Rational water use indicators for public schools in Recife, Brazil

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ABSTRACT

This paper seeks to propose rational water use indicators for public schools in Recife, Brazil. The methodology consists of a cadastral survey, the use of questionnaires, and identification of leakage in the hydro-sanitary facilities. The results indicate that even though water consumption is not as high as pointed out in the literature, the schools still present a considerable amount of physical water losses, in addition to having a low perception regarding the rational use of water. Based on these results, this study supports the development and application of water conservation actions within the school environment.

Key words | public buildings, water conservation, water consumption

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INTRODUCTION

As water demand in cities has increased, many regional and urban centers in both developed and developing countries are facing water shortage scenarios due to a variety of factors, including climate change, prolonged periods of drought, pollution of water sources, and increases in the levels of urbanization and population growth. The Mediterranean countries, Australia, the USA, and Brazil are examples of countries facing these conditions. This situation has led governments to establish both voluntary and mandatory measures to promote reduced water consumption (Kanakoudis 2002; Kanakoudis *et al.* 2011, 2013a, 2013b, 2015, 2016; Makki *et al.* 2013; Willis *et al.* 2013; Kanakoudis & Gonelas 2015).

Water demand in buildings is influenced by various factors, such as climate conditions, price and availability, sanitary installations, and the types of equipment used in buildings, in addition to the culture and consumption habits of users (Kanakoudis 2002; Willis *et al.* 2013; Kanakoudis & Gonelas 2014, 2015; Makki *et al.* 2015). The unit of water-consumption data used for analysis depends on the scale of the analysis (e.g. liters per household, liters per person) (Makki 2014; Makki *et al.* 2015). In schools, the unit most commonly used is liters per student (Cheng & Hong 2004; Gonçalves *et al.* 2005; Farina *et al.* 2011).

For non-residential buildings, such as public schools, the analysis of water consumption is quite difficult, as the number of users and the time that they spend in the school buildings both vary significantly depending on the day (Farina *et al.* 2011). In addition, water systems in public buildings often suffer many leaks and users tend to use water wastefully. This scenario usually occurs because users are not adequately aware regarding environmental conservation, are not directly responsible for the payment of the water bill, and because the maintenance system is either inefficient or does not even exist (Cheng & Hong 2004; Gonçalves *et al.* 2005; Soares *et al.* 2017).

This is actually the reality at many public schools across all regions of Brazil, as verified in studies by Gonçalves *et al.* (2005), Ywashima (2005), and Soares *et al.* (2017).

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Water conservation on a building scale is a set of activities, measures, and incentives whose main objectives are reduction in water demand, improved water use, reduction of losses and waste, implementation of methods and technologies to save water, and increased awareness on the part of users (Kanakoudis 2002; Gonçalves *et al.* 2005; Kanakoudis & Gonelas 2015; Kanakoudis *et al.* 2016). The implementation of these actions is associated with a previously conducted water audit.

In order to understand the water consumption pattern in a building, it is necessary to quantify and analyze a set of indicators which take into account not only the volume of water consumed in the building during a certain period of time, but also the assessment of losses due to leakage and the behavior of water users (Gonçalves *et al.* 2005; Ywashima 2005; Kanakoudis *et al.* 2011, 2013a, 2013b, 2015; Makki 2014).

The objective of this study is to determine values for indicators of rational water use in public schools in the municipality of Recife, Pernambuco, Brazil. It is thereby expected to support the implementation of water conservation programs for this type of building.

MATERIAL AND METHODS

The methodology developed was adapted from Gonçalves *et al.* (2005) and Ywashima (2005). Water efficiency in schools is a topic rarely found in international journals. The above-mentioned studies are relevant in Brazil because they developed methodologies to quantify water use indicators. The first study focused on results linked to water losses. The second contributed to the quantification of user behavior towards water consumption. Both were developed at public schools.

The methodology follows the steps below:

(a) select schools;
(b) determine all water consumption points at the schools;
(c) determine the presence of leakage or malfunction in the hydro-sanitary equipment;
(d) apply questionnaires to assess users' perception;
(e) determine the consumption indicator, leakage index, and user perception index for rational use of water.

