Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

REVISTA AIDIS

de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica.

WATER LOSS MANAGEMENT, INTERVENING FACTORS IN BAHIA ACCORDING TO TYPE OF SERVICE PROVIDERS

Jossy Mara Simões Cardoso [1]
* Patrícia Campos Borja [2]
Renavan Andrade Sobrinho [3]

Recibido el 12 de abril de 2020; Aceptado el 13 de enero de 2021

Abstract

In Brazil, water losses in public supply systems are still a challenge, with the national average (~ 34%) being much higher than countries like Japan or Germany, which have reduced their rates close to 10%. Despite the importance of the topic, studies that investigated the causes of losses in different types of service providers are still incipient. Thus, this article aims to discuss the factors that have influenced water losses in service providers in Bahia. The study presents a scenario of water losses and develops an investigation in four municipalities, two are served by municipal authorities and two by the state concessionaire Embasa. The investigation involved the analysis of selected indicators and the application of questionnaires with technicians and managers. In 2018, the average distribution loss index reached 27%, below the national average. In this study, it was found that the water supply systems operated by Embasa performed better, especially regarding water losses, macro-measurement, hydrometering and micro-measurement. The municipalities presented difficulties with a performance between unsatisfactory and very unsatisfactory, with emphasis on micro-measurement gauging (average score1.0), water loss policies (1.0), partnerships (0.8), team incentives (1.1), planning (1.2) and new technologies (0.9). It was found that the investments made by Embasa, its planning and the incentives of financing agents certainly contributed to its performance. Conversely, public policies and the basic sanitation financing model have made it difficult for municipalities to access resources, contributing to their weaknesses.

Keywords: types of service provision, water supply, water losses.

[1] Unidade Regional de Itabuna da Empresa Baiana de Águas e Saneamento, Brasil.
[2] Departamento de Engenharia Ambiental, Mestrado em Meio Ambiente, Águas e Saneamento, da Universidade Federal da Bahia, Brasil.
[3] Departamento de Engenharia Ambiental da Universidade Federal da Bahia e Empresa Baiana de Águas e Saneamento.
* *Corresponding author:* Departamento de Engenharia Ambiental, Escola Politécnica, Rua Aristides Novis, 2, Federação, Salvador-Bahia-Brasil. Postal Code. 40210-630. Email: borja@ufba.br; patborja@gmail.com

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

Introduction

The control and reduction of water losses are important for the performance of service providers. High losses imply the increase in water demand levels, the need for new sources to feed supply systems and the consequent increase in tariffs due to the escalation in expenses of service providers with electricity, chemicals and personnel. The increase in tariffs causes social impact since the price of water may imply consumption restrictions and repercussions on the population's health.

The control of losses also allows the efficient use of water in hydrographic basins, and, consequently, the preservation of the ecological functions of ecosystems. On the other hand, the situation of water scarcity in Brazil, which has already been aggravated in some regions in face of climate change, has revealed how urgent it is to adopt political, environmental, technical-operational, normative and social strategies for loss management.

In Brazil, supply systems have an average of 34% water loss, while in the Northeast region this average is around 39.6% (Brasil, 2019). Countries such as Japan and Germany, which have high-performance water distribution networks, managed to reduce losses to approximately 10% (Brasil, 2019), revealing Brazil's great challenge.

In Brazil, since 1995, especially within the scope of the then Sanitation Sector Modernization Program (PMSS, Programa de Modernização do Setor Saneamento), there was a certain incentive for service providers to adopt water loss management programs, within the scope of institutional development actions. However, such incentive did not become a continued action inserted in a broader public policy. On the contrary, it favoured specific, discontinuous programs and projects focused on a few service providers, with a concept that strictly incorporated the technical dimension of loss reduction and control, without considering the technical-operational, institutional, normative, social and political complexity of water loss management strategies (Andrade Sobrinho, 2012). Little did such initiative dialogue with local realities, not only in terms of the technical characteristics of water supply networks, but also in the administrative, technical-operational and financial conditions of the service providers.

In the National Basic Sanitation Law, of 2007, it is up to the regulatory agency, among other objectives, to establish standards and norms; defining tariffs that guarantee economic-financial balance, reasonable tariffs and the efficiency and effectiveness of the provision services; and established goals. These mechanisms prove to be important for advancing loss management programs, which has been carried out by some regulatory agencies, such as the State Agency for the Regulation of Delegated Public Services of Rio Grande do Sul (AGERGS), which defined a goal for the Distribution Loss Index of 37.47% for the year 2020.

Among the factors that have been little studied and may influence the levels of water loss are the types of service providers and the corresponding peculiarities regarding the complexity level of the water supply systems, territorial scope of the provision of services, size and

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

characteristics of the population, technical-administrative and operational conditions, among others.

In Brazil, state services of water provision have different types of providers, each with its own peculiarities. These differences may be economic-financial, technical-operational, administrative and managerial capacity, regarding coverage and quality of services.

In face of the relevance and scarce literature about the factors that have influenced the level of losses, especially according to the type of service providers, the present study aims to answer the following question: Which are the factors that have influenced water losses, considering the different types of service providers? Thus, this article aimed to identify the factors that can influence water losses in each service provider, with the state of Bahia as its investigation area. Thus, initially, the scenario of water losses in the municipalities of Bahia was constructed from the available secondary database and a field study was carried out in four municipalities in order to developed the study.

Water losses

Water losses are a problem in supply systems in Brazil and worldwide, even in allegedly developed countries. According to the survey made available by the Smart Water Networks Forum (SWAN, 2011), Non-Revenue Water (NRW) in large cities can vary between 3%, as in Melbourne, Australia, and 62% in the case of Sofia, Bulgaria. Indexes below 10% are only found in countries with highly developed economies. Among these countries, Japan has shown successful strategies. According to Yamazaki (cited in Ariyoshi, 2014), the country has adopted specific actions for each range of water losses (Frame 1).

