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HYDROMETERING OF THE INTEGRATED SUPPLY SYSTEM OF PIAUITINGA: THE IMPORTANCE OF MICROMETERING IN COMBATING LOSSES

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Abstract: The multiple uses that are made of the water present in the Piauitinga river basin are conflicting, mainly for domestic supply, since the quality and quantity of available raw water have deteriorated over the years, due to several factors. This research aimed to analyze the hydrometering of the Integrated System of Piauitinga and show the importance of micromeasurement in the fight against losses. The investigation was guided by a conceptual framework of reference that made it possible to identify the five most recurrent anomalies in micromeasurement, a considerable technical factor. For the development of the research, quantitative investigation techniques were used, making use of information collected in the field by the monthly collection system of the Sanitation Company - DESO, obtained through reports that allowed identifying the characteristics, and quantifying the anomalies previously defined as parameter, making it possible to create percentage indexes in relation to the general occurrences of each location. Considering the analyzes carried out in this study, it can be stated that rates were found regarding real connections, ranging from 0.20% in a best scenario to 6.69% in the worst scenario for cut connections, from 15.98% to 43.95% for suppressed connections, and from 80.80% to 52.88% for active connections. The results showed that direct action is needed in the replacement of water meters, not only with the aim of establishing and charging targets, but also in promoting a better operation of the existing water meter park. Seeking to guarantee its sustainability, in view of the universalization of services with efficient management of the supply system.
Keywords: Hydrometry. Micro measurement. Losses. Sustainability. Supply System.

INTRODUCTION

Currently, in the world, approximately 1 billion people have difficulty accessing drinking water and springs have been the target of intense exploitation and degradation. In addition, around 2.6 billion people do not have access to adequate sewage solutions (UN-HABITAT, 2011).

In Brazil, efforts are still needed to universalize access to drinking water. In 2016, 87.3% of households connected to the general network had daily water availability, a percentage that was 66.6% in the Northeast. In this region, in 16.3% of households water supply occurred from one to three times a week and in 11.2% of households from four to six times, according to the results of the Continuous National Household Sample Survey 2012-2016, released by IBGE (2019).

One of the main problems faced by public service providers focused on regional sanitation in Brazil are the high losses in the volume of water distributed in relation to the water collected, so it is essential to establish strategies to control water losses, mainly in regions with scarcity and conflicts over its use. In the case of the state of Sergipe and the municipalities served by DESO, the rate of losses in distribution reached a percentage of around 59.37% in 2013, according to a survey presented by the National Sanitation Information System (SNIS, 2013). This high percentage implies serious environmental damage in the search for new sources to meet the needs of water use and economic losses, reducing the revenue of the company responsible for water supply (TSUTYIA, 2004).

The water supply system must meet universalization targets, but there are losses from the capture of the resource in the springs to its final destination, which for users, can be caused by deficiency in the operation, in the maintenance of the networks, in the inefficiency of the systems macro and micro measurements and even problems in commercial management.

In view of this, sanitation companies are directly involved in this problem and have the challenge of combating water losses and rationing the volume consumed, in order to meet the growing demand, without having to increase the exploitation and degradation of springs in an unsustainable way (PIECHNICKI et al., 2011).

According to the National Secretariat for Environmental Sanitation (SNSA), loss rates are directly associated with the quality of infrastructure and system management. To explain the existence of water losses at levels above the acceptable, some hypotheses can be raised, such as: leak detection failures; distribution networks operating at very high pressures; problems in the quality of systems operation; difficulties in controlling clandestine connections, measuring, calibrating and renewing the macro and micro meters park; absence of loss monitoring program; culture of increasing supply and individual consumption, without concerns about conservation and rational use; pragmatic decisions, not foreseen in the project, to expand the load and extend the networks to more peripheral areas of the systems, to serve new consumers, among other hypotheses. The water loss index is also related to the hydrometering index, which refers to the water connections measured by the total number of water connections and the micromeasured volume of water, which consists of the average volume of water determined by the flow meters installed in the building extensions (SNSA, 2012).

For the determination and identification of losses, it is fundamental that the volumes in each part of the system are measured, through macro and micro measurements. The inoperability and absence of micro-measurement are one of the main causes of apparent losses, however, it is neglected by some operators. The international experience and that of some Brazilian cities leads to the conclusion that consumption in areas with unmeasured connections is limited to the supply capacity of the system, as the user has no reason to save water or avoid waste.