Selection of schools, determination of water consumption points and pathological manifestations in the hydro-sanitary systems

Through coordination with the Secretariat of Education, six public schools were selected for the study. The water consumption points in the different school sectors were identified through on-site observation. During a second visit, the team carried out a survey of pathologies in the hydro-sanitary systems in order to identify leakage. In some cases, a third visit was conducted in order to verify the existence of corrective maintenance being carried out at the installations.

Two of the schools (Schools 04 and 02) were studied comprehensively by Soares *et al.* (2017), during 2014 in order to understand the end use water consumption at those buildings. Water meters were installed to enable water consumption monitoring at an end use level and how it was broken down into distinct water use events.

Application of questionnaires regarding user perception of rational water use

The methodology applied to assess user perception regarding the rational use of water is based on Ywashima (2005), and adapted for this study into two techniques: a structured interview and monitoring forms.

Both the questionnaires and the monitoring forms were based on the definition of different user types, grouped in four questionnaires encompassing questions related to water use activities.

Table 1 shows the division of the questionnaires and monitoring forms applied during the field visits.

Determination of indicators

To determine the water consumption at the school, the vacation months of January, June, July, and December were disregarded. As the population and working hours of the building during these periods is extremely different, the water consumption pattern will be atypical.

The Indicator of Consumption (*IC*), measured as L/student/day, was calculated according to Equation (1), relating the water consumption in the building to the

Table 1 | Types of questionnaires applied to users at the selected schools

Questionnaire	User type	Basic question content
B	Restroom users: school board, teachers, and remaining employees.	- How the washbasin, flush valve, urinals, showers, and restrooms are used. - Monitoring of waste and/or loss of water at the consumption points.
C	Responsible for food preparation and cleaning of the kitchen: cooks.	- Characterization of cleaning activities. - Characterization of food preparation. - Monitoring of waste and/or loss of water at the consumption points.
E	Responsible for cleaning the external area: janitor and general services assistant.	- Characterization of cleaning and maintenance activities.
I	Responsible for cleaning the internal area: janitor and general services assistant.	- Characterization of cleaning and maintenance activities.

Source: adapted from Ywashima (2005) and Nunes (2015).

consumer agent over a given amount time.

$$IC = \frac{Cm \times 1000}{NA \times Dm} \quad (1)$$

where Cm is the mean annual consumption in m³/month, NA is the number of consumer agents, and Dm is the number of weekdays per month.

The monthly consumption value was obtained from the counts issued by the local water supply company during the period studied. For the number of weekdays per month, a standard of 22 days was adopted.

For the number of consumer agents (NA), only students were considered. Workers do not generally remain at the school for the same length of time as the students. In Brazil, it is common for educational professionals to work at more than one institution. It was therefore decided to not consider them as part of the consumer agent total. In addition, Gonçalves *et al.* (2005), Farina *et al.* (2011), Cheng & Hong (2004), United Kingdom Department for Education and Skills (2002), and Mays (2001) consider only the number of students when calculating NA.

There are three types of students at the schools: those who study full time, those who study extended hours, and those who study during only one shift. For the schools having a student body divided into different shifts, the methodology of Nunes (2015) was employed, which consists of applying a factor that considers all students as belonging to only one shift. Under this criterion, the number of students who study full time is multiplied by a factor of 2, because they remain at the school for two shifts, while those who study for two shifts, three times a week, are multiplied by a factor of 1.6.

To determine the User Perception Index (UI) through application of the questionnaires, the principal activities and the different ways to carry them out were identified, making it possible to classify them according to the amount of water wasted. Subsequently, a score was associated with each method of carrying out an activity, divided according to the environment within the building where the activity takes place, so that those adopting more sustainable methods of use would be 'rewarded' upon having achieved a maximum score. The higher the score, the higher the UI, that is, the users' perception regarding the rational use of water, according to its description in the methodology adapted from Ywashima (2005).