Frame 1. Actions to control leaks in Japan, by ranges of water losses

Approximate Leakage Rate	Purpose of Leak Reduction	Work Means
More than 35%	To decrease surface leakage and apparent losses.	Human wave tactics, door to door check, distribution pressure control, public education.
35-25%	To decrease underground leakage and water theft.	Zoning, exact piping maps, training and good equipment.
30-25% (overlapping 2nd)	To stop recurrence of leakage.	Big increase in leakage control work and starting replacement of aged pipes.
25-15%	To carry out through leakage control work.	Revision of working method and acceleration of pipe replacement.
15-5%	To wrap up the proactive leakage control work.	Completion of pipe replacement and collection, and analysis of leakage data.
Less than 5%	To keep the minimum rate.	Leakage management using continuous monitoring data.

(Yamasaki, S., 2011 apud Ariyoshi, 2014).

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

Ziegler *et al.* (2011) considered that water losses are an obstacle for sustainability because it causes a series of effects:

- Economic: costs of exploration, treatment and transportation of water that was lost without generating any revenue for the service provider and costs of repairs. In relation to the population, impacts on tariffs in view of the water distributed and which did not generate revenue.
- Social: due to supply losses, such as low pressure, service interruptions and unequal supply. As well as health risks, since sewage and other pollutants can enter the pipelines when the pressure drops or the supply is interrupted.
- Ecological: compensating for water losses by further increasing water extraction places additional stress on water resources and requires the use of additional energy. Gumier (2005) considers that the additional volumes removed from water sources can compromise sustainable management, making it difficult for self-cleaning, sediment transport, etc.

Thus, loss management represents economic gains with the extension of investments and an increase in average billed consumption, social gains due to the quality of services and fair prices, as well as environmental benefits with the preservation of natural wealth.

Actual losses or physical losses of water resulting from leaks bring problems to the population's supply, since it influences the availability of water and on the costs of producing treated water (consumption of energy, chemicals, and personnel, among others). Its reduction allows the use of existing facilities to increase supply, without expanding the production system (Brasil, 2014).

Leakage, visible or not, occurs in several parts of the system, such as: drainage basins, water collection points, water purification facilities, reservoirs, networks and, building extensions and other operational units. For Gomes (2011), the frequency of these leaks depends on the conservation state and age of the infrastructure, on its planning and execution, on service pressure, on the kind of surrounding soil, on the existence of traffic and soil movement, and on the presence of an integrated loss monitoring system.

According to Covas and Ramos (2007) and to Thornton *et al*. (2008), real losses are related to the way systems are designed, constructed, operated and maintained during its lifespan. They are also related to poor installation, unskilled labour, the use of bad materials, incorrect handling of materials before installation, incorrect backfill, works on other adjacent infrastructures, corrosion, the density and length of branches, environmental conditions, such as cold weather, the existence of active loss control and the practice of infrastructure rehabilitation.

Losses are influenced by environmental conditions related to soil movement, changes in temperature (which wear out pipes due to the movements of contraction and expansion), humidity levels, which can generate an increase in internal stresses in pipes and fittings, causing the joints to rupture or disengage (Gomes, 2011; Ziegler *et al.*, 2011).

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

Leakage control is essential for the reduction of losses. It is a complex movement that demands coordinated actions in different areas from the services provider, including direct detection and reparation of existing leaks, programmes for the rehabilitation of pipes and pressure control in the network (Morais & Almeida, 2007).

Water losses in Brazil and services providers

In Brazil, the average water loss in the supply network, in 2018, was 34%, a high number compared to the average in developed countries (Brasil, 2019). Between 2006 and 2018, water losses decreased only 3% (Brasil, 2019), indicating that despite the investments in water supply systems in the last decades, especially between 2003 and 2016, the efforts to control water loss were not enough to change the scenario.

Regarding the type of service provider, data reveal that in 2018 autarchies and municipal public companies had the highest average of the water loss index in the distribution (35.3% - indicator that relates the volume of total losses, real and apparent, with the length of the water distribution network) and the gross index of linear losses ((24.2% - indicator that relates the total volume lost, real losses and apparent losses, to the total volume produced or made available in the system), followed by private companies and soon after by the State Water and Sewer Companies (mixed-capital company, public company and regional authority) (Table 1).

Table 1. Average distribution loss index and linear loss gross index by type of service provider

Type of provider	Number of municipalities	Proportion of municipalities	Average distribution loss index*	Average linear loss gross index**
Municipal direct public administration	429	8.7	28.8	17.8
Municipal autarchy/ municipal service	380	7.7	35.3	24.2
State Sewer and Water Companies	3,925	79.9	34.2	19.0
Micro-regional authority	6	0.1	32.9	12.0
Private company	172	3.5	34.7	15.9
Social organization ***	1	1	8.1	1.2
Total	4,913	100.0	33.8	19.2

(*) Data between 4% and 85% were considered in order to provide greater reliability to the analysis.
(**) It met the criterion of the distribution loss index.
(***) Data from this service provider were not accounted in face of its representability.
Adapted and translated from SNIS – 2018 (Brasil, 2019).

In the National Basic Sanitation Plan (Plansab, *Plano Nacional de Saneamento Básico*), the Water Distribution Loss Index (IPD, *Índice de Perdas na Distribuição de Água*) is one of the indicators to monitor and evaluate the implementation of the Plan, which predicted goals to be achieved by 2033 (Table 2).

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

Table 2. Short, medium and long term goals for the Index of water losses in distribution to Brazil and macro-regions, according to Plansab (2013)

Indicator	Year	Brazil	N	NE	SE	S	MW
A6. % of losses in water distribution index	2010	39	51	51	34	35	34
	2018	36	45	44	33	33	32
	2023	34	41	41	32	32	31
	2033	31	33	33	29	29	29

Translated from Brasil (2013).

In 2018, the average rate of losses in distribution in the country was 34% (Brasil, 2019), below that established by Plansab (36%). In that year, in the Southeast region, the water distribution systems presented 29.0% of losses; in the Midwest region, 29.2%; in the South, 30.3%; and in the Northeast, 39.6%. In most of these regions, the targets were achieved. The North almost met the target of 46%, since in 2018 the losses were 46.0% (Brasil, 2019).

