https://doi.org/10.1590/S1413-415220230140

Scientific Paper

Technologic protocol applied to medium size water supply systems aiming at water efficiency and loss reduction

Protocolo tecnológico aplicado a sistemas de abastecimento de água de médio porte visando à eficiência hídrica e à redução de perdas

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ABSTRACT

Water supply systems are basically composed of water intake, adduction, treatment, reservation and distribution, and in each component there is a variable amount of water and energy loss, which is present in any supply system. Water losses, which divides into real and apparent, occurs along the whole structure, focusing on water distribution networks because of the amount of connections that lead to bigger losses. Seeking to reduce these losses, procedures and techniques can be applied. This research aimed to propose an appropriate protocol to help managers of small and medium-sized water supply systems control and reduce their loss rates. To develop the protocol, the following steps were carried out: diagnosing the system, evaluating existing methodologies and proposing a protocol for this goal. The proposed protocol demonstrates an ability to adapt to the system's demands and the managers' capability to apply it, and can bring significant impacts with its application, leading to an improvement in water and energy efficiency in water systems.

Keywords: water supply systems; losses; protocol.

RESUMO

Os sistemas de abastecimento de água são compostos basicamente de captação de água, adução, tratamento, reservação e distribuição, e em cada componente ocorre uma quantidade variável de perdas de água e energia, que estão presentes em qualquer sistema de abastecimento. As perdas de água, que se dividem em reais e aparentes, ocorrem ao longo de toda a estrutura, com destaque às redes de distribuição de água, que, por conta da quantidade de conexões, provocam as maiores perdas. Buscando reduzir as perdas, existem procedimentos e técnicas que podem ser aplicados. Este trabalho objetivou propor um protocolo adequado para auxiliar gestores de sistemas de abastecimento de água de pequeno e médio porte, com sistemas limitados, a controlarem e reduzirem seus índices de perdas. Para o desenvolvimento do protocolo foram realizadas as etapas de: diagnostico do sistema, avaliação de metodologias existentes e proposição de protocolo para esta finalidade. O protocolo proposto demonstra a capacidade de se adequar às demandas do sistema e a capacidade de aplicação dos gestores, podendo trazer impactos significativos com sua aplicação, promovendo a melhoria da eficiência hídrica e energética em sistemas hídricos.

Palavras-chave: sistemas de abastecimento de água; perdas; protocolo.

INTRODUCTION

Water resources demand efficient use to meet the demands of populations in constant growth, considering their availability (DIGHADE; KADU; PANDE, 2014). The management of municipal water supply systems is a complex task, and providing drinking water while preserving water resources represents this difficulty, with a significant part being lost during the process through leaks and thefts in the distribution network (ROJEK; STUDZINSKI, 2019; AL-WASHALI *et al.*, 2020).

To improve efficiency in supply systems, the main factor to be worked on is reducing water losses (AHOPELTO; VAHALA, 2020). Losses represent about 126 billion cubic meters per year, in an estimated value of US$ 39 billion per year (LIEMBERGER; WYATT, 2019). In 2020 the rate of losses in water distribution systems in Brazil was 40.1%; in other words, of all the water captured for supply, about two fifths were not counted (SNIS, 2021).

Effective management to control and reduce losses is an essential task for sanitation companies to remain competitive (KUSTERKO *et al.*, 2018).

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Conflicts of interest: the authors declare no conflicts of interest.
Funding: none.
Received on: 10/26/2023 – **Accepted on:** 04/27/2024

According to Heller and Padua (2016), water losses can be divided into real losses, which correspond to the volumes resulting from leaks and overflowing from units of the system, and apparent losses, which are the volumes from clandestine connections and irregular by-passes in the extension of connections, plus the volumes not accounted for due to stopped hydrometers, subtests, fraud, reading errors and the like.

Among the tools used to quantify water losses, water balance is one of the main (MARQUES *et al.*, 2021). It is a method standardized by the International Water Association (IWA) that consists in dividing the volumes into authorized for consumption and water losses. The volumes that are authorized for consumption involve those measured in hydrometers and estimated consumptions, in order to compose the volume of water invoiced in the system. The authorized consumptions that are not invoiced, added to the actual losses and apparent ones, make up the volume of water not invoiced (SILVA, 2019).

Another tool used in the determination of losses is the method of minimum night flows, which can be applied in measuring zones, assuming that human activity during the late night and early morning is minimal (SERAFEIM *et al.*, 2022).

In this way, the methods used to determine losses combined with available software and technologies allow an integrated approach to combat losses.

This work aimed to develop a technological protocol for improvements in loss control in real water supply systems.

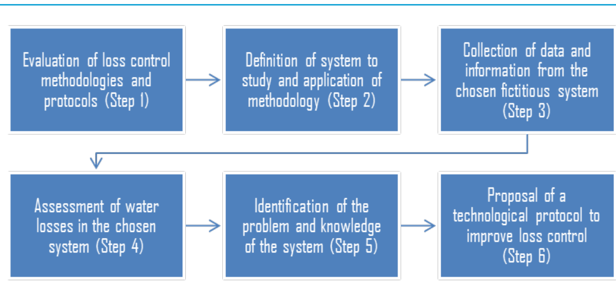
METHODOLOGY

When starting the methodology, we felt the need to define what a protocol is, that is, a series of actions focused on achieving a result or objective; and the tools presented earlier are the resources to be used in such protocol. Thus we set about enumerating the tools that can be applied in a medium-sized supply system.

The proposed methodology can be divided into stages, according to the flowchart provided in Figure 1. The work of Nogueira and Silva (2023) presented some initial results of this research, such as a methodology for the elaboration of the protocol and its first stage, that of diagnosis.

Evaluation of existing protocols

The loss control method created by the State Basic Sanitation Company of the State of São Paulo (Sabesp) — the Method of Analysis and Solution of Water Loss Problems (MASPP) — is based on the Plan-Do-Control-Act system, seeking to characterize the problems and standardize actions.



Source: Nogueira and Silva (2023).

Figure 1 – Flowchart of the stages of the proposed protocol.

The protocol COM+ÁGUA.2, presented by the Brazilian Ministry of Cities, aims to understand all aspects of the problem of losses and perform technical, social and interpersonal approaches, among others, in order to improve system performance (MINISTÉRIO DAS CIDADES, 2018).

The Water and Sewage Company of Brasília (CAESB) has its methodology focused on technical actions to combat losses, aimed at improving the system used to obtain and analyze data to promote actions in the field.

The Loss Reduction Program of the Intermunicipal Sanitation Regulatory Agency of Rio Grande do Sul (Agesan-RS) is established through technological and methodological actions, both structural and non-structural.

Table 1 shows a comparison between the protocols.

Characterization of the studied system

The fictitious system created is based on the systems found in cities of Minas Gerais with populations of up to 30 thousand inhabitants. Systems are characterized by the following:

- Missing or incomplete network register.
- Flow monitoring only at the water treatment plant (wtp) inlet.
- No pressure monitoring, only point measurements with manual gauges.
- No loss reduction programs or field leak geofencing/investigation.
- Absence of data on apparent losses.
- Has measured and invoiced water volume data.
- Acts only with corrective maintenance.
- There is no concrete planning for system growth and improvement.
- Low number of pressure reducing valves (prvs), causing pressures above the limit in some neighborhoods.

RESULTS AND DISCUSSION

Diagnosis stage

Based on the definition of the system's components and its diagnosis, a protocol was proposed to assist in the management and control of losses, allowing the implementation of measures according to the local and economic possibilities of the manager, as shown in Figure 2.

The measures proposed in Figure 2 were classified according to technical and economic feasibility, so that the actions in green represent the most viable to implement, those in yellow have an average viability and those in red are more complex to implement.

Diagnosis begins with information on flow measurement. The initial measurement of uptake is considered as primary and consolidated data for the beginning of the protocol. Starting from this, it is necessary to understand the system's micromeasurement, whether there is a measurement at the output of the treatment and whether there are measurement sectors in the network. In possession of some of these data, it is possible to perform an estimated water balance and a basic diagnosis of the system.

With the data on micromeasurement, WTP output, and other complementary information, a general and more complete water balance can be performed in order to contribute to the complete diagnosis of the system.

As for the pressure measurement, we seek to understand if there is monitoring, and if the method of nocturnal minima can be applied to quantify losses; otherwise we can evaluate the application of measurement sectors for point or continuous data collection.

Table 1 – Comparison between existing protocols.

	MASPP Sabesp	COM+ÁGUA.2 Ministry of Cities	CAESB	PRP Agesan-RS
Focus	Standardization of processes and personal improvement	Reduction of water losses. Management of energy use, social mobilization and organizational management	Determination of losses in order to identify the volume of water lost	Identification of the causes and formatting of structural and non-structural actions following a hierarchy
Premise	Characterize the real problem through data and, from that, treat the problem	Define the income and loss of a system; make a diagnosis of losses; design a plan for reduction and control of losses	Definition of measured, micromeasured and presumed volume	Technological actions: register/manage, measure and act. Methodological and human actions: define processes, plan and educate, measure, control, evaluate and standardize
Technical actions	Measurement of control items. Performance indicators	Technological approach on real, apparent losses and use of electricity. Water balance and performance indicators	Water balance and method of minimum night flows. Sectorization of networks, pressure monitoring and control, detection of leaks, evaluation of deployment of VRPs	Registration of networks and consumers, flow, pressure and water level measurements, sectorization project, network improvements, implementation of PRVs
Methodological and human actions	Analysis of processes and procedures, training	Social mobilization, organizational management	–	Redesigning processes, training, goals, standardization, audits
Adaptability according to system size	Low	High	Average	Average
Complexity of deployment	High	Low	Average	High
References	Cianfanelli (2012)	Ministério das Cidades (2018)	Gonçalves (1998)	FUNASA (2014)

PRV: pressure reducing valve.
Source: the authors (2023).

To evaluate the control measures already applied by the manager, we can check if there is a technical record of the system, through registration of georeferenced networks, registration of system units, reserving volumes, pumping data, among others.

Other control measures to be analyzed are the existence or not of studies of losses in the system, leak detection programs (geofences), and whether there is a technical team trained to manage the system and perform the control and reduction of losses. The protocol provides for actions that the manager can implement if he has not applied the control measures.

Information is obtained from the analysis of the following pillars: flow measurement, pressure measurement and existing control measures. These lead to the complete system diagnosis for adequacy and application of the final protocol to implement the control measures that will assist in the management and reduction of losses in the system.

Final protocol — control measures

From the diagnosis, a flowchart was created to implement the management and loss control measures, as presented in Figure 3.

Like Figure 2, the measurements were classified according to the feasibility of implantation and the time needed for it.

Feasibility was defined based on field experience, taking into account the complexity of the actions to be performed, the knowledge or material that is required to apply them and the potential costs that can be generated for the system manager.

Protocol considers performance by identifying four bottlenecks: real losses, apparent losses, hydro-energy efficiency and planning.

To reduce real losses, one of the actions for the short and long term is social mobilization, promoting the conscious use of water, regularizing irregular connections, monitoring leaks by the population.

A fundamental tool to guide the actions of the system is its technical register, including networks, pumping, reservoirs, records and other system components, ranging from a simple register to a georeferenced one, with altimetry and other data of interest.

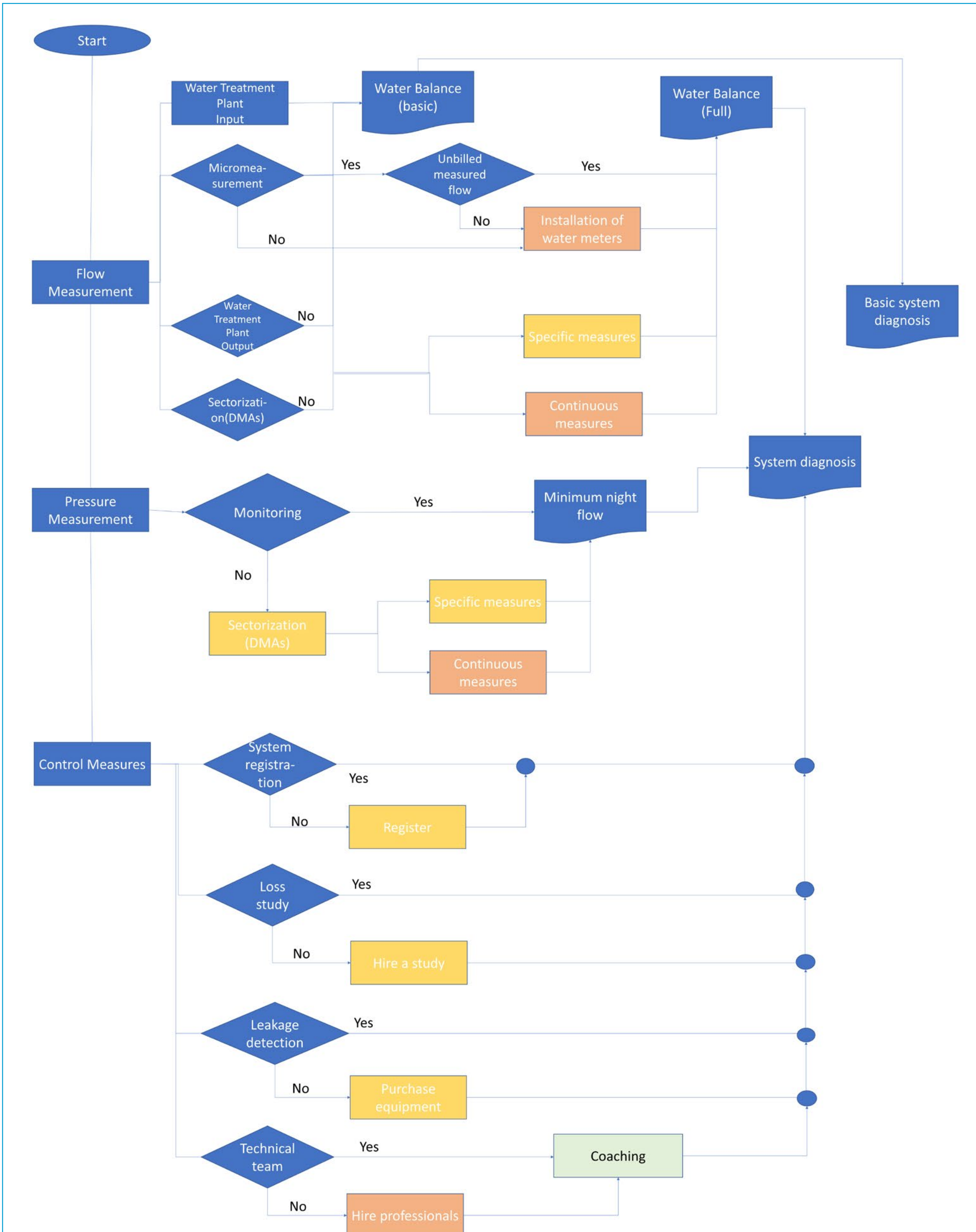
With the flow and pressure data it is possible to perform simulations and network models, seeking to understand the correct functioning and to assist in the expansion and improvement of the system. The more data and the better the technical record, the better the results of these studies, promoting better knowledge of the network and identification of real losses.

Finally, the most efficient and complex measure of implementation regarding the control of real losses is the sectorization of the system and pressure control. This measure involves works in the network for physical separation of network stretches, interconnection of other stretches, installation of PRVs and registers, which explains the technical and economic complexity involved; however, application can be done in stages and usually yields expressive results.

In order to combat a system with disabilities in the management of apparent losses, the protocol indicates the refinement of the commercial register, allowing to understand the network of users who are registered and including even users who are not charged, but need to have their volumes measured for control.

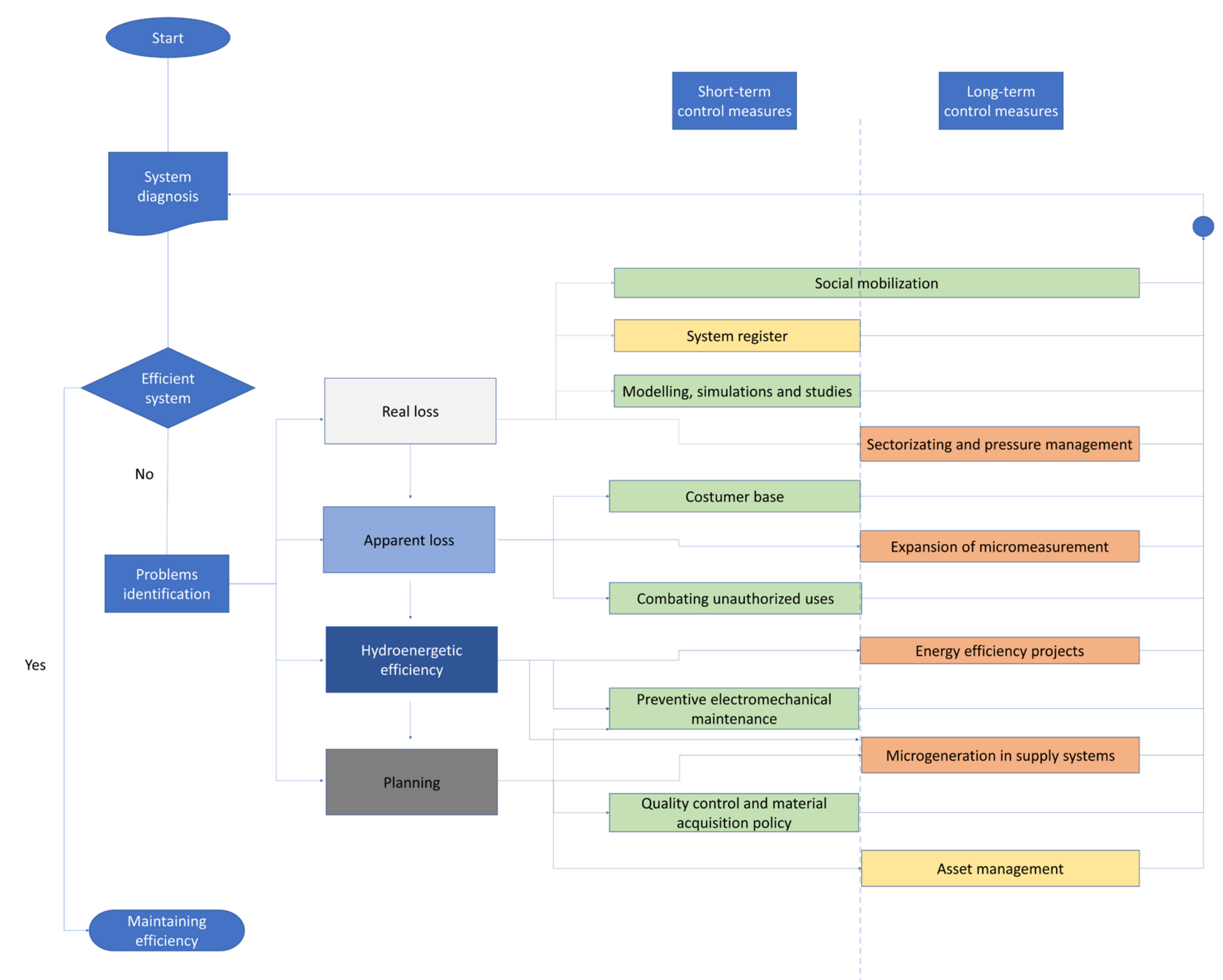
Another high cost measure that can be applied in stages is the expansion of micromeasurement, and also the qualification of this micromeasurement, installing water meters at public points, which are sometimes not charged and therefore not measured, making it difficult to detect leaks at these points.

The fight against clandestine and by-pass connections on the networks occurs through short-term measures and, together with a policy of incentives and social tariffs, can obtain significant results. The implementation of social tariff tends to influence users who previously chose not to connect to the



Source: Nogueira e Silva (2023).

Figure 2 – Systems diagnosis protocol.



Source: the authors (2023).

Figure 3 – Loss control measures protocol.

distribution network due to economic vulnerability, and sometimes opted for clandestine connections, to become part of the manager's revenue, considering that they can access quality water at prices compatible with their realities.

As for the issue of a deficient hydro-energy system, we recommend the application of studies seeking to apply efficient pumping systems and, when possible, the implementation of microgeneration in the systems. Microgeneration is possible with photovoltaic power systems and pump systems functioning as turbines in pipelines with large unevenness.

Preventive electromechanical maintenance is also fundamental in this process, sustaining the energy efficiency of electromechanical components, and avoiding unnecessary consumption of water and energy.

As for the planning sector of a sanitation system manager, actions such as the implementation of quality control and purchase of materials, the training of managers and operators, allowing the structuring of processes, and the correct asset management of the system manager are recommended.

The protocol must be applied continuously, enabling the identification of results and new bottlenecks, so that it is possible to maintain control actions corresponding to the reality of the system according to the current situation.

CONCLUSIONS

Knowledge of the system used and the techniques available is essential to begin controlling and managing losses in a supply system. Therefore, it is crucial to gather all available information in order to understand which are the main demands and which are viable to be addressed in that reality.

The loss management model has the potential to promote improvements from management to the operation of supply systems, comprising structural and non-structural actions, allowing the manager to understand the feasibility of applying it to his system.

The proposed protocol aims to adapt to each situation and be applied continuously, providing alternatives that can be implemented so long as the manager has the investments and technical capacity to carry them out. In this way, it is understood that the protocol fulfills its objective of assisting in the management of losses in small and medium-sized supply systems.

With the new sanitation regulation — Law 14,026/2020 (BRASIL, 2020) — requiring greater organization of municipalities and system managers, a growing interest and development in the area of water efficiency in sanitation systems is expected, as well as growth in investments and opportunities in the sector.

AUTHORS' CONTRIBUTIONS

Nogueira, F.P.: Conceptualization, Data Curation, Investigation, Methodology, Project Administration, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing. Silva, F.G.B: Conceptualization, Formal Analysis, Methodology, Supervision.

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