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Promoting Water Efficiency in a Municipal Market Building: A Case Study

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Abstract: This study aimed to determine the water demand of a Municipal Market building to propose water use efficiency measures. The flushing cisterns have the highest water consumption (63.15%), followed by washbasins, restaurant and coffee shop taps, and hairdresser's showerhead (31.64%). Therefore, the implementation of two main categories of solutions: reducing water consumption through the adoption of efficient devices and installing a rainwater harvesting system (RWHS) when drinking water quality is not required, was evaluated. These solutions were organized in four distinct scenarios: (1) Flushing cistern replacement by dual-flush ones; (2) washbasins, restaurant, coffee shop taps, and hairdresser showerhead replacement; (3) scenario 1 combined to a RWHS for recharging the replaced flushing cisterns and (4) combining scenarios 3 and 4. Under scenarios 1, 2, 3, and 4, the expected water consumption reduction was 28.36%, 17.06%, 57.36%, and 74.41%, respectively. As a result, the annual water bill reduction was €3835.81 (scenario 1), €2307.07 (scenario 2), €7757.65 (scenario 3), and €10,064.73 (scenario 4). Furthermore, to ensure the harvested rainwater attains the required standard for recharge flushing cisterns, it is advisable to dispose of the first-flush rainwater collected after a long dry period.

Keywords: water efficiency; municipal market; rainwater harvesting system (RWHS); water bill reduction

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1. Introduction

Water is the most essential of natural resources. Nevertheless, freshwater ecosystems and the available water resources are threatened by the continuously rising water demand [1]. Urban population growth, changing lifestyles, and increasing water pollution are the leading cause of this phenomenon [2,3]. Besides, climate change involves higher temperatures and changes in the intensity and precipitation patterns, jeopardizing water quantity and quality. This consequence of climate change is more notorious in regions or countries experiencing water scarcity and shortage [4], such as southern Europe and the Iberian Peninsula [5,6]. Since buildings are one of the highest consumers of potable water globally [7], the urban water cycle is affected by climate change [8], but it also contributes to it. Indeed, water potabilization processes, water delivery to consumers, and wastewater treatment use significant amounts of energy, contributing to increasing CO_2

emissions [2,8–11]. In several European countries, including Portugal, it is estimated that daily water consumption varies from 120 to more than 200 L/habitant/day [8,12]. However, despite the significant water consumption in residential and commercial buildings, not all uses require potable water. Indeed, in 50% of the residential water consumption and 75% of water consumed in commercial buildings drinking water quality is not required [12]. In this scenario, promoting water use efficiency in urban areas is crucial. The optimization of water management can be achieved by implementing two main categories of solutions: (i) reducing water consumption through the adoption of efficient products or devices (e.g., flushing cisterns, taps, and showers), reducing the water waste and loss [2,7,10]; (ii) identification of new water sources, allowing to reduce the pressure on traditional water sources, when drinking water quality is not required [4,7,8,13–16], these including rainwater harvesting systems (RWHS) and grey water reuse, can be operated at the onsite scale, cluster scale, or distribution systems [7,15]. According to a review on [7], research has demonstrated that grey water reuse is economically attractive as an alternative water supply system for single housing in a water-stressed region, and the cost of water is high. Conversely, when considering commercial buildings, RWHS can be more effective in reducing water consumption and may include lower related costs and technological complexity during the installation and operation [4]. Although the water cistern is the most expensive component, the RWHS installation viability also depends on potable water prices, water demand, water savings, precipitation amounts, runoff area, operation and maintenance costs, and payback period [13,17–20]. Nevertheless, even when the payback period is around 19 years [12], the positive impacts of RWHS in the environment [6,8,14,17,21,22] and the improvement of companies' image [12] can bring higher benefits than the initial investment. The existing research worldwide focuses predominantly on RWSH installation in residential buildings [17,21–27]. Therefore, literature concerning commercial buildings is much more scarce and focused on large buildings [4,8,28–32], and concerning small buildings is almost inexistent [33]. In Portugal, RWHS have received little research interest and are mainly focused on large commercial buildings [12,34–37]. Therefore, the aim of this research is: (a) To determine the water demand and the water end-uses of a small size municipal market; (b) to propose water use efficiency measures and analyze their feasibility and costs; (c) to evaluate the impact of the joint implementation of a RWHS for the flushing cisterns recharge and the proposed measures in (b) on water savings and the reduction of water bills. Concomitantly, the water quality of the roof runoff was assessed. Considering the lack of information in this field and the occurrence of more than 300 municipal markets and small commercial centers only in Portugal [38], this research will be highly relevant for municipal and private commercial building managers, and it might be a starting point for other researchers.