Nonetheless, the goals established by Plansab were extremely conservative with the reduction of only 8 percentage points in 20 years, 18 points for the North and Northeast regions. It would be expected that the Plan would not consider an IPD over 30% acceptable by 2033. Within the programmes provided by Plansab, the control of water losses is part of the Structural Sanitation Program, which has actions aimed at supporting the provision of services. These actions include: the control of water losses and rationalization measures and energy efficiency, support for physical and commercial registrations, and technical training for managers and providers (Brasil, 2013). According to the Plan, the existence of an effective reduction loss programme would be a criterion for selecting and prioritizing financing.

Types of public water service provision

Among the factors that have been little studied and can influence the levels of water loss in the distribution networks are the types of service providers and the corresponding peculiarities regarding the level of complexity of the water supply systems, territorial scope, size and characteristics of the population, physical-natural characteristics, technical-administrative and operational conditions, etc.

In Brazil, the provision of services is the responsibility of the municipal public power, as established by the Federal Constitution, art. 30 (Brasil, 1988). The municipality can provide services directly or delegate to another entity. Direct provision can be centralized, through an office without legal personality that integrates the municipal administration, or decentralized, also called indirect. In this case, the municipalities, through specific law, may create an autarchy, a municipal public company or a mixed economy company to provide the services, thereby guaranteeing administrative and financial autonomy to the provider (Alexandrino & Paulo, 2011).

The delegation of service provision can be made to mixed-capital companies, public companies or private companies, always by bidding. There is also the provision for associated management, within the scope of the inter-federative cooperation, which can be carried out

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

by a public consortium or cooperation agreement (Law N. 11,107 / 2005). Another type of provider is a community organization whose activities are carried out by organized entities or local residents (Law N. 11,445 / 2007).

Regarding the scientific production about the management of losses according to the different types of service providers, the literature has taken a still restricted approach on the subject, although the loss index has been used as an indicator of efficiency in the provision of services. In this sense, it is necessary to carry out studies that seek to deepen this discussion in order to investigate the different strategies used and the levels of performance.

A study carried out by Heller, Coutinho and Mingoti (2006), investigated the performance of 600 municipalities in Minas Gerais, according to the different types of services providers. Results suggest that municipal autarchies show a higher percentage of households with water distribution network, lower tariffs and employed fewer workers in middle activities, and these, if not higher in some respects, were equivalent to the State Company (Copasa, *Companhia de Saneamento de Minas Gerais*). According to the authors, the proximity between users and municipal administration, the integration with other public policies and the decentred administrative structure offset the privilege in the distribution of resources that Copasa had at the time of Planasa. The municipalities served by Copasa/MG were characterized by having a greater contingent of workers in middle activities, a greater number of hydrometered household connections, less water loss and more expensive tariffs.

Heller, Sperling, *et al.* (2009) made a comparative analysis of the technological performance of public water supply and sewage services in four municipalities in Minas Gerais. They identified that although all providers were inserted in a range of losses considered high, only the municipalities operated by Copasa had a plan specific for the control of losses through inspection of clandestine networks, maintenance of water meters and replacement of old networks.

Nunes Junior *et al.* (2010) aimed to understand the decision-making process between the concession of public water supply and sewage services to Copasa/MG and the maintenance of the Autonomous Water and Sewage Service (SAAE, *Serviço Autônomo de Água e Esgoto*) in the municipality of Sete Lagoas (MG). The authors found that even with the political interference that reflected losses in revenue, privileges and impaired the image of the autarchy with the population, the final decision was to continue the SAAE. The decision was motivated by the lack of positioning of the municipal representatives, which in a way reflected the polarization of public opinion between the desire to improve services and fears of rising tariffs and unemployment.

When comparing the performance of the different types of Brazilian public water provision services, Heller *et al.* (2012) verified that direct administration showed the lowest hydrometering numbers, contrarily to private companies and regional companies, which stood out for having the highest hydrometering numbers. Regional companies also stood out

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

for the low default rate. According to the authors, these results are justified by the fact that private companies and regional companies provide services under commercial efficiency criteria, in search of profitability, which requires the expansion of hydrometering.

Methodology

This research project consisted of a descriptive investigation aiming to delineate the characteristics of the studied phenomenon, water losses and type of service provider. To this end, a secondary database search and a field study in four municipalities previously selected in the state of Bahia were carried out. Thus, a survey was carried out in a secondary database of water losses in the municipalities of Bahia and a field study was carried out in four previously selected municipalities, in order to promote studies on the planning and control of losses.

The research of secondary data aimed to define the Bahian scenario of water losses from economic-financial, administrative and operational indicators selected in the Sanitation Information System (SNIS, Sistema de Informação sobre Saneamento). The indicators were analysed according to the types of public water supply service provider in Bahia: direct administration, autarchy, public company and mixed economy company – Empresa Baiana de Águas e Saneamento S/A (Embasa).

The field study aimed to understand the dynamics of water loss management and the intervening factors, by service provider, and for that purpose, data were collected through a questionnaire, elaborated from the literature review and the results of the studies of Andrade Sobrinho (2012) on water and energy loss management in water supply systems. The questionnaires contained 35 questions (indicators) divided into 4 analytic categories: technical, operational, planning, administrative and financial, and social. For each question, participants could choose according to the indicator's performance between great, good, average and poor, weights 4, 3, 2, and 1 were assigned to each classification, respectively. Thus, it was possible to construct Pareto Diagrams, with the weighted average between the frequencies of each classification with the corresponding weights per assessed indicator. Finally, a performance level was established for each indicator, namely: very unsatisfactory, ranging between 0 and 1.4, unsatisfactory, between 1.5 to 2.4, satisfactory between 2.5 and 3.4 and very satisfactory between 3.5 and 4.0.

In order to select the municipalities to be studied, the socioeconomic profile and similar characteristics of water services were considered, aiming to have a similar reality (Table 3). Based on these criteria, four municipalities were chosen, two of them were supplied by municipal autarchies (Autarchy A and Autarchy B), and two by the state company (Embasa A and Embasa B). In total, 48 people took part in the research project answering questionnaires, 24 managers and 24 technicians from the service providers' water loss management area. The research project was approved by the Research Ethics Committee of the Nursing School of the Federal University of Bahia (CAAE 95518418.1.0000.5531 and *Parecer* N. 2.937.377).