The Piauitinga Integrated Supply System does not exclude itself from this reality with the identification of functional anomalies in the micro-measurement system. It is necessary to implement actions to reduce losses, reduce operating expenses and the amount collected in the springs, thus increasing the availability of the resource so that it is possible to guarantee the fulfillment of current and future demands. Thus, a deep analysis of the micromeasurement of the system that is at the tip of this process is necessary. In addition to providing important information for the company's financial health, the volume measured so that it can be transformed into billed volume, is an instrument of discipline for the rational use of water.

Apparent water losses are directly related to unauthorized consumption and measurement failures, which can occur due to meter reading errors, fraud in water meters, clandestine connections in the network, inconsistent water meter records, errors in data manipulation and in the billing, among other factors.

Therefore, the relevance of the subject under study occurs not only in the context of apparent commercial losses in the Integrated Supply System of Piauitinga, with information on micromeasured volumes, compared with what was produced and billed, but also as a diagnosis of the situation of the water meter park. of the system to enable better management and planning to control water losses.

METHODOLOGY

The research made use of both qualitative and quantitative research techniques, making use of the collection of bibliographic information from sanitation companies in the country, theses, articles, documents from the Ministry of Cities and the Sanitation Company of Sergipe-DESO, in addition to data from the Sanitation Management System-GSAN and DESO's Commercial Reporting System-SRC.

For the development of the research, the following studies were carried out:

a) Documentary research on water loss programs developed by companies in the supply sector, loss systems, micrometering management, improvements in the commercial system, loss indicators, micrometering water balance, characteristic and situation of hydrometering of the Integrated Supply System of Piauitinga - SIAP.

b) Field research in the municipalities that comprise the SIAP, aiming to collect data that support the exploratory analysis on the characteristics and conditions of the SIAP water meters through monthly consumption readings and which are available in the DESO information systems.

Data were collected in a cycle of 12 (twelve) months comprising the period from the beginning of January 2018 to the end of December 2018. The worst of the 12 scenarios was considered as an analysis parameter. In the field to collect the information, the meter readers used a Portable Microcomputer - MCP and processed by the GSAN and the Commercial Reporting System - SRC, thus producing synthetic reports of the existing connections and occurrence reports, as shown in Figures 1 and Figure 2 extracted from the System of Commercial Reports-SRC-DESO. After processing and analyzing these data, percentage indexes were created that made it possible to inform the real situation of the SIAP micro-measurement park and a view of the current situation, thus making it possible to identify the points of anomalies to be treated to improve losses.

CHARACTERIZATION OF THE STUDY PLACE

CHARACTERISTICS OF THE HYDROGRAPHIC BASIN

The study was carried out in the area of the Piauitinga river basin, which includes the municipalities of Boquim, Estância, Lagarto, Salgado and Itaporanga D'Ajuda. It is inserted in the geographical mesoregion of Sergipe wild areas (Microregion of Lagarto) and East Sergipano (microregions of Boquim and Estância) and is located between the geographic coordinates of 10°34' and 10°45'S and 37°22' and 37°34 'W. It has 419.335 km² of area with a perimeter of 128.251 km, and can be classified as third order, it is 59.86 km long, with a drainage of tributaries that add up to 976.22 km. Its main source is located in the municipality of Lagarto and its mouth in the municipality of Estância. The climate in the region of the municipality of Lagarto is classified as Subsumed Megathermal, with an average annual precipitation value of 1,182.8 mm. The average annual temperature is 28°C, varying between 22.3°C for the wettest and coldest months (July to August) and 26°C for the driest and hottest period (December to March). The main land use and occupation activities are agricultural crops and pasture, with occasional areas covered with seasonal forest, broadleaf forest and riparian forest. (PIAUÍ RIVER HYDROGRAPHIC BASIN PLAN, 2015).

The relief features a predominance of flat features at low altitudes. (BOMFIM, 2002). The soils in the region are classified as Dystrophic Red Yellow Argisol, Dystrophic Red Yellow Latosol and Fluvial Neosol, according to the Brazilian Soil Classification System (EMBRAPA, 2006).