2. Materials and Methods

2.1. The Case Study

Bragança (Latitude: 41°48′20′′ N; Longitude: 6°45′25′′ altitude: 673 m) is the main city of northeast Portugal, with 24,078 inhabitants [39]. The climate is continental with Mediterranean influences. Annual mean precipitation is around 700 mm, occurring mainly in autumn and winter but in a very irregular pattern [40]. According to the information provided by the municipality, the water demand per year in this city is around 3,757,615 m^3. Approximately 80% of this water is for domestic consumption, whereas the remainder is for commercial and industrial uses. Bragança is one of the Portuguese cities with the highest water demand: about 260 L/inhabitant/day [41]. Bragança Municipal Market has a total built area of 8000 m^2. The metal roof area is approximately 3171 m^2 (Figure 1).

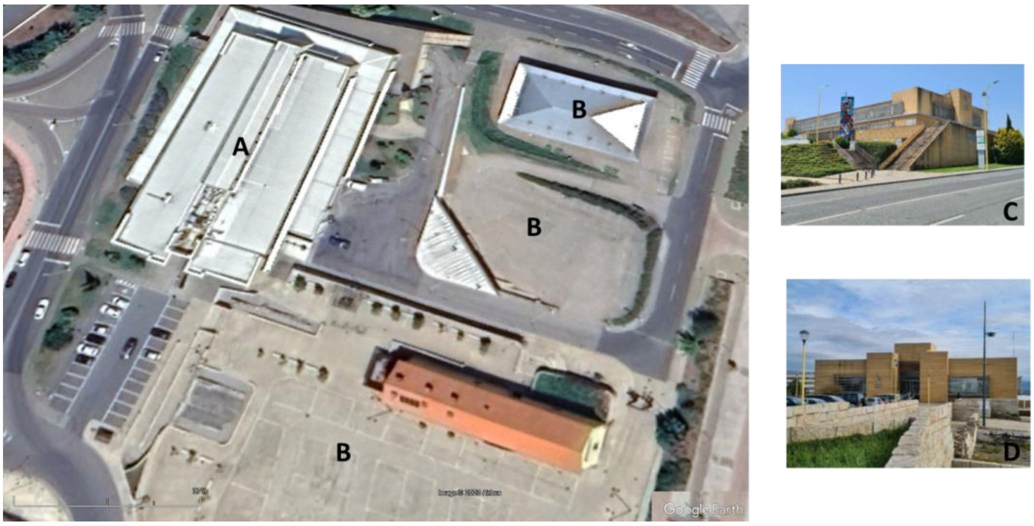

Figure 1. Market building (**A**), Weekly fair area (**B**), and Market building details (**C**,**D**).

The building consists of 3 floors: the semi-underground floor (parking lot, warehouses, and the nightclub), the ground floor (supermarket, other small stores for regional products and services), and the top floor (restaurant, call center, hairdresser and the Third Age University). The building is open to the public from Monday to Sunday. The nightclub is open twice a week. The busiest day is Friday because of the weekly fair next to the market building). The number of Third Age University students, call center staff, store owners (including the hairdresser, restaurant, coffee shop, and supermarkets), and store and nightclub estimated customers/week is shown in Table 1. According to the data provided by the municipality, the mean monthly indoor water consumption from 2016 to 2018 was 250 $\pm$ 28 m^3, showing no significant seasonal variation. This pattern aligns with [17], showing that indoor water consumption in buildings does not vary significantly throughout the year.