In summary, the UI of the school was established according to the following steps:

(a) For each method of performing the activity analyzed, there is a corresponding score, as well as a maximum score that could be obtained for the activity. Table 2 is an example showing the listing of points per activity for the 'restroom' environment.
(b) Calculate the point total obtained and the maximum possible points for each environment.
(c) Calculate the UI per environment, which is the ratio between the total points achieved and the total maximum points possible multiplied by 100, and represent them in a spider graph.
(d) Calculate the points obtained by dividing the UI of each environment by 100 and multiplying it by the factor for

Table 2 | Assessment of rational water use by restroom users

Activities		Points	Maximum points
B1	User washes their hands:		
a	with the tap always open	0	4
b	with the tap closed when applying soap	4	4
B2	User takes a shower:		
a	leaves the register open for less than 10 min	4	4
b	leaves the register open for more than 10 min	0	4
c	does not perform this activity at the school	0	0
B3	Upon finding some broken hydro-sanitary equipment, what does the user do?		
a	informs the school board	4	4
b	does nothing	0	4
c	is not able to realize when it is broken	0	0

Source: adapted from Nunes (2015).

each environment. These factors were established as a function of the distribution of consumption for each environment. Because a typical day of water consumption at the schools investigated by Soares *et al.* (2017) was similar to that of the schools studied by Ywashima (2005), the factors adopted were: restroom (39); kitchen (39); internal (11) and external areas (11).

(e) Calculate the total points obtained to determine the UI for the school.

(f) Classify the UI of the school according to Oliveira (2013), consistent with Table 3.

The leakage index (IL) aims at measuring the amount of equipment presenting pathologies, defined as the ratio between the points of the system with leakage and the total points of use of the system during a given month.

Table 3 | Classification of the user perception index values regarding rational use of water (UI) according to comprehensiveness ranges

Comprehensiveness ranges for UI (%) values	Classification of UI
0–49.9	Low
50–79.9	Medium
80–100	High

Source: adapted from Oliveira (2013).

This is defined according to Gonçalves *et al.* (2005) by:

$$IL = \frac{\sum P_v}{\sum P_t} \times 100 \quad (2)$$

where IL is the index of leakage (%); P_v is the number of points of use of the system with the leakage during the month in question; and P_t is the total number of points of use during the same month.

The ideal way to obtain the amount of consumed water lost by leaks would be to implement sectorized measurement. However, because a sectorized metering facility in several schools was not feasible due to lack of resources, the nominal leakage loss values indicated by Gonçalves *et al.* (2005) were used, as shown in Table 4.

RESULTS AND DISCUSSION

The local water company provided the historical data for water consumption at the schools studied (m^3/month), and

Table 4 | Estimated volume lost to leakage

Sanitary equipment type	Type of leak	Estimated loss
Faucets (bathroom, sink, general use)	Slow drip	6–10 liters/day
	Medium drip	10–20 liters/day
	Fast drip	20–32 liters/day
	Very fast drip	>32 liters/day
	Stream Ø 2 mm	>114 liters/day
	Stream Ø 4 mm	>333 liters/day
	Leak in flexible connector	0.86 liters/day
Urinal	Visible stream	144 liters/day
	Leak in flexible connector	0.86 liters/day
	Leak in register	0.86 liters/day
Flush toilet	Visible streams	144 liters/day
	Leak from the tube that fills the tank	144 liters/day
	Valve sticks open when flushed	40.8 liters (assuming the valve is open for a period of 30 seconds, at a flow rate of 1.6 liters/second)
Shower	Leak in register	0.86 liters/day
	Leak in feeder pipe near wall	0.86 liters/day

Source: Gonçalves *et al.* (2005).

the Secretariat of Education of the State of Pernambuco provided the population counts for the years 2012–2015. Considering an average of 22 weekdays per month, the *IC* for the schools over time were calculated and presented according to Figure 1. Table 5 lists some characteristics of the schools studied.

In all cases, the absence of a clear trend in the indicator of consumption is observed, with significant variations across time. These variations may be explained by several factors, such as the presence of leaks and overdue maintenance, the holding of special events at the school (science fairs, parent-teacher conferences), or even periods of irregular recess, each of which may affect water consumption in different ways. It should be noted that none of the schools contain well-preserved sanitary equipment. In addition, preventive maintenance is not carried out, only corrective maintenance occurs. Furthermore, the buildings are generally old and without signs of recent renovation.