The vegetation present in the region can

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DESO	GSAN- SANITATION MANAGEMENT SYSTEM SUMMARY STATEMENT OF CONNECTIONS IN THE MONTH (01/2018) REGIONAL MANAGEMENT: 2- SOUTH BUSINESS UNIT: 1-METROPOLITAN Place: 399 -POV NOVA DESCOBERTA	**PAG 73 640** 05/02/2018 08.08.43 **R1003**

1-WATER

1.1-CONNECTION MOVEMENTS

Existing: 605 Working: 319 Cut: 21 Deleted: 265

Cut(month): 0 On(month): 2 Reconnected(month): 1

1.2-SAVINGS

Existing: 607 Working: 321 Cut:21 Suppressed: 265

1.2.1-EXISTING ECONOMIES BY CATEGORY

Residential: 601 Commercial: 0 Public: 5 Industrial: 1

1.2.2-OPERATING ECONOMIES BY CATEGORY

Residential: 317 Commercial: 0 Public: 4 Industrial: 0

1.3-HYDROMETERS

Operating: 319 Cut: 21 Read: 18 Installed: 2 Stopped: 2

1.4-CONSUMPTION(m3)

Estimated not Hydrometered: 0 Estimated Hydrometered: 50 Actual Hydrometered. 131 Billed: 181

2-SEWAGE

2.1-CONNECTION MOVEMENTS

Existing: 0 Working: 0 Cut: 0 Suppressed: 0

2.2-SAVINGS

Existing: 0 Working: 0 Cut: 0 Suppressed: 0

2.2.1-EXISTING ECONOMIES BY CATEGORY

Residential: 0 Commercial: 0 Public: 0 Industrial: 0

2.2.2- ECONOMIES OPERATING BY CATEGORY

Residential: 0 Commercial: 0 Public: 0 Industrial: 0

Figure 1 Synthetic Statement of Connections.

16/02/2018												
SRC-Commercial Reporting System												
READING OCCURRENCE												
Regional	Location	Registration	Mat Clie	Name	Type	Title	Name	Property number	Neighborhood	Hydrometer	Code	Type
2	POV NOVA DESCOBERTA	7065248	7355823	GILZA FAGUNDES DOS SANTOS	STREET	null	A-LOT. ALCIDES BISPO	13	POV.NOVA DESCOBERTA	A16021490	38	HYDRATANT WITHOUT REPAIR
2	POV NOVA DESCOBERTA	7113315	7431791	MARISA MAIARA DE JESUS FARIAS	STREET	null	A.LOT. RIBEIRO	45	POV.NOVA DESCOBERTA	A13N085644	38	HYDRATANT WITHOUT REPAIR
2	POV NOVA DESCOBERTA	7061331	7355742	HELENA VIEIRA DA SILVA	STREET	null	B-LOT. ALCIDES BISPO	16	POV.NOVA DESCOBERTA	A16A021492	30	HYDRATANT NOT WORKING
2	POV NOVA DESCOBERTA	7061340	7355750	GIVALDA DA SILVA	STREET	null	B-LOT. ALCIDES BISPO	15	POV.NOVA DESCOBERTA	A16A021491	38	HYDRATANT WITHOUT REPAIR
2	POV NOVA DESCOBERTA	4147189	4147189	JOSEFA ARAUJO LISBOA	STREET	null	DA IGREJA	336	POV.NOVA DESCOBERTA	A98N456679	12	WITHOUT HYDRANT
2	POV NOVA DESCOBERTA	4147006	4147006	HELENA MARIA DE SANTANA	STREET	null	DA IGREJA	211	POV.NOVA DESCOBERTA	A98N456675	11	BROKEN HYDRANT
2	POV NOVA DESCOBERTA	4154584	4154584	ANTONIO SABINO	STREET	null	DA IGREJA	253	POV.NOVA DESCOBERTA	A98N456678	60	CLOSED HOUSE
2	POV NOVA DESCOBERTA	4146700	4146700	NOEL FERREIRA DE ARAUJO	STREET	null	DA LARANJA	2940	POV.NOVA DESCOBERTA	A98N457106	11	BROKEN HYDRANT

Figure 2: Synthetic Statement of Reading Occurrences.

be classified as Seasonal Semideciduous Submontane Forest and transition between Seasonal Forest and areas that have undergone changes with agriculture (MINISTÉRIO DO MEIO ENVIRONMENT, 2006).