Table 1. Estimate average number of market users/week.

	Men	Women	Total
Third age university students	15	61	76
Call center staff	3	22	25
Store owners/staff	5	14	19
Costumers [1]	620	980	1600
Nightclub costumers [2]	300	300	600
Total	943	1377	2320

[1,2] The number of customers/was estimated through the surveys addressed to the store owners/staff (Appendix A).

2.2. Water Consumption Use Patterns Characterization

As the nightclub has an entrance and sanitary equipment independent from the rest of the building, the water consumption will be analyzed separately. The volumes of flushing cisterns were measured by registering the maximum level, making a discharge, and filling the cistern manually with a calibrated lab beaker (accuracy level $\pm$5%) until the initial level was restored. In order to obtain the water flow rates in urinals, their outlets were covered with adhesive tape. Simultaneously, the discharge duration time was measured in seconds when the flow meter was activated. Finally, the water in the outlet was measured using the calibrated beaker. The water flow rates of washbasins, restaurant, coffee shop taps, and hairdresser's showerhead were determined by recording the duration of filling a certain volume "X" in a 10 L capacity bucket. Then, with the aid of the calibrated beaker, the final volume of water in the bucket was obtained. In commercial and institutional buildings, there is a wide variation in the habits and environmental awareness of water consumers [8]. Therefore, concomitantly, to discern the water use behavior and patterns, surveys with different specifications were addressed to: (1) 50 market and 50 nightclub customers; (2) all the store owners/staff; (3) 15 students from the Third Age University (10 women and 5 men) and (4) call center staff (5 women and 3 men). The restaurant's water consumption calculation was based on the taps' flow rate and frequency of use according to the information obtained in the specific surveys for restaurant staff. Water expenditures in the coffee shop are estimated based on the number of coffees served daily and dishwashing expenditures. In turn, water consumption at the hairdresser was determined considering: (a) shower flow rate; (b) the number of clients (6 men and 30 women per week); (c) average hair washing time (3 min for men and 10 min for women) (Appendix A). Surveys were conducted in the winter (January 2022) and again in the summer (July 2022) for market and nightclub customers to assess if there would be seasonal significant differences in the water use behavior. In doing so a One-way ANOVA test was used.

2.3. Water Use Efficiency Measures

Considering the obtained results for water consumption, the flow rates of these water devices were adjusted to the reference values of class "A" water efficiency (the highest efficiency) of the Portuguese labeling system [42]. Besides, suggestions for more efficient devices were proposed to achieve higher water efficiency when possible. Furthermore, the proposals considered the Portuguese labeling system recommendations concerning public buildings (efficiency, price, and ease of installation). The proposed measures were organized in scenarios (Table 2) and subsequently analyzed considering the obtained data concerning water use (Section 2.2).

Table 2. Proposed water saving scenarios in the Bragança municipal market.

Scenarios	Measures
1	Flushing cistern replacement by dual-flush ones
2	Washbasins, restaurant, coffee shop taps, and hairdresser showerhead replacement
3	Scenario 3: Scenario 1 + Simulation of a RWHS for recharging the replaced flushing cisterns
4	Scenario 2 + Scenario 3

Concomitantly, the economic viability of each of the listed measures was analyzed for scenarios 1 and 2. This approach considered the initial investment to implement the proposed water efficiency measures, the water bill reduction (because of the implementation of water use efficiency measures), and the turnover period.