It is important to note that the schools have widely different profiles. School 01, for example, had poorly-conserved sanitary installations and a house located on its property, whose consumption was included with that of the school. School 03 is a military school, with a transient, variable population who sleep, take showers, and prepare meals at the location. School 05 is located close to one of the upscale areas of Recife, and has well-preserved sanitary installations. School 06 has a student body with students who are present full time and a better-than-average infrastructure.

School 06 had a very low consumption of water during the first two years compared with the final two years. According to data from the local water company, its water meter had problems. Therefore, the consumption considered for the first two years corresponds to the historical average for the school in the company's database.

Farina *et al.* (2011), investigating schools in Italy, found consumption indicators that varied between 10 and 30 L/student/day. Cheng & Hong (2004) determined an average of 30 L/student/day in Taiwanese schools. It should be noted that even though the countries have very different realities, schools in Italy have consumption indicators very similar to those at the Brazilian schools studied.

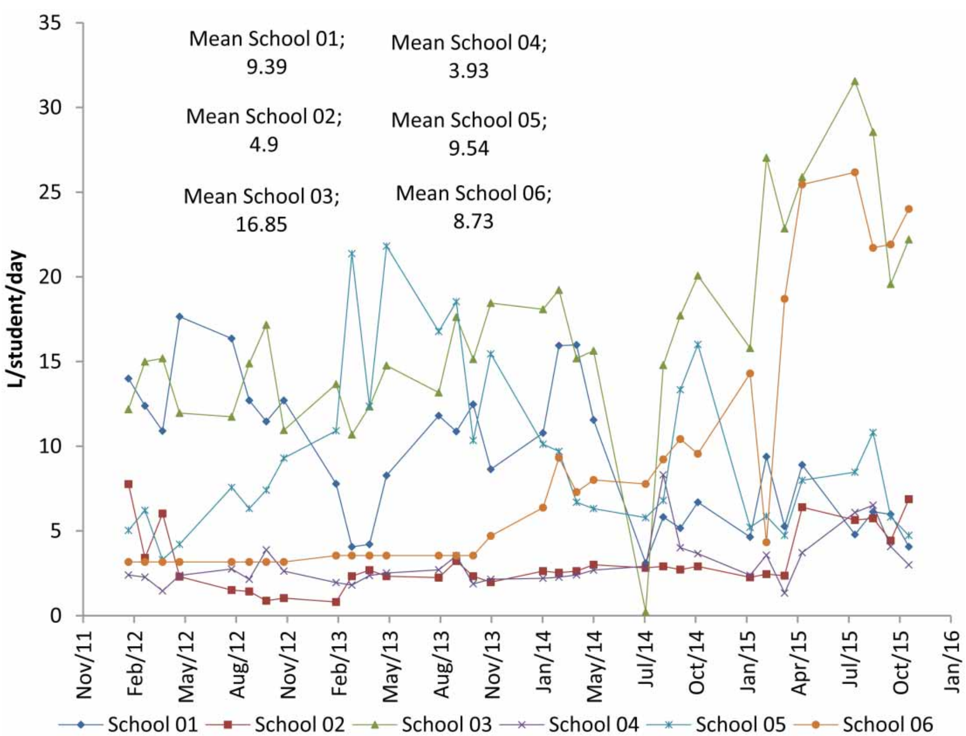

Figure 1 | Indicators of water consumption (*IC*) for the studied schools, 2012–2015.

Table 5 | Characteristics of the studied schools

School	Number of students	Number of employees	Number of consumer agents (NA)	Maintenance type	State of equipment conservation	Last renovation performed
01	950	44	950	Corrective	Terrible/precarious	No records
02	483	33	483	Corrective	Regular	No records
03	1,468	228	1,468	Corrective	Regular	No records
04	949	72	1,262	Corrective	Regular	No records
05	1,047	54	1,047	Corrective	Regular	2013
06	506	44	670	Corrective	Terrible/precarious	No records

The user behavior towards water use is one of the factors that influence water consumption volumes. If the users have a low level of awareness about the rational use of water, greater losses will occur due to inadequate consumption practices. Figure 2 shows the spider graphs of the UI per environment, as well as of the school as a whole, applying weighted values for each environment according to the amount consumed.