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

Table 3. Criteria used in the selection of municipalities

Characteristics	Criteria
Total population	More than 100.000 inhabitants
Urbanization rate	More than 80%
Gini Index	Between 0.5 e 0.6
GDP *per capita*	Between R$9,000.00 and 14,000.00
Water losses in distribution (low)	15 to 20%
Water losses in distribution (high)	More than 40%
Population supplied by water network (%)	Similar between municipalities
Hydrometering index (%)	More than 80%
Micro-measuring index related to consumption (%)	More than 80%
Location	Outside the Metropolitan Region of Salvador

Cardoso, Borja, Andrade Sobrinho (2018) based on data from IBGE (Brasil, 2010).

Results and discussion

Water loss management scenario in municipalities in the State of Bahia

In 2018, Bahia's population was estimated to be 14.812.617, of which 85% had access to the water supply network (Brasil, 2019). Embasa is the largest provider of public water supply services in the State, serving 367 municipalities in 2018, corresponding to 91% of the state's population. In 2018, the average loss index in the distribution was 26.9%, with a variation between 4.0 and 75.2%, being lower than the national average (Brasil, 2019). Although several factors may explain this variation, the analysis of the data allowed to observe that the systems with average of connections of 4,914 presented smaller losses, while the systems with average of 15,895 higher losses. However, only 4 municipalities, out of 389, had losses less than 4% and 7%.

Considering the types of service providers, in 2018, municipalities presented the highest index of losses in distribution, the gross index of linear losses and the Index of losses per connection (L/day.con), respectively 38.4%, 29, 2m³/day.km and 366.5 (L/day.con). It was observed that the best performance among providers was that of Embasa.

Analysing the indicators by type of provider, it could be seen that Embasa had the best performance in terms of coverage with hydrometering, macro and micro-measurement gauging, with services with direct administration having the worst. In face of the low macro-measurement and micro-measurement gauging of the providers of direct administration, municipalities and the public company, water loss data was probably estimated, influencing its reliability, and the results should be analysed cautiously.

It is important to highlight that Embasa's water tariff, in 2018, was 7 times higher than that of direct administrations, 2.3 times that of municipalities and 4.3 times that of the public company. It is also observed that Embasa made between 2004 and 2018 the largest investment *per capita* in water supply regarding the population served (2.2 US$/served inhab.) and was the biggest beneficiary with resources from the state government (93% of the total

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

of US$ 37,64 million), reaching 72 municipalities in its area of operation (21%). Both municipalities and the municipal public company did not receive funds from the state government and among the municipalities with services provided by the direct administration, only two were contemplated.

Embasa was also the provider that most accessed costly resources (99% of the US$ 283,36 million), covering 97 municipalities. The Autonomous Water and Sewage Services and the Municipalities of also accessed these resources, reaching around 12% and 29%, respectively, of the municipalities where they provide the services. As for non-onerous resources, the State Concessionaire accessed about 97% of the US$ 720,36 million of the federal budget allocated to Bahia, reaching around 89% of the municipalities under its responsibility (Table 4).

Table 4. Performance indicators by type of service provider. Bahia, 2018

Indicator	Direct administration	Autarchy	Public company*	Mixed economy concessionaire/ Embasa
Number of municipalities	11	26	1	367
Number of total active water connections	47,495	344,716	7,287	3,068,420
Extension of the water network (km)	755.7	4,128.4	71.0	39,818.9
Total water service index (%) **	78.6	79.8	100.0	68.3
Urban water service index (%) ***	69.2	96.2	100.0	96.2
Macro-measurement index (%)	17.9	28.7	0.0	85.6
Hydrometering index (%)	6.57	82.6	60.2	98.0
Index of micro-measurement related to	0.0	69.5	56.5	92.5
Revenue loss rate (%)	91.3	30.7	-5.08	21.9
Distribution loss index (%) ****	36.4	38.4	4.8	26.1
Gross index of linear losses (m^3/day.km)	13.4	29.2	2.5	9.6
Loss rate per connection (L/day.con)	251.2	366.5	23.0	114.4
Number of municipalities that reported losses	7 (63%)	19 (73%)	1 (100%)	354 (96%)
Average water tariff US$/$m^3$	0.21	0.21	0.21	0.21
Productivity index: (Active savings/total staff-equivalent)	276.5	307.1	231.7	521.7
Total investment in water supply between 2004 to 2018 (in US$1,000.00)	4,570.79	30,737.97	49.29	741,656.71
Average investments *per capita* in water between 2004 and 2018 (US$/ served inhab.)	2.37	2.63	0.37	7.81
Average state investments *per capita* in water between 2004 and 2018 (US$/inhab.)	22.4	0.41	0.000	2.20
Number of municipalities benefiting from state resources between 2004 to 2018	2	1	0	74

(*) Not considered in the analyses due to representativeness; (**) It refers to the relationship between the total population served by the public water network by the total population of the municipality; (***) It refers to the relationship between the urban population served by the public water network by the urban population of the municipality; (****) Considering acceptable water losses ranging from 4% to 85%, according to data provided by Snis - 2018, depending on the level of data reliability. (Brasil, 2019).

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

The investments made by Embasa, associated with its ability to access onerous and non-onerous resources from the state government, allowed the improvement of its performance, including in terms of water losses. On the other hand, it was observed that both municipalities and direct administration services, in addition to not being provided with resources from the state government, also have difficulties in accessing costly and inexpensive resources, certainly in the face of technical, managerial difficulties, and mainly to comply with the federal government rules for access to resources. The data reveal that the financing model has privileged the State Concessionaire and also that the government of Bahia does not have a policy for investments in water supply outside the area of delegation of this Concessionaire, producing an inequality in the distribution of state resources and focusing services with greater capacity to access resources from other entities. The need to review the financing model in the state of Bahia is evident.

Water loss management in the four municipalities studied

Analysing the service providers' indicators based on the field study carried out in four municipalities, it was found that the water supply systems operated by Embasa had a better overall performance, especially regarding water losses, macro-measurement coverage, hydrometering and micro-measurement (Table 5).

Table 5. Performance indicators by type of service provider in the studies municipalities in Bahia, 2018.