Scenarios 3 and 4 regarded the possibility of the simulation of a RWHS for recharging the flushing cisterns. In this study, the sizing of the RWHS simulation was based on the simplified method suggested in the Technical Specification ETA 0701 adopted in Portugal for the design, dimensioning, construction, and maintenance of these systems [43]. According to ETA 0701, the volume of usable rainwater in a given period is determined by the expression (2):

$$V_a = C \times P \times A \times \eta_f \quad (1)$$

where:

- V_a: volume of rainwater in the reference period that can be used (liters);
- C: runoff coefficient (dimensionless);
- P: average precipitation accumulated at the site (mm);
- A: catchment area (roof) (m^2);
- η_f: hydraulic filtering efficiency (dimensionless).

The value of 0.9 can be adopted for both C (because the roof is made of metal) and η_f (considering that the filters have regular maintenance and cleaning, as suggested by the manufacturer, a maximum hydraulic filtering efficiency η_f = 0.9 can be admitted). The average monthly precipitation was obtained from [44] considering series from 2010 to 2021. ETA 0701 demands upstream filters and recommends evaluating the need to divert the first flush according to the intended uses and local pollution intensity. Therefore, roof runoff was collected twice (in March and April 2022) from roof downpipes to evaluate the need to divert the roof runoff first flush. Water quality parameters (Appendix B) were determined in triplicate.

3. Results

3.1. Characterization of Building Water Devices and Their Use Patterns

As no significant seasonal differences in customers' water use behavior were found (One-way ANOVA: $p > 0.05$), the survey results were used as a whole to estimate the number of uses of the different devices.

3.1.1. Flushing Cisterns (Market Area: N = 17; Nightclub: N = 5)

These devices are all of the same model and brand. The average discharge volume is 9 L, and they are classified as water efficiency category E (Portuguese Labelling system [42]). Considering the surveys, it was estimated that there were 138,912 discharges/year in the Market area and 60,480 in the nightclub.

3.1.2. Urinals (Market Area: N = 8; Nightclub: N = 4)

According to survey data, the average occurrence of 11,016 and 7200 discharges/year was estimated in the market area and the nightclub, respectively. Therefore, the average discharge volume for the devices in the market area is 2 L (water category efficiency A) and 4 L (water category efficiency B) for those installed in the nightclub.

3.1.3. Taps

- WC basin taps (Market area: N = 20; Nightclub: N = 5): These taps have an average flow of 4.64 L/min (water efficiency category B). The estimated total uses were around 119,160 and 28,800 times/year in the market and the nightclub, respectively.
- Restaurant taps (N = 2): The average flow is 15 L/min (water efficiency category E);
- Coffee shop tap (N = 1): The average flow is 10.91 L/min (water efficiency category C).

According to the surveys, market staff, and Third Age University students were in the building around 5.8 days/week and used the washbasin taps 3.8 times/day. Since the taps are timed, each use lasts approximately 5.6 s. Therefore, on average, the users pressed the push bottom twice for each use. The restaurant taps are used for 50 min daily, and the coffee shop tap is used for 20 min daily.

3.1.4. Dishwashing Machines (N = 3) Coffee Shop (N = 1), Restaurant (N = 1) and Nightclub (N = 1)

Each dishwashing machine spends 2.8 L for each cycle of washing. This device is used in the restaurant twice daily (for 6 days/week), in the cafe once daily, and in the nightclub twice weekly.

3.1.5. Hairdresser Shower

The current average flow rate is 9.86 L/min (water efficiency category C).

3.1.6. Floor Cleaning

A 60 L capacity industrial cleaning machine (twice a week) and a 15 L capacity bucket (four times a day) are used to clean the market floor. A hose and a mop are used to clean the nightclub floor. The hose is connected to a tap with a flow rate of 8.05 L/minute for 60 min twice a week.

3.2. Water Use Characterization and Proposed Water Saving Measures

Based on the characterization of the water devices and users' water use behavior patterns, the estimated average annual water consumption in the market's building and nightclub was 2841.55 m^3/year, as shown in Tables 3 and 4.

Table 3. Monthly and annual water consumption in the Market building by use category.