It is important to note that only the workers took part in this part of the study, and not the student body, similar to the studies by Soares *et al.* (2017). An end use water consumption analysis was carried out at schools 02 and 04, through the installation of water meters at almost all points of consumption in the building. This analysis identified that kitchen activities, and the cleaning of classrooms and external areas are what consumes the largest volume of water. Only the employees are involved in these activities, therefore students were not interviewed at this stage of the research.

The 'restroom' and 'internal area' environments presented, in general, the best indices. This result may have occurred because the students did not participate in this interview. The 'internal area' environment showed good results due to the cleaning practices for floors of both classrooms and restrooms. In turn, the 'external area' environment presented the worst practices, generally consisting of the use of a hose to wash the floor.

Table 6 lists the classification of the UI according to Oliveira (2013) and establishes a comparison with the results by Soares *et al.* (2017).

Even with all of the schools presenting values above average (>50%), it is still necessary to encourage their communities to use water more rationally. Around 20% of the activities in the schools are still carried out in a wasteful manner. Educational campaigns for both employees and students to become multiplier agents can be a good resource for increasing the UI.

Another point to be observed is the physical losses in the system due to leakage. Table 7 shows the *IL* for the schools investigated. At this stage, it was not possible to carry out a survey of pathologies in School 03, because access was restricted to military activities in some areas of the school.

None of the schools had a preventive maintenance system, but relied only on corrective maintenance. The maintenance services are controlled directly by the Secretariat of Education, that is, the schools are not free to conduct the necessary services autonomously. Generally, they have to wait for a team from the Secretariat or for a special budget to proceed with the repair. This process can mean having to wait days for a leakage to be properly fixed.

Roccaro *et al.* (2011) implemented structural and non-structural measures as at two schools in Sicily, Italy. The structural measures included the repair of leaks and the installation of economizing equipment, resulting in a water consumption reduction of around 50%.

Nunes (2015) emphasizes that the schools may show a low *IL* and still have considerable losses, such as in the case of School 04, which registered losses of up to 62% of water consumption. This occurs due to the existence of different types of sanitary equipment and leakage magnitude. In this methodology, a tap with a slow drip and a flush with a broken valve, for example, are accounted similarly, even though the latter wastes much more water.

