rainwater)	5,2	68,6	5,2	68,6
Average rainfall (mm)	125,4	61,1	125,4	61,1

Sustainable development indicators (IDS)	Island Grande		Island Murutucu	
	IDS (local)	DEGREE IDS (BS)	IDS (local)	DEGREE IDS (BS)
Population with 15 years or more of study (%)	1,5	2,27	1,9	4,1
Interest for SAAC (%)	83	83,0	74,0	74,0
Time of Return on Investment –TRC (Months)	7,3	94,8	9,8	88,3
Benefit / cost ratio - B/C (%)	38,9	38,9	18,7	19,7
Existence of environmental laws	100	100,0	100	100,0
Representation of civil society in the environment council (%)	33	13,0	33	13,0
Existence of local social organizations	100	100,0	100	100,0
Water supplied (L per capita/day)	16	100,0	14	100,0
Total Coliformes (%)	93,3	5,55	100	0,0
E. coli	6,0	20,0	12,0	20,0
pH (lower reservoir)	5,38	52,0	5,0	41,0
Turbidity (UT)	0,47	91,0	0,5	90,5

Source: Prepared by the authors.

Figure 1 - Location indicator of the calculation of the degree of operation in EBS.



Source: adapted from Kronemberger; Carvalho; Clevelario Junior (2004).

Then, the indicators were hierarchically aggregated through arithmetic mean, from the indicator to the theme and from the theme to the dimension, as shown in Table 5.

The indicators were given equal weights in setting the thematic and dimensional indices, being considered as equally important to characterize the situation of each subject and dimension.

Table 6 - Sustainability indices by themes and dimensions.

Combination of results by Theme		
Themes	Indexes (SAAC 1)	Indexes (SAAC 2)
Rainwater (atmosphere)	64,8	64,8
Education	2,3	4,1

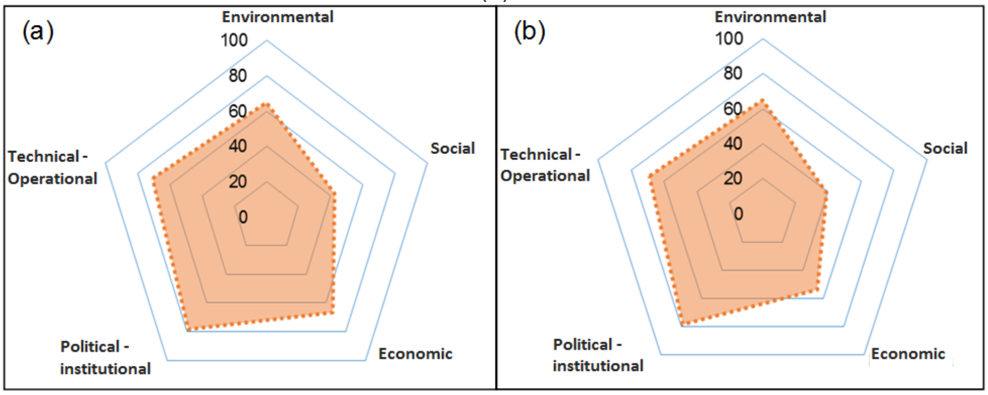
Combination of results by Theme		
Themes	Indexes (SAAC 1)	Indexes (SAAC 2)
Acceptability	83,0	74,0
Investments and benefits	66,8	54,0
Environmental legislation	100,0	100,0
Social organization	56,5	56,5
Water Volume of SAAC	100,0	100,0
Water quality of SAAC	42,1	37,8
Combination of Results by Dimension		
Dimensions	**Indexes (SAAC 1)**	**Indexes (SAAC 2)**
Environmental	64,8	64,8
Social	42,6	39,0
Economic	66,8	54,0
Political-institutional	78,2	78,2
Technical Operational	71,0	68,9
Combination of results by SAAC		
Island	**SAAC 1**	**SAAC 2**
Grande	67,4	----
Murutucu	-----	61

Source: Prepared by the authors.

RESULTS AND DISCUSSION

Figure 2 presents the previously calculated indices of the five dimensions in the form of radar graphs. Therefore, it facilitates the comparison between the two supply systems (SAAC 1 – Island Grande and SAAC 2 – Island Murutucu) and their assessment with regard to sustainability.

Figure 2 - Representation of the indices of sustainability dimensions: (a) SAAC 1; (b) SAAC 2 (b).



By interpreting the graphs in Figure 2, it is possible to observe that the performance of the two systems is similar. For example, with regard to the environmental dimension, the SAACs 1 and 2 are potentially sustainable. This assessment is confirmed by both the average annual rainfall of Belém (2,533.6 mm), considering data from the National Institute of Meteorology (INMET), as well as the pH value above 5.0 in approximately 74% of rainwater samples collected directly from the atmosphere in the islands Grande and Murutucu.

As for the Social dimension, this showed the worst performance. The SAACs 1 and 2 reached intermediate degree (index 42.6) and potentially unsustainable (index 39.0), respectively. Among the themes that constitute this dimension (see Table 6), the Education theme was the one that reached the lowest level (indexes 2.3 for SAAC 1 and 4.1 for SAAC 2).

The low classification reached by the theme Education may indicate, *a priori*, that the locals may face difficulties in understanding the maintenance of these supply technologies. However, the poor performance in relation to formal education can be mitigated by health education and environmental actions, because according to Andrade Neto (2003); Miranda (2011), environmental education is an integrative instrument, allowing the involvement of the communities´ members to be benefited by the supply of technologies, promoting self-assessment and appropriation of new techniques.

The indicator for the Interest of SAAC – which also constitutes the Social Dimension - presented the best performance within this dimension (indexes 83.0 for SAAC 1 and 74.0 for SAAC 2). That much so in the evaluation of SAAC 1 this reached sustainable degree and SAAC 2 showed potentially sustainable level (data present in the Table 6).

However, the unacceptability of 100% of the population of both islands in the system has allowed assessment by means of observation *in loco* that some riparian have doubts about the quality of rain water for human consumption. Furthermore, the use of a supply technology requires a change of attitude for those (locals) that has always had their lives determined by the dynamics of water in the Amazon, including for their own water consumption.

Consequently, this study ratifies the need for the members of local communities to participate in health education and environmental activities, in order to take ownership of scientific knowledge underpinning the SAAC. That is so, according to Andrade Neto (2013), rainwater will soon be judged as the safest water for human consumption.

With regard to the Economic dimension, it reached a potentially sustainable performance SAAC 1 and Intermediate 2 in SAAC. The Indicator Time of Return on Investment achieved the highest performance in this dimension - indices 94.8 for SAAC 1 and 88.3 for SAAC 2 (refer to Table 6). In this scenario, it was possible to infer that if the monthly local inhabitant's expenses to purchase water of doubtful quality were invested in SAACs, these technologies would be paid in approximately 7 and 10 months in Great islands and Murutucu, respectively.

The indicator Benefit/Cost Ratio presented a lower performance in that dimension (economic dimension) - indexes 38.9 for SAAC 1 and 19.7 for SAAC 2. The assessment of this indicator considered the possibility of payment of SAAC by each user family, comparing the value of the system with the reduction of the expenses of the beneficiaries of SAACs 1 and 2 with the purchase of water within an annual cycle.

But it is necessary to emphasize that investments in SAACs may not correspond to such significant short-term advantages. However such alternatives can lead to great benefits in the medium and long terms, as a significant reduction in purchase of water cost - considering a period longer than 12 months, and hospitalization and medicines due to waterborne diseases.

Investing in sanitation produces benefits in many sectors such as health, environment, and economy ones. It is estimated that for every dollar invested in sanitation, one could save up to 4.3 US dollars in global health and the Gross Domestic Product (GDP) to grow by around 1.5% (OMS, 2014).

The dimension that contributed most positively to the assessment of systems was the Political and Institutional. In this dimension, SAACs 1 and 2 were classified as potentially sustainable, achieving the index 78.2 (index observed in Table 6).

The assessment of sustainability of Political and Institutional dimension was carried out by identifying local environmental policies and spaces for social participation that can ensure the reapplication of water supply technologies such as public policy.

Thus, the assessment of the systems for the Existence of Environmental Laws indicator showed that the systems are sustainable - the SAACs 1 and 2 obtained the index 100.0 - mainly due to the creation of the Municipal Environmental Policy (PMMA) in 2003. This policy encourages the development of technologies that provide the rational use of natural resources.

As for the indicators related to the topic Social Organization, the indicator Existence of local social organizations was able to evaluate the two SAACs as sustainable - SAACs 1 and 2 obtained the index 100.0 - due to the existence and operation of local social organizations[1] .

The importance of social participation in the process of reapplication of social technologies is also seen in the context of the Brazilian semiarid region by Soares Júnior e Leitão (2017). According to these authors, the implementation of water tanks by programs such as the One Million Cisterns Program (P1MC) which has social mobilization and actions of sanitary and environmental education. This process of social mobilization is translated not only in quantitative terms through the number of cisterns constructed, but by promoting new forms of participation and popular organization.

The Technical and Operational dimension also contributed positively to the evaluation of systems. In this dimension, SAACs 1 and 2 were classified as potentially sustainable - obtained indices 71 and 68,9, in a respective way (see Table 6).

The indicator Water Supplied obtained the highest classification in this dimension (index 100.0 for the two SAACs), since the systems provide a greater volume of water than the daily consumption by the families on the islands Grande and Murutucu for drinking, washing food and cooking. On the other hand, the Total Coliforms indicator achieved the worst performance - indexes 5,55 for SAAC 1 and 0,0 for SAAC 2 (refer to Table 5), being classified as unsustainable.

Meanwhile, even with low performance of SAACs regarding bacteriological patterns (Total Coliformes and *E. coli*), the user of SAAC 1 mentioned that cases of diarrhea and abdominal pain have reduced among users of the system families. As such information could not be confronted with local health indicators due to the lack of official data, the GPAC Amazonia researchers attributed this reduction to the behavioral change from the health and environmental education actions promoted by UFPA, according to Andrade Neto (2003, p.4), "[...] the better the levels of sanitary and environmental education and knowledge of hygienic practices of users, the safer the water quality in cisterns".

Thus, from the observation of Figures 2a and 1b, one can infer that SAACs 1 and 2 are in a potentially sustainable situation. This condition is corroborated by the sustainability indexes of SAAC 1 and SAAC 2 (see Table 6), by the areas occupied by the polygons in the figures mentioned and by the smaller angularity between the vertices of the polygons. According to Fenzl, Mendes and Fernandes (2010), in radar graphs, the larger the area occupied by the polygon and the lesser angularity of its vertices, the greater the sustainability degree.

FINAL CONSIDERATIONS

The islanders of Grande e Murutucu, similar to what occurs in many rural communities in the Amazon, consume water withdrawn directly from the river which is possibly compromised by anthropogenic actions. Therefore, many of the local population show some interest in the implementation of alternatives that enable their access to clean water, and consequently, provide reduction on water pathologies incidence.

At the same time, the implementation of projects in rural areas that promote changes in culturally ingrained attitudes must be done in a joint and dialogued manner so that the local inhabitants recognize such actions as promoting their welfare, and this process of social transformation implies understanding the reality. With regard to the aforementioned is why the GPAC Amazonia researchers believed that it was of fundamental importance to carry out a systemic analysis of the communities contemplated by the SAACs from the application of an evaluation of the proposed sustainability thereof.

Thus, this research adopted a manner to operationalize the evaluation of sustainability considering dimensions, themes and indicators. These data were grouped through thematic indexes, dimensional indices and sustainability index of each SAAC. In a general way, the results obtained indicate that the performance of SAACs 1 and 2 correspond to a potentially sustainable condition.

Regarding the indices of sustainability dimensions, the best performance was the political-institutional dimension; while the social dimension had the lowest performance. While it is important to note that no dimension reached the minimum ratio (unsustainable degree).

The index reached by the social dimension indicates the need for continuous actions of sanitary and environmental education. With respect to the performance observed in the economic dimension, more precisely with regard to SAAC 2, warns about the need for organization of social actors to ensure the institution of SAACs as public policy.

Nevertheless, there is still the need for further studies in order to define which actions will be taken to achieve the coveted sustainability. Further analysis of water, for example; the assessment of other aspects of the economic dimension such as reduction of expenses with medicines, decrease in the number of days not worked, and hospitalizations due to SAACs propitiate the cooling occurrences of waterborne diseases. Thus, some indicators were not included in this study because of the lack and/or absence of data.

Therefore, the realization of this evaluation by pointing out weaknesses in SAACs, indicates the need to carry out new studies, but also points to a path where there is the possibility of evolution of the proposed methodology for assessing sustainability, encouraging the birth of a process in which social actors no longer passively adjust to the ongoing transformation processes, and planners in the public and private sector will be fitted to develop social policies considering local peculiarities.

Sustentabilidade de tecnologias de abastecimento de água de chuva: modelo de avaliação para ilhas do município de Belém

RESUMO

Nas ilhas Grande e Murutucu, que integram o município de Belém, estado do Pará, a falta de água potável é um dos grandes desafios para a melhoria da qualidade de vida de seus habitantes. Ainda é comum o consumo de água dos rios locais sem nenhum tipo de tratamento. Este contexto foi decisivo para a realização de pesquisas que culminaram no desenvolvimento e implantação de dois Sistemas de Aproveitamento de Água da Chuva (SAACs), um em cada ilha mencionada. O presente artigo tem como objetivo relatar e discutir resultados de pesquisa realizada sobre a avaliação da sustentabilidade dessas tecnologias de abastecimento para os ribeirinhos belenenses. Para tanto, empregou-se uma adaptação da ferramenta Barometer of Sustainability, por meio da definição de 5 dimensões e seus respectivos temas e indicadores, cujo resultado permitiu constar que os sistemas de aproveitamento de agua de chuva desenvolvidos são potencialmente sustentáveis e constituem solução de engenharia que pode promover o desenvolvimento social e melhorar a qualidade de vida da população

PALAVRAS-CHAVE: Água potável. Chuva. Aproveitamento. Barômetro da Sustentabilidade. Ilhas.

NOTES

[1] Information on the latter indicator was obtained during field surveys, since the government was consulted and it does not have systematic data on the existence of social groups in rural communities of Belém.

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Recebido: 20 fev. 2018.

Aprovado: 22mair. 2018.

DOI: 10.3895/rts.v14n34.7839

Como citar: SILVA, A. D. da, *et al.* Sustainability of rain water supply technologies: a methodology applied to Belém county islands. **R. Tecnol. Soc.,** Curitiba, v. 14, n. 34, p. 63-81, out./dez. 2018. Disponível em: <https://periodicos.utfpr.edu.br/rts/article/view/7839>. Acesso em: XXX.

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