Equipment	Consumption (m^3/Month)	Consumption (m^3/Year)	Percentage (%)
Flushing cisterns	104.18	1250.16	44.00
Washbasin taps	17.02	204.24	7.19
Urinals	3.67	44.04	1.55
Restaurant taps	36	432	15.20
Coffee shop tap	5.24	62.88	2.21
Dishwashing machines	0.2	2.4	0.08
Hairdresser shower	12.54	150.48	5.30
Floor cleaning	2.16	25.92	0.91
Nightclub	55.78	669.36	23.56
Total	**236.79**	**2841.48**	**100**

Table 4. Monthly and annual water consumption in the nightclub by use category.

Equipment	Consumption (m^3/Month)	Consumption (m^3/Year)	Percentage (%)
Flushing cisterns	45.36	544.32	81.32
Washbasin taps	4.11	49.32	7.37
Urinals	2.4	28.8	4.3
Dishwashing machine	0.05	0.6	0.09
Floor cleaning	3.86	46.32	6.92
Total	**55.78**	**669.36**	**100**

Therefore, water-saving measures were implemented only on flushing cisterns, washbasins taps, coffee shop and restaurant taps, and hairdresser showerhead because they are the most water-consuming devices (Tables 3 and 4). Because it is impossible to regulate the inlet water mechanism to reduce the current discharge in the existing flushing cisterns, it was proposed to replace them with dual-flush equipment classified as water efficiency category A/A++ both in the market area and in the nightclub (Scenario 1). As a result, the flow rates can be reduced to 4.5 L/discharge in the Market area. Each unit costs €94.55 + VAT (2023 prices). In the nightclub, reducing the flow rates to 6 L/discharge is possible. Each flushing cistern costs €44.90 + VAT (2023 prices). Thus, considering the market area plus the nightclub, the average annual water consumption of flushing cisterns would decrease from 1794.48 to 987.96 m^3.

Scenario 2 proposes the replacement of the washbasins, coffee shop, and restaurant taps, and the showerhead from the hairdresser:

- Washbasin taps can be replaced by equipment classified as water efficiency category A+ with an average flow of 1.8 L/min. Each tap costs €83.50 + VAT (2023 prices). Thus, the average annual water consumption of the washbasins, considering the market area plus the nightclub, would decrease from 253.56 to 106.56 m^3/year;
- Restaurant taps can be replaced by water efficiency category A devices with an average flow of 8 L/min. Each tap costs €147 + VAT (2023 prices). It is estimated a reduction in water consumption from 432 to 192 m^3/year;
- Coffee shop tap can be replaced by one classified as water efficiency category A with an average flow of 5 L/min. the price tap is €70.16 + VAT (2023 prices). It is expected a decrease in water consumption from 62.88 to 28 m^3/year;

- Hairdresser's showerhead can be replaced with one classified as water efficiency category A with an average flow of 5.7 L/min. The price is €40.52 + VAT (2023 prices), and the estimated water consumption reduction is from 150.48 to 87 m^3/year.

Scenario 3 proposes a combination of Scenario 1 with the simulation of a RWHS for recharging the replaced flushing cisterns (Table 5 and Figure 2). Because of the location of the roof downpipes, the chosen roof area for the simulation was 1646 m^2. Nevertheless, considering the monthly consumption and the available rainwater volume, the generated water is enough for the proposed use. For the flushing cisterns with annual and monthly water consumption of 987.96 and 82.33 m^3, respectively (Scenario 1), a cistern with a volume of 50 m^3 will allow for a total rainwater harvesting of 821.31 m^3 (83.13%), requiring the use of water from the public supply only from June to September (166.65 m^3) (Table 5). Scenario 4 proposes to simulate the water consumption reduction by considering Scenarios 2 and 3 together.