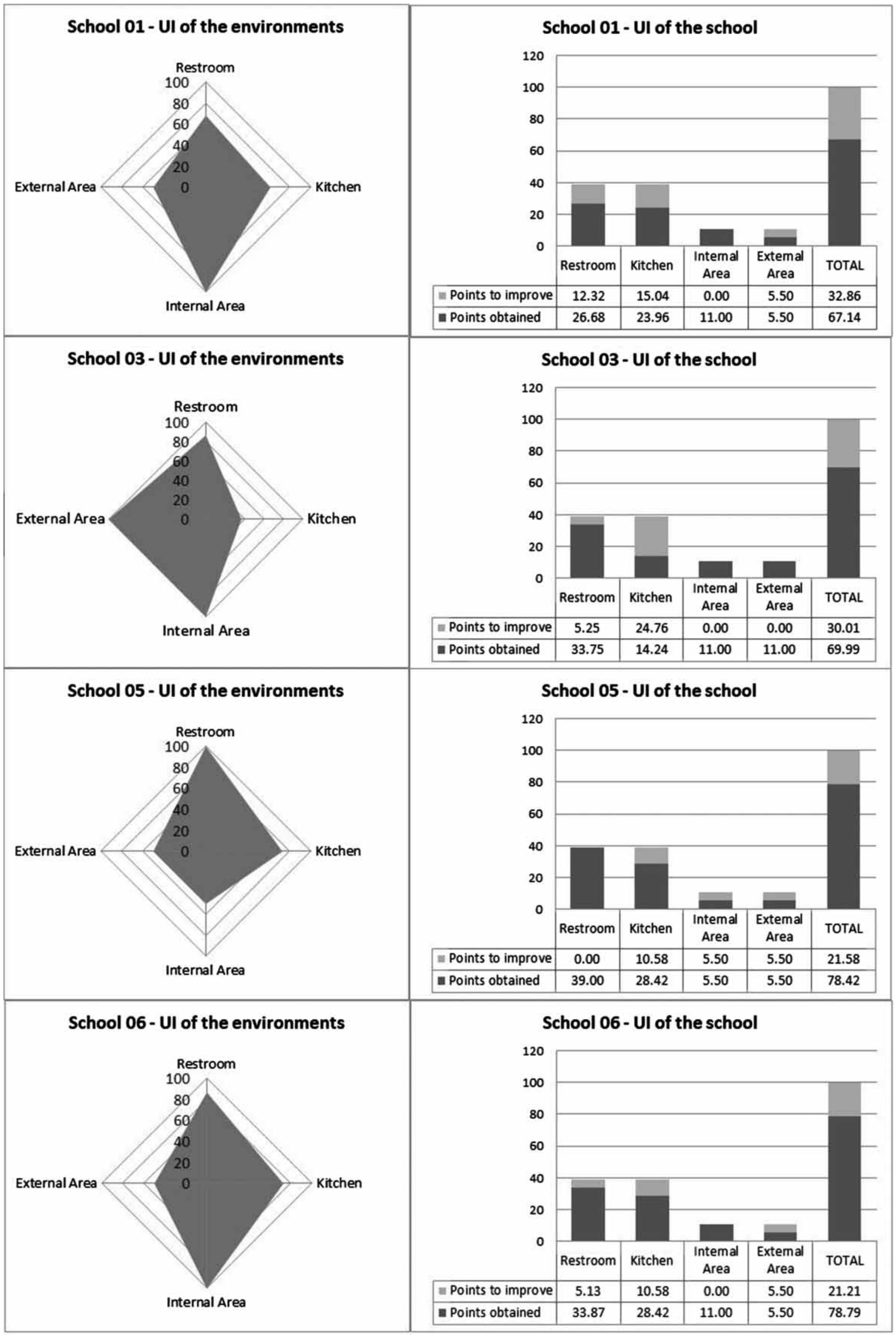

Figure 2 | Indices of user perception about the rational use of water at the studied schools.

Table 6 | Classification of user perception index about the rational use of water

	User perception index (UI)				
	Restroom	Kitchen	Internal area	External area	School
01	Medium	Medium	High	Medium	Medium
02[a]	Medium	High	Low	Low	Medium
03	High	Low	High	High	Medium
04[a]	High	Medium	Low	Low	Medium
05	High	Medium	Medium	Medium	Medium
06	High	Medium	High	Medium	Medium

[a]Results by Soares *et al.* (2017).

Table 7 | Leakage indexes (IL) for the studied schools

School	Index of leakage (*IL*)	Losses estimate
School 01	20.00%	5.38%
School 02	27.78%	8.06%
Mean School 04 (Nunes 2015)	7.29%	18.00%
School 05	16.28%	6.51%
School 06	5.88%	1.18%

CONCLUSIONS

The procedures presented in this paper enable the consumption of water to be diagnosed at school building facilities. This can be useful in verifying the need to employ specific methodologies of environmental education in order to promote the use of water in a rational and responsible way. The methodology presents results capable of allocating investments to the highest priority actions, thus providing a viable alternative for developing countries that often have limited financial resources.

Among the schools studied, it was observed that the school community helps shape an environmental awareness about the rational use of water. However, the poor condition of the sanitary systems in the buildings may contribute to physical losses that can represent more than 50% of water consumption, occurring due to the age of the buildings and the absence of an efficient preventive maintenance. In addition, the sanitary equipment does not make use of water-saving technology.

By comparing the results obtained with the averages found in the literature, the schools are far below the level expected, despite having both physical and non-physical losses. This may occur because some locations have a water supply restricted by the local water company. An investigation considering the student body should also be performed, in case there are no restrictions to water use that would explain such a low index and in order to quantify the index of perception for the student body. The analysis of IC should not be limited to only numerical evaluation, as some contradictions might conceal the malfunctioning of hydro-sanitary equipment.

In general, educational actions encouraging the rational use of water should be disseminated at the schools in order to enable the index of perception to be maintained or increased. These actions will tend to generate more aware citizens who will contribute to the sustainable use of water during their daily routine both in and out of school.

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