In relation to the physical aspects of geology and hydrogeology, the presence of three distinct groups can be observed in the area of the Piauitinga River basin: the Barreiras Group, the Lagarto Formation and the Granulitic Complex. Estância, which are put in contact, through a fault perpendicular to the course of the river, which allows the appearance of water, since the fault is the tectonic event responsible for the occurrence of mineral water mines as found in the city of Salgado. The Piauitinga River basin has the privilege of being comprised between three hydrogeological domains of good permeability, which are the Cenozoic Superficial Barrier Formations, the Cristalino and the Estância Group.

The main recharges of underground springs occur through rainfall, associated with the geological structure and hydrogeology that allow a quality water surplus with good annual availability, guaranteeing the supply of populations beyond the basin area (WATER BASIN PLAN OF THE PIAUI RIVER, 2015).

CHARACTERISTICS OF THE INTEGRATED SUPPLY SYSTEM OF PIAUITINGA-SIAP

The Integrated Water Supply System of Piauitinga-SIAP, serves a total of 03 (three) municipal seats and 54 (fifty-four) locations, making a total of 48,596 (forty-eight thousand, five hundred and ninety-six) real connections and 37,603 (thirty seven thousand six hundred and three) active connections, these numbers comprise 38.44% of the real connections and 40.32% of the active connections of the Regional Operations Management South-GOSU, supplying the supply need to serve approximately 145,788 (one hundred and forty-five thousand seven hundred and eighty-eight) people, has two surface collections, one on the Piauitinga River in the town of São Bento in the municipality of Salgado and the other on the Piauí River at the Dionísio Machado Dam in the town of Fazenda Grande in the municipality of Lagarto, comprises also to the system 15 (fifteen) deep wells, where today 08 (eight) are in full operation and has 116,707 km (one hundred and sixteen seven hundred and seven) kilometers of pipelines, has a daily operation of 24 (twenty four) hours with a production of 21,986 (twenty-one thousand, nine hundred and eighty-six) m^3/day.

RESULTS AND DISCUSSION

DIAGNOSIS OF HYDROMETERING

In all aspects, whether due to the parsimony in the use of water by customers, or the essential determination of the volumes measured at each customer, it is fundamental for any system to have 100% hydrometering, as well as the existence of an updated and reliable commercial register, under penalty of living with distortions in the billing of customers and deficiencies in the calculation of micromeasured volumes (TARDELLI, 2016). Table 1 presents the hydrometering indices and Figure 3 shows a comparison between these hydrometering indices.

A diagnosis was carried out in the locations served by SIAP in the municipalities of Salgado, Boquim, Lagarto, Riachão do Dantas, Simão Dias and Poço Verde. For each of these municipalities, the characterization of water connections was identified based on the purpose of service: Residential; Commercial; Industrial and Public.

As for the physical conditions found in the micromeasurement of the SIAP, it was observed that during the annual cycle of monthly measurements, 05 (five) most recurrent anomalies among the 11 (eleven)

Region/Cia/Systems	Hydrometering index (%)
Brazil	92,4
North East	87,9
DESO	99,3
GOSU	73,76
SIAP	77,38

Table 1. Hydrometering indexes

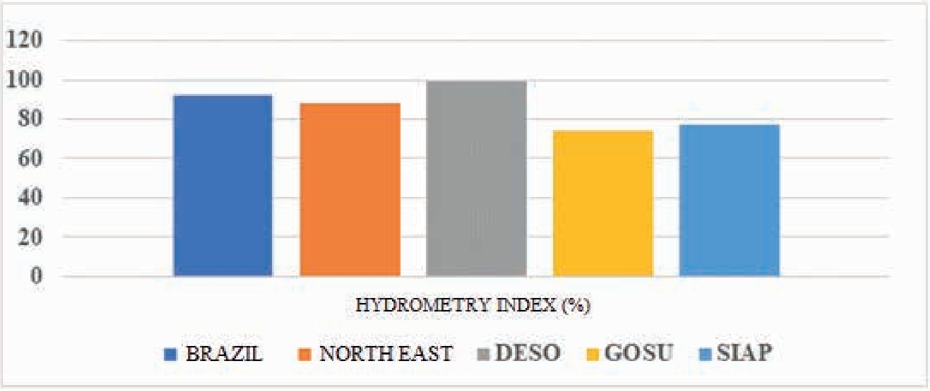

Figure 3 - Comparative Diagnosis of Hydrometering.

Municipalities / Towns	Hydrometration index (%)
Boquim	52,88
Salgado	71,08
Lagarto	76,76
Riachão do Dantas	81,85
Simão Dias	80,80
Poço Verde	55,85

Table 2. Hydrometering Indexes of SIAP Municipalities

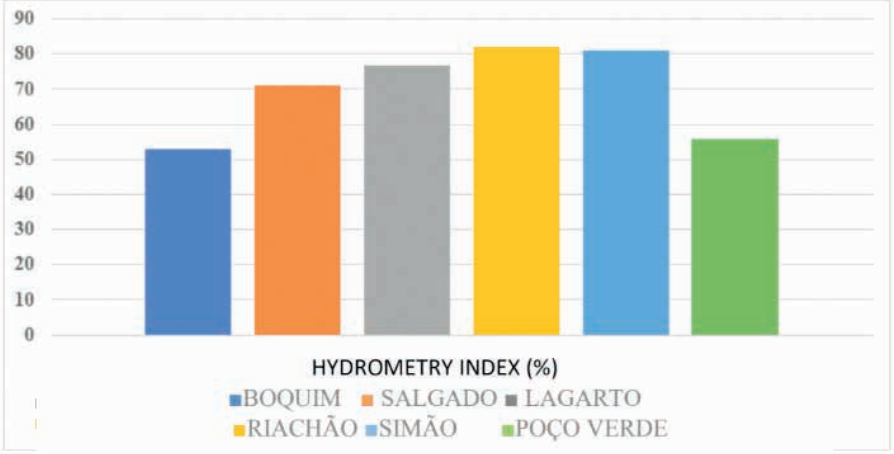

Figure 4 - Comparative Diagnosis of Water Metering in SIAP Municipalities.

registered in the MCP system, depending on the recurrence were considered: Hydrometer Stopped; Broken hydrometer; No Hydrometer; Sweat and/or Grounded Hydrometer and Underground Hydrometer.

Micrometering anomalies are factors that directly influence apparent losses, as it is proven the waste of water caused by users who do not have the meter installed, poorly installed meters, with their incorrect operation. Measuring equipment does not measure flow directly, but through the relationship between fluid velocity and cross-sectional area of the pipe or the relationship between volume and time. Thus, the inaccuracy of the equipment can be a consequence of any mistake in one of these factors (BRAZIL, 2007). Table 2 presents the water metering indices of the municipalities and towns supplied by the SIAP and Figure 4 shows a comparison between these water metering indices.

In the case of micrometering, failures occur when the water meter undersizes measurements, when its operation is stopped, or has installation time longer than recommended for its effectiveness and when there are impediments to reading the water meters. By measuring the hydrometer, it is possible to analyze billing and regulation of treated water consumption, in addition to determining sewage billing, as it relates to water consumption (SANTOS, 2013). Therefore, the water metering index expresses in percentage the active registered connections with meters in relation to the total number of registered and active connections, being hydrometered or not (LEÃO, 2014).

Table 3 shows the total situation of the connections of the municipalities that comprise the entire Operational Management South-GOSU and of the municipalities that comprise only the Integrated Supply System of Piauitinga-SIAP and presents the indexes that SIAP represents for GOSU.

The scenario of the five main occurrences in the micro-measurement of the Integrated Supply System of Piauitinga is represented in Figure 5, while the occurrences of the micro-measurement of the Integrated Supply System of Piauitinga by municipality are represented in Figure 6.

With these results, it is necessary to implement policies in the system of macro measurement, sectorization, micro measurement, correction of irregularities in building branches, replacement of water meters that present functional anomalies and improve the operational control of the distribution system.

The need to measure and plan future investments with actions to control water losses is relevant, considering not only the minimization of real and apparent losses, but mainly taking into consideration,the sustainability of a water supply system from the point of economic-financial point of view, but mainly environmental. These points can be the subject of future investigations, so that knowledge about the phenomenon of efficiency in water use, making it possible to identify broader and more efficient strategies to face the challenges posed to providers of public water supply services in the country.

The rate of 43.95% of suppressed connections is quite worrying, this situation demands continuous resources from the company, as they need to be constantly inspected to avoid clandestine reconnections. As for consumption, there is no control since the company does not bill, does not collect and, above all, a large amount of water is offered, since consumers are not concerned with waste, since they do not pay anything, causing high levels of loss and provide an incentive for exacerbated consumption of the resource in addition to the environmental impact, economic and operational factors unfavorable to the system operator, as shown

System	Residential	Commercial	Industrial	Public	Connection status			
					Real	Cut	Sppressed	Active
GOSU	121.149	3.703	206	1.375	126.433	4.624	28.552	93.257
Indices to Real GOSU Connections						3,66%	22,58%	73,76%
SIAP	46.608	1.508	88	395	48.596	908	10.085	37.603
Indexes in Relation to the Real Connections of the SIAP						1,87%	20,75%	77,38%
Representative Indexes of SIAP as to that of GOSU					38,44%	19,64%	35,32%	40,32%

Table 3. Comparison of the Situation between GOSU and SIAP connections

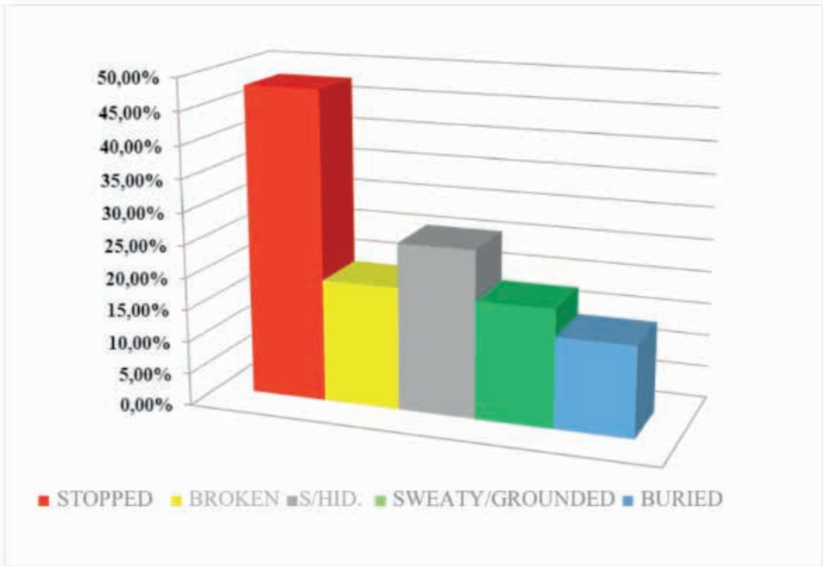

Figure 5 - Occurrences of the SIAP water meters.

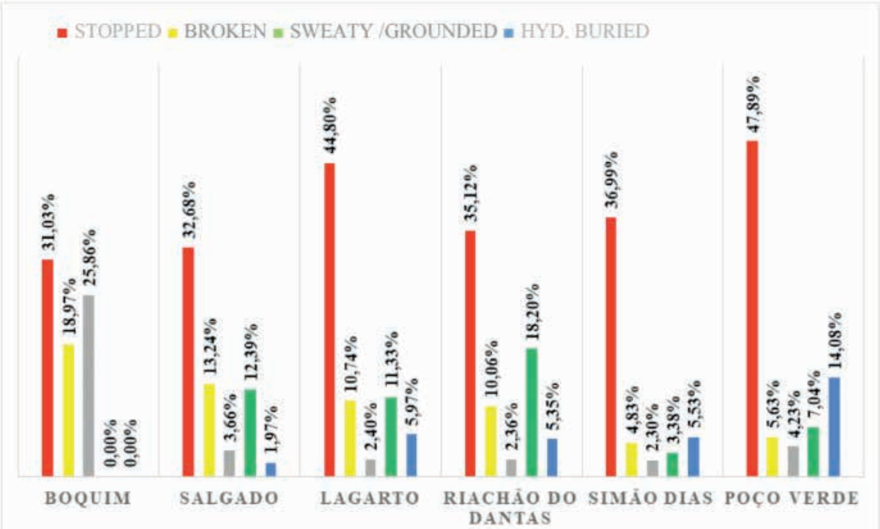

Figure 6 - Occurrences of hydrometers in the municipalities that comprise the SIAP.

in Table 4.

Considering the 05 (five) occurrences directly linked to the functionality of the micromeasurement, the indices shown in Table 6 were found.