Table 5. RWHS cistern sizing simulation.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	87.05	1646	116.05	82.33	33.72	50	0.00	0.00
November	92.54		123.38	82.33	41.05		33.72	0.00
December	88.19		117.58	82.33	35.25		50.00	0.00
January	93.45		124.59	82.33	42.26		50.00	0.00
February	81.17		108.22	82.33	25.89		50.00	0.00
March	70.34		93.78	82.33	11.45		50.00	0.00
April	81.85		109.13	82.33	26.80		50.00	0.00
May	46.06		61.41	82.33	−20.92		50.00	0.00
June	28.18		37.57	82.33	−44.76		29.08	15.67
July	11.36		15.15	82.33	−67.18		0.00	67.18
August	18.92		25.23	82.33	−57.10		0.00	57.10
September	41.73		55.64	82.33	−26.69		0.00	26.69
Total	740.84		987.73	987.96				166.65

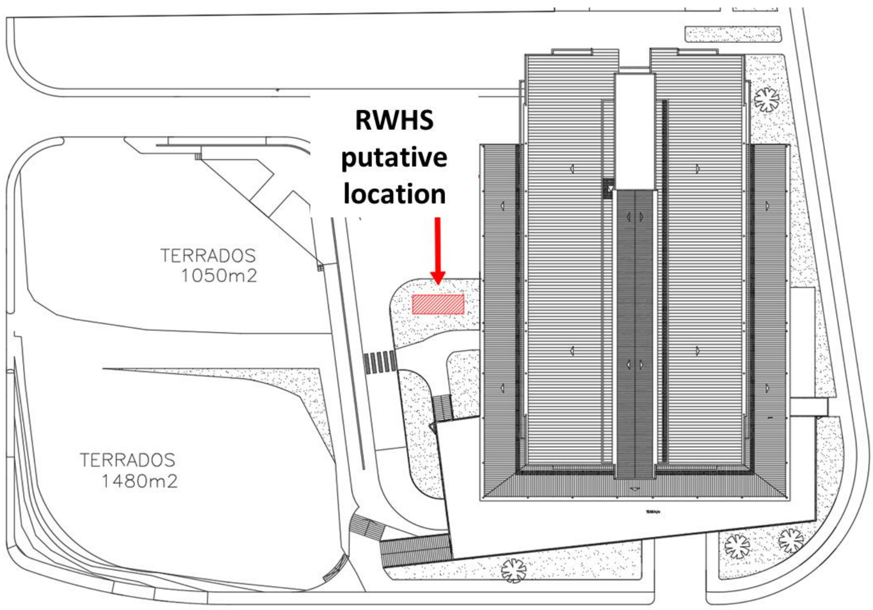

Figure 2. Market building and RWHS putative location.

Considering the available area, the best option is the prefabricated high-density polyethylene cisterns because they are easier to install, avoiding high construction disturbances that would impact the regular operation of this building and its adjacent area.

Table 6 presents the predicted annual water consumption, cost with and without water-saving measures for each scenario, and the turnover period for scenarios 1 and 2. As the municipality did not provide the water network plans, the RWHS installation economic reliability was not evaluated. Indeed, the RWHS installation bill includes the prefabricate cistern and accessories (e.g., pumps, filters, valves, drainage pipes, and other utilities) and the rainwater distribution network's cost. Besides, without knowing the water network in detail, it is difficult to evaluate and define the pumping system required as well as the rainwater distribution network's cost. Nevertheless, considering scenario 4, which includes: (1) flushing cisterns replacement; (2) washbasins, restaurant, and coffee shop taps replacement; (3) hairdresser's showerhead replacement, and (4) RWHS implementation, the water savings could reach 74.41% and the water bill is substantially reduced.