Indicators	Autarchy A	Autarchy B	Embasa A	Embasa B
Total population (inhab.)	215,183	150,832	153,831	164,844
Urbanization rate (%)	81.0	87.0	90.0	84.0
Population supplied by water services (%)	96.7	87.4	100.0	99.8
Distribution loss index (%)	12.0	60.0	29.7	36.3
Gross index of linear losses (m³/day.km)	15.9	46.2	11.1	15.7
Loss rate per connection (L/day.con)	125.5	572.8	144.9	197.2
Macro-measurement index (%)	0.0	0.0	100.0	100.0
Hydrometering index (%)	84.3	89.0	100.0	99.8
Index of micro-measurement related to consumption (%)	41.4	96.5	99.0	97.1
Number of active water connections	63,337.0	50,577.0	51,184.0	47,747.0
Extension of the water network (km)	507.0	621.5	665.9	596.6
Produced water volume (m³)	21,511.0	17,400.0	9,213.4	10,275.6
Consumed water volume (m³)	21,133.0	6,957.0	6,335.9	5,989.4
Average water tariff US$/m³	0.6	1.0	1.5	1.5
Total investment in water supply between 2004 to 2018 (in US$1.000.000.00)	5.1	3.9	6.7	3.1
Average investments *per capita* in water between 2004 and 2018 (US$/served inhab.)	1.8	1.8	2.9	1.3
Average state investments *per capita* in water between 2004 and 2018 (US$/inhab.)	0.0	0.0	0.0	0.0

Cardoso, Borja, Andrade Sobrinho (2018) based on Brasil, 2019.

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

Embasa A showed the best performance, with lower linear losses, good level of losses in distribution, excellent coverage of macro-measurement, micro-measurement with hydrometer higher level of total and per capita investments (US$ 2.9/inhab. attended), among 2004 to 2018. Certainly, this performance is related to the planning efforts to control losses and the level of investments made.

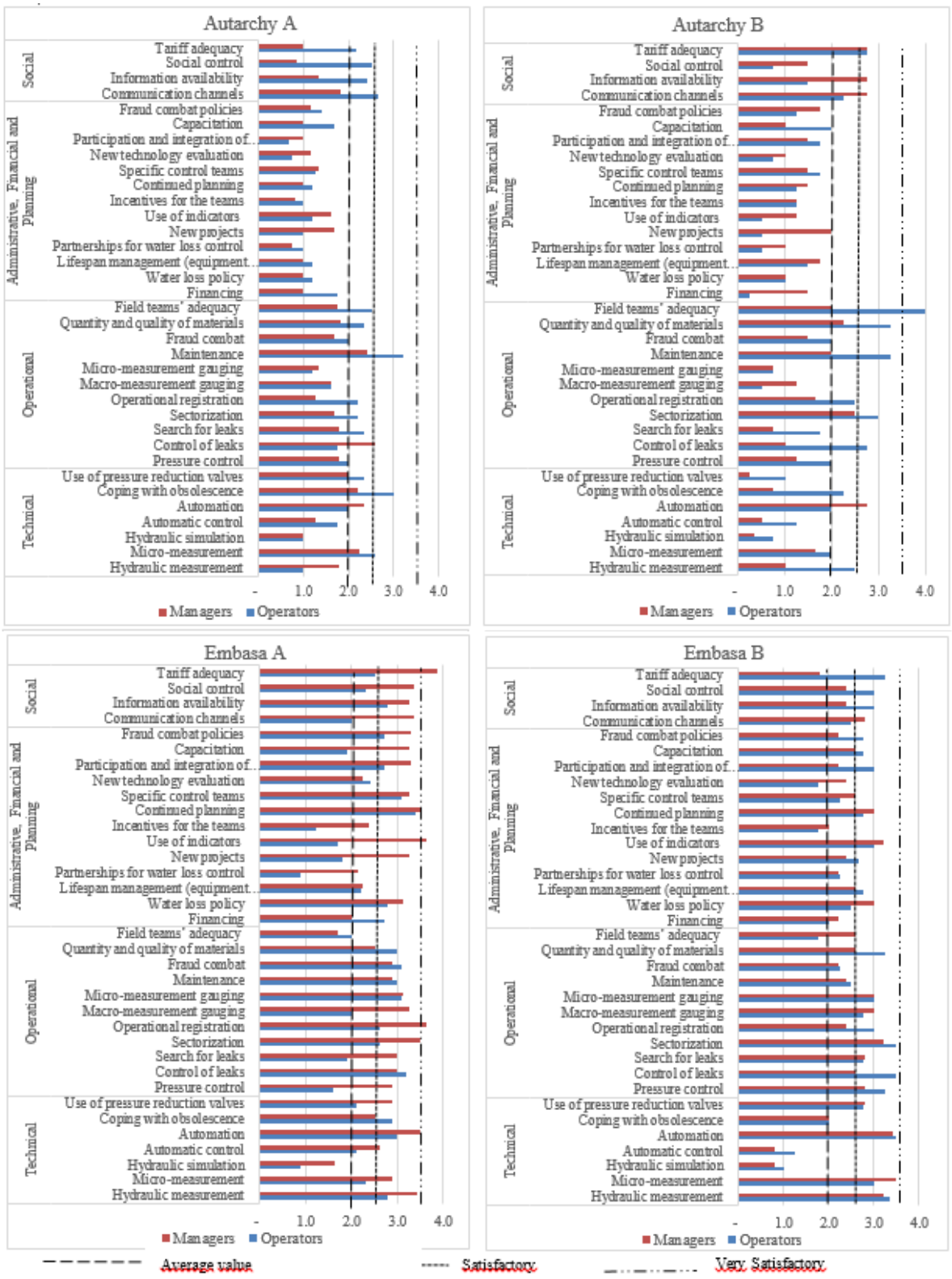
In terms of loss management planning, it can be noticed that Autarchy A did not have a specific plan for this action. Autarchy B presented action proposals to reduce water losses by forming a team to detect leaks, a campaign for the rational use of water and monitoring the evolution of losses. Prevention measures were not identified and those foreseen were generic, with no definition of goals. Contrastingly, Embasa A's 2018 Action Plan was very specific in the description of activities, presenting preventive and corrective actions, with active loss control, pressure monitoring, technical registration of networks, active search for leaks, withdrawal of irregular connections, and the implementation of macro flow meters. Embasa B's Action Plan was also specific in the description of activities, with sectors and action targets, corrective measures, training of professionals and the prevention of losses through the replacement of water meters and active pressure control.

It can be seen that in the municipalities where Embasa provides the services, there was a planning effort to avoid water losses. The perception of technicians and managers of water supply providers about loss management was obtained from the information provided in the applied questionnaires (Figure 1).

The results indicated for the provider Embasa A that in the results of both groups, no indicator was evaluated as very satisfactory. In the case of technicians, there was no indicator with this level of classification, since managers considered automation, registration, sectorization, the use of indicators, continued planning and the adequacy of rates as very satisfactory. In addition, for technicians, the hydraulic simulation indicators, partnerships for water loss control and incentives for the teams were considered very unsatisfactory, but for managers, no indicator deserved this classification.

In the assessment of the analysis categories, both groups, with 54% converging opinions between them, considered 69% of the indicators satisfactory. Of the seven indicators in the technical category, two (57%) were assessed as satisfactory by both groups. In the category of operational aspects, there was a convergence of opinions in six out of the eleven indicators, with the most of them (73%) being assessed as satisfactory and none as unsatisfactory. In the planning, administrative and financial category, there was a convergence of opinions in eight (62%) of the thirteen indicators. In total, five indicators (38%) were assessed by both groups as satisfactory, namely: water loss policy, specific control teams, new technology evaluation, participation and integration of teams and fraud combat policies. Only one indicator was considered unsatisfactory (partnerships for water loss control). In the social category, considering both groups, all four indicators were evaluated as satisfactory, with convergence of opinions in only information availability (25%).

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021



Cardoso, Borja, Andrade Sobrinho (2018).

Figure 1. Evaluation of loss management indicators at service providers. Bahia-Brazil, 2018.
Cardoso, Borja, Andrade Sobrinho (2018).

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

The results suggest a tendency for managers to better assess the provider's performance in managing water losses, which can influence planning processes aimed at improving actions. However, the data indicate that for both technicians and managers, the service provider has carried out actions for the management of losses in a satisfactory manner, especially regarding actions related to operational and planning, administrative and financial aspects. In the case of the provider Embasa B, in a joint analysis of the data of the groups it was possible to notice that no indicator reached the level of very satisfactory. However, according to technicians, the automation, control of leaks and sectorization indicators were very satisfactory; for managers, on the other hand, only micro-measurement gauging would be in this degree of satisfaction. In addition, in the joint assessment, the automatic control and hydraulic simulation indicators were classified as very unsatisfactory for both groups. Considering the two groups, 63% of the indicators were judged satisfactory, with 59% converging evaluation between them.

As for the analysis categories, the results indicated a convergence of assessment between technicians and managers in the technical category. Four (57%) out of the seven indicators in this category were assessed as satisfactory and none as very satisfactory. In the category of operational aspects, in seven (64%) out of the eleven indicators there was a convergence of opinions for a satisfactory classification. Both groups rated maintenance, fraud combat and field teams' adequacy as unsatisfactory. In the planning, administrative and financial category, technicians and managers converged their opinions on nine (69%) indicators of the 13 analysed. In total, seven indicators (54%) were assessed by both groups as satisfactory, and six (46%) as unsatisfactory, namely: financing, partnerships for water loss control, incentives for teams, new technology evaluation and fraud combat policies. As for the social category, among the four indicators only in one (communication channels) there was a convergence of opinions, considered satisfactory.

These results indicate a certain harmony between the perception of operators and managers, although there was disagreement, especially regarding the adequacy of tariffs, pressure control, field teams' adequacy and the participation and integration of teams. The data reveal that loss management at Embasa B, according to technicians and managers, had a performance that varied between satisfactory and unsatisfactory, with predominance of the former. The best assessed were the operational and social categories. In Autarchy A, in a joint analysis of the two groups, no indicator reached the level of very satisfactory and only three (8.6%) were satisfactory, although there was no convergence for the indicators facing obsolescence, maintenance and communication channels. An evaluation between unsatisfactory and very unsatisfactory prevailed, being, respectively, 54% and 37%. Considering the data from the two groups, 19 (54%) of the indicators were assessed as unsatisfactory, with convergence in eight (42%).

Regarding the analysis categories, only one (14%) of the seven indicators in the technical category was rated as satisfactory (coping with obsolescence) and 71% (5) as unsatisfactory. In the category of operational aspects, there was a convergence of opinions in seven (64%) of the eleven indicators, six of which (55%) were unsatisfactory. In the planning, administrative

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

and financial category, technicians and managers converged their opinions on nine (69%) indicators of the 13 analysed, all of which were assessed as unsatisfactory. The worst assessed in this category, by both groups, were the indicators: incentives for the teams, participation and integration of teams, water loss policy, new technology evaluation, lifespan management (equipment and piping), continued planning, specific control teams. Considering the assessment of both groups regarding the social category, only communication channels (1=25%) out of the four indicators was considered satisfactory. The other indicators showed a high divergence indicating different understandings regarding social control, tariff value and information availability, a condition that certainly influences the management of water losses.

The results show the difficulties that the Autarchy A provider has faced in managing losses according to the assessment of technicians and managers, especially when it comes to the planning, administrative and financial and social categories. Analyzing the data of the two groups in Autarchy B, no indicator reached the level of very satisfactory and only one (field teams' adequacy) was considered in this classification by the technicians. Still for both groups, the indicators were assessed between unsatisfactory and very unsatisfactory, being, respectively, 34% (12) and 46% (16). Only seven (20%) of the indicators were assessed as satisfactory.

As for the categories of analysis, it was observed that of the seven indicators of the technical category, 57% (4) were assessed as unsatisfactory and none as satisfactory. In the category of operational aspects, five (46%) out of the 11 indicators were considered satisfactory, with only one converging in the evaluation (sectorization). In the planning, administrative and financial category, technicians and managers converged their opinions in 10 (77%) indicators of the 13 analysed, with six (46%) converging on the unsatisfactory classification. Regarding the social category, two (communication channels and tariff adequacy) of the four indicators, were assessed as satisfactory by both groups.

Results showed, despite some divergences between the groups that, according to technicians and managers, the management of water losses in Autarchy B has had a performance between unsatisfactory and very unsatisfactory, with considerable convergence between the groups, especially regarding the planning, financial and administrative aspects. With the results of the study and the contribution of the literature, some factors have been identified as influencing the management of water losses by different types of service providers (Table 3).

Conclusion

In Bahia, in 2018, the State Concessionaire was the largest provider of public water supply services, serving 91% of the population, followed by municipal autarchies (26), services directly administrated by city halls (11), with only one municipal public company that provides services in Sobradinho. On average, the loss rate in distribution, that year, reached 27%, below the national average.

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

In this study, it was observed that, in 2018, the municipalities whose public water systems were operated by Embasa had better performance in the management of water losses. Municipal autarchies had the highest rate of losses and low levels of coverage with hydrometering, and macro and micro-measurement gauging. Nonetheless, the services with direct administration registered the worst performance of the evaluated indicators. On the other hand, it was observed that Embasa's total water service index was lower and the water tariff was significantly higher.

Findings suggest that between 2004 and 2018, Embasa made the highest level of investments (96% of the total). Both municipal autarchies and direct administration services had difficulties in accessing the resources from the Union, the state government and financing agents, while Embasa obtained 99% of the onerous resources and 98% of the non-onerous resources. Results indicate that the financing model has been favourable to Embasa and that the state government lacks a public policy that includes all municipalities. The strong inequality of access to resources, combined with the difficulties of local governments in Brazil, may explain the low performance of autarchies and direct administrations.

In the field study, it was found that the water supply systems operated by Embasa had a better overall performance of the analysed indicators. At Embasa A, according to technicians and managers, water loss management occurred satisfactorily and at Embasa B between satisfactory and unsatisfactory, with a predominance of the former. Both providers highlighted as unsatisfactory the following indicators: automatic control, coping with obsolescence, field teams' adequacy, financing, partnerships for water loss control, incentives for teams, new technology evaluation and hydraulic simulation.

Results indicated the difficulties faced by Autarchy A provider and the performance assessed between unsatisfactory and very unsatisfactory in Autarchy B, with emphasis on the indicators: micro-measurement gauging, water loss policies, partnerships, incentives for teams, continued planning, and new technology evaluation. The existence of action plans to manage water loss in Embasa was a determining factor in the progress made. On the other hand, the investments made and the incentives from financing agents certainly also helped the verified performance. In the case of the Autarchies, several weaknesses were identified in water loss management, weaknesses that are related to the lack of a public policy directed towards the strengthening of such providers, mainly ensuring access to Union resources. Since the National Sanitation Plan in the 1970s, theses providers went through the drastic reduction of investments in the 1990s and the expansion of investments between 2003 and 2016. Recently, they have been placed outside the financing model, a scenario that must be reviewed.

Finally, this study made it possible to identify a series of factors, which may contribute or hinder the management of water losses by type of service (Table 6). The study highlighted the need for more complex, multidimensional approaches, with actions based mainly on a strategic planning resulting from a collective effort from technicians and managers, with the

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

development of partnerships with service providers, regulatory bodies and representatives of civil society, to establish a continued policy for the management of water losses.

Table 6. Factors that influence water loss management by service providers

	Categories	Autarchy and municipal company
Advantages	Technical-administrative	The provision of services is easier when compared to companies operating in several municipalities. Possibility to design systems more appropriate to the local reality, facilitating loss management. The possibility of better wages can attract professionals that are more qualified. There may be a greater commitment by employees due to their links with the municipality.
	Political	Managerscan be direct supporters of actions to manage water losses. The proximity between users and the service provider can favour the active participation of the population in the actions of planning, raising awareness and controlling water losses.
Advantages	Economic-financial	Administrative and financial autonomy allows greater flexibility to execute activities, including for collection and investments, with a high potential to be more appropriate to local conditions and realities. Possibility of tariffs would be more appropriate, favouring payment and avoiding illegal connections. Costs of work and services can be more compatible with the needs and possibilities of the provider, allowing having resources for the management of losses.
	Social	Possibility of lower rates, influencing payments and avoiding illegal connections. The communication channel with the provider is facilitated in participatory processes.
Disadvantages	Economic-financial	Loss management requires investments that may be incompatible with the provider's revenues. It may be difficult to access resources in the face of funding criteria. It does not benefit from the economy of scale that allows lower costs, interfering in the control of losses. More difficulties to obtain resources from the state government.
	Political	The municipal government may present obstacles to actions to manage water losses, such as strict control of illegal water connections in the face of issues of political sponsorship, for example. Administrative discontinuity can affect the continuity of actions.
	Technical-administrative	Many municipalities, especially small ones, may have a reduced capacity of professionals with technical, administrative and financial qualifications. Difficulties for technological innovation.
	Categories	State Company
Advantages	Technical-administrative	Enough technically qualified personnel, when compared to municipal services. Greater balance in management due to having a more stable technical staff. It can have an information system to monitor and guide loss management. Openness to innovation. Possibility of preparing technical notes for standardization and monitoring of procedures
	Political	Easy dialogue with various agents in search of partnerships, political support and financing. Greater political power for the manager, enabling specific programs to manage losses. The practice of strategic planning and the use of the ISO system can favor actions for water losses. They are subject to a regulatory agent who can establish actions for the management of losses.
	Economic-financial	Greater investment capacity, benefiting from financing models. Greater ability to access resources, whose agents have required loss management The economy of scale can make it possible to reduce costs, allowing resources for the management of losses. Make it easier to obtain resources from the state government.
Disadvantages	Technical-administrative	It operates more complex systems, many in medium to large cities, with dense and disordered urbanization, introducing difficulties in the management of SAAs and water losses. It simultaneously meets the demand of the municipalities under its responsibility, resulting in inequalities in service in the face of several factors, such as the distances from the municipal and/or regional units and the central administration. Municipalities with less profitable systems may have precarious assistance, with little investment, less qualified technical staff, less access to technologies and may have greater water losses. Outsourcing practice in all activities, making the execution of actions precarious. Staff has a tendency to resist changes, making new agendas or procedures more difficult. It is aimed at the design of conventional systems with high cost of implementation, operation, with greater complexity, making it difficult to manage losses.
	Political	Administrative discontinuity can affect the continuity of the actions planned and being executed, due to the change of managers and administrative structure. Strongly influenced by political agreements, influencing the quality of the governing and managerial body. Possibility of influencing the regulatory entity that integrates the same administration as the provider.
	Social	Self-sustainability influences tariffs and may be incompatible for some users. The hierarchical management model hinders participatory processes, influencing loss programs.
	Economic-financial	The business model geared towards self-sustainability, moving it away from the social function and implying a hierarchy of activities where loss management can be neglected. Unified tariff system, with higher tariffs, with the possibility of lack of payments and illegal connections. The focus on economic and financial viability influences the adoption of actions in deficient municipalities.

Cardoso, Borja, Andrade Sobrinho (2018), based on field study results and literature, highlighting Heller, Coutinho & Mingoti (2006); Moraes et al. (2008); Andrade Sobrinho (2012) and Abes (2017).

Revista AIDIS de Ingeniería y Ciencias Ambientales:
Investigación, desarrollo y práctica. ISSN 0718-378X
Doi: http://dx.doi.org/10.22201/iingen.0718378xe.2021.14.2.75518
Vol. 14, No.2, 960-977
6 de agosto de 2021

References bibliográficas

Alexandrino, M., Paulo, V. (2011) *Direito administrativo descomplicado,* 19. ed. rev. e atual, Método, São Paulo, 382 pp.

Andrade Sobrinho, R. (2012) *Gestão das perdas de água e energia em sistemas de abastecimento de água da Embasa: um estudo dos fatores intervenientes na RMS*, Master's thesis, Mestrado em Meio Ambiente, Águas e Saneamento, Escola Politécnica, Universidade Federal da Bahia, 288 pp. Retrieved from: http://repositorio.ufba.br/ri/handle/ri/14153

Ariyoshi, H. (2014) Strategy for water leakage control in Japan: In view of the water resources, *IWA Workshop on Water & Energy and Water Loss.* Tokyo, Japan.

Brasil (1988) *Constituição da República Federativa do Brasil*, Congresso Nacional, 05 de outubro de 1988.

Brasil (2013) *Plano Nacional de Saneamento Básico* – PLANSAB, Ministério das Cidades/Secretaria Nacional de Saneamento Ambiental, 172 pp.

Brasil (2019) *Diagnóstico dos Serviços de Água e Esgoto – 2018*, Sistema Nacional de Informações sobre Saneamento (SNIS), 180 pp.

Covas, D,. Ramos, H. (2007) Minimização de perdas de água em sistemas de abastecimento. In: Gomes, H. P.; Garcia, R P.; Rey, P. L. I. (org.), *Abastecimento de água: o estudo da arte e técnicas avançadas,* UFPB Publishing, João Pessoa, 47-66.

Gomes, R. J. (2011) *Modelação matemática como ferramenta de gestão e exploração de sistemas de distribuição de agua*, Doctoral dissertation, Universidade de Coimbra, 274 pp. Retrieved from: http://hdl.handle.net/10316/17988

Gumier, C. C. (2005) *Aplicação de modelo matemático de simulação-otimização na gestão de perda de água em sistemas de abastecimento*, Master's thesis, Mestrado em Engenharia Civil, Arquitetura e Urbanismo, Universidade Estadual de Campinas, Faculdade de Engenharia Civil, Arquitetura e Urbanismo of Campinas, Brasil, 160 pp. Retrieved from: http://repositorio.unicamp.br/jspui/handle/REPOSIP/258175

Heller, L., Coutinho, M.L., Mingoti, S.A. (2006) Diferentes modelos de gestão de serviços de saneamento produzem os mesmos resultados? Um estudo comparativo em Minas Gerais com base em indicadores, *Eng Sanit Ambient*, **11**(4), 325-336.

Heller, P. G. B., Nascimento, N. O., Heller, L., Mingoti S. A. (2012) Desempenho dos diferentes modelos institucionais de prestação dos serviços públicos de abastecimento de água: uma avaliação comparativa no conjunto dos municípios brasileiros. *Eng. Sanit. Ambient*., **17**(3), 333-342.

Heller, P. G. B., Von Sperling, M., Heller, L. (2009). Desempenho tecnológico dos serviços de abastecimento de água e esgotamento sanitário em quatro municípios de Minas Gerais: uma análise comparativa. *Eng. Sanit. Ambient*, **14**(1), 109-118. Accessed on: 09 in September in 2018.Retrieved from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1413-41522009000100012&lng=en&nrm=iso

Moraes, L. R. S., Borja, P. C., Silva, M. M.; Santos, M. R. A. dos; Andrade, C. C. L. C. de; Sampaio, A. D. (2008) *Gestão dos Serviços de Saneamento Ambiental dos Municípios do Consórcio Intermunicipal da Costa dos Coqueiros: Limites e Possibilidades – Relatório Final.* DEAUFBA/CICC/Fundação Onda Azul, Salvador, 230 pp.

Morais, D. C., Almeida, A. T. (2007). Group decision-making for leakage management strategy of water network. *Resources, Conservation and Recycling*, **52**(2), 441-459. doi: http://dx.doi.org/10.1016/j.resconrec.2007.06.008

Nunes Jr., T. T., Heller, L., Silva, P. L., Rezende, S., Radicchi, A. L. A. (2010) Prestação dos serviços de água e esgotos em Sete Lagoas-MG: "o SAAE é nosso" ou "que venha a Copasa"?. *Revista Brasileira de Estudos Urbanos e Regionais*, [S.l.], **12**(1), 119-139. Accessed on: 26 in October in 2018, retrieved from: http://rbeur.anpur.org.br/rbeur/article/view/235

Thornton, J., Sturm, R., Kunkel, G. (2008) *Water loss control manual,* 2 ed, McGraw-Hill, New York, pp. 700.

SWAN, Smart Water Networks Forum. (2011) *Stated Non-Revenue Water Rates in Urban Networks – 2011*, Walton-On-Thames.

Ziegler, D., Sorg, F., Fallis, P., Hübschen, K., Happich, L., Baader, J., Trujillo, R., Mutz, D. ; Oertlé, E., Klingel, P., Knobloch, A. (2011) *Guidelines for Water Loss Reduction – A Focus on Pressure Management*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, 232 pp.