Considering the indices of the 05 (five) occurrences directly linked to the functionality of the micro-measurement that were found, it is concluded that:

As for the stopped water meters, rates that varied from 31.03% in the best scenario in the municipality of Boquim to 47.89% in the worst scenario in the municipality of Poço Verde were found, given this situation, the information collected in the readings did not reveal the actual consumption, because when reading the stopped water meters, the average of the last six months of consumption is considered, thus generating completely inconsistent consumption data. to operate normally, thus charging an average of the last few months, completing the fourth cycle, the meter itself opens a case for its replacement.

For broken water meters, the rates vary from 4.83% in the best scenario in the municipality of Simão Dias to 18.97% in the worst scenario in the municipality of Boquim, in this situation the information on the occurrences is transmitted immediately by the meter reader and its replacement is requested, because when reading the broken water meters, the average consumption is considered, thus generating totally inconsistent consumption data.

In situations without a hydrometer, rates ranging from 2.30% in the best scenario in the municipality of Simão Dias to 25.86% in the worst scenario in the municipality of Boquim, a situation in which the information on the occurrence is also transmitted immediately by meter readers and demand its installation, because when the reading is carried out in situations like this one considers the average consumption or the minimum tariff, it can occur due to a procedural failure in the implementation of the new connection, removed by vandalism by third parties or by the user himself, thus generating data totally inconsistent consumption.

In the sweat/ground water meters scenario, indexes ranging from 0.00% in the best scenario in the municipality of Boquim to 18.20% in the worst scenario in the municipality of Riachão do Dantas were found; Once the reading is carried out in situations like this, it can be considered the average consumption or the minimum tariff, it may occur due to lack of adequate protection of the water meter or procedural failure in the implementation of the new connection, exposed to weather conditions, internal humidity arises, where the anytime back to normal situation.

While for buried hydrometers, the indices vary from 0.00% in the best scenario in the municipality of Boquim to 14.08% in the worst scenario in the municipality of Poço Verde; In view of this situation, the information on the occurrence is immediately transmitted by the meter reader and the transfer of the installation site is requested, when the reading is carried out in situations like this, the average consumption or the minimum tariff may be considered, it may occur due to a procedural failure in the implantation of the new connection or damage to the cover of the protection box, thus accumulating residues such as debris and sand, thus generating inconsistent consumption data.

CONCLUSION

Considering the analyzes carried out in this study, it can be concluded that indexes were found in the analyzed municipalities regarding real connections: cut indices vary from 0.20% in a best scenario in the municipality of Poço Verde to 6.69% in the worst scenario in the municipality of Salgado; suppressed, the indices vary from 15.98% in

County	Indexes in Relation to Real Connections			
	Real	Cut	Suppressed	Active
Boquim	607	3,46%	43,66%	52,88%
Salgado	1.449	6,69%	22,22%	71,08%
Lagarto	31.384	1,19%	22,04%	76,77%
Riachão do Dantas	3.587	1,62%	16,53%	81,85%
Simão Dias	11.073	3,22%	15,98%	80,80%
Poço Verde	496	0,20%	43,95%	55,85%
Total	**48.596**	**6,69%**	**43,95%**	**52,88%**

Table 4. Indexes of SIAP connections

Municipality/Towns	Index in relation to General Occurrences				
	Hyd. Stopped	Hyd. Broken	No Hyd.	Hyd. Sweaty /Grounded	Hyd. Buried
Boquim	**31,03%**	**18,97%**	**25,86%**	**0,00%**	**0,00%**
Salgado	**32,68%**	**13,24%**	**3,66%**	**12,39%**	**1,97%**
Lagarto	**44,80%**	**10,74%**	**2,40%**	**11,33%**	**5,97%**
Riachão do Dantas	**35,12%**	**10,06%**	**2,36%**	**18,20%**	**5,35%**
Simão Dias	**36,99%**	**4,83%**	**2,30%**	**3,38%**	**5,53%**
Poço Verde	**47,89%**	**5,63%**	**4,23%**	**7,04%**	**14,08%**

Table 6. Indices of occurrences of water meters in the municipalities that comprise the SIAP.

the best scenario in the municipality of Simão Dias to 43.95% in the worst scenario in the municipality of Poço Verde; active the indices vary from 80.80% in the best scenario in the municipality of Simão Dias to 52.88% in the worst scenario in the municipality of Boquim;

It can also be concluded that it is necessary to implement a program that aims to deal with anomalies in the micromeasurement of the Integrated Supply System of Piauitinga, and the replacements led to an increase in the micromeasured volume, reducing the apparent loss rate and, consequently, increasing the volume billed.

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