Table 6. Water consumption and cost without and with water-saving measures and investment turnover.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Consumption without Measures (m^3/year)	2841.48	2841.48	2841.48	2841.48
Predicted Consumption with Measures (m^3/year)	2035.64	2356.80	1211.72	727.04
Predicted water saving (m^3/year) and (%)	805.84 (28.36)	484.68 (17.06)	1629.76 (57.36)	2114.44 (74.41)
Predicted equipment costs (€) [1]	1832.05 *	2576.28 *	-	-
Annual water bill without Measures (€) [2]	13,800.96 *	13,800.96 *	13,800.96 *	13,800.96 *
Predicted Annual water bill with Measures (€) [2]	9965.15 *	11,493.89 *	6043.31 *	3736.23 *
Annual water bill reduction (€) [2]	3835.81 *	2307.07 *	7757.65 *	10,064.73 *
Investment turnover (years)	0.48	1.12	-	-

* Price + VAT; [1] Flushing cisterns (Scenario 1) and taps and shower replacement (Scenario 2). The works, replacement and maintenance costs were not considered as the permanent municipality's staff carries them out; [2] Calculated according to the municipality's water price estimation methodology.

3.3. Rainwater Quality Collected in Roof Runoff

The first water sample (March 2022) was obtained after an extended dry period [44] and after the desert dust intrusion from North Africa [45]. The highest values for conductivity, turbidity, TSS, nitrite, nitrate, and phosphate were observed in this sample. Furthermore, total microorganisms and fecal coliforms also showed higher density (Table 7). Unfortunately, the present study did not determine fecal coliforms (E. coli). Nevertheless, Heterotrophic plate counts 37 °C can be regarded as an indicator of the presence of fecal coliforms and other pathogens.

Table 7. Rainwater parameters recorded in March and April 2022.

Parameters	Sample 1	Sample 2
Temperature	12.1 °C	6.5 °C
pH [1]	7.48	7.13
Conductivity (µS/cm)	50.7	10.1
Turbidity (NTU) [1]	26.9	3.3
Alkalinity (mg $CaCO_3$/L)	30.1	106.2
Total solids (mg/L)	56	70
Total suspended solids (mg/L) [1]	12	6
Hardness (mg $CaCO_3$/L)	20	6
Nitrite (mg/L)	0.17	0.026
Nitrate (mg NO_3^-/L)	3.93	<0.5
Ammoniacal nitrogen (mg/L) [1]	n.d.	0.08
Phosphate (mg PO_4^{-3}/L)	0.25	0.04
Chloride (mg/L)	4.5	6
Sulphate (mg/L)	n.d.	5.77
COD (mg O_2/L)	26.13	31.36
Heterotrophic plate counts 22 °C (CFU/mL)	127	50
Heterotrophic plate counts 37 °C (CFU/mL) [2]	57	23
Total coliforms (CFU/mL)	97	83

[1] Flushing cistern water quality requirements: pH: 6–9; Turbidity $\leq$ 5 NTU; Ammoniacal nitrogen $\leq$ 10 mg/L; $BOD_5 \leq 25$ (mg O_2/L) and *Escherichia coli* $\leq$ 10 (CFU/mL) [46]; [2] may indicate the presence of pathogen bacteria and other microorganisms [47]; n.d.: not determined.

4. Discussion

The determination of the water end- uses showed that flushing cisterns followed by the washbasins and other taps were the most water-consuming devices (Tables 3 and 4). The market and nightclub flushing cisterns represent 63.2% of the total water consumption. Therefore, this amount of water can be supplied from non-potable sources. Similar trends were reported by the review carried out by [8], where the water consumption by flushing cisterns in commercial buildings reached 67% of the total water consumption, and [48] found that flushing cisterns represented between 52% and 84% of total water consumption in office buildings. Based on the water-end uses data, either of the proposed water-saving scenarios has potential water savings: from 28.4% (scenario 1) to 74.4% (Scenario 4). If only scenarios 1 and 2 were implemented in the majority of the public and commercial buildings in the region, a reduction in the pressure on local freshwater ecosystems and resources [49,50], in energy consumption (both in public water supply and wastewater treatment systems) and CO_2 emissions [2,6,7,9,10,42,51–54] would undoubtedly occur. Although determining water end-uses is the crucial starting point for implementing water sustainability measures, no water end-uses were measured in any research concerning the installation of RWHS in commercial buildings cited in the present research. As a result, the water consumption was estimated based on experts' opinion or technical specifications, which can limit the reliability of this measure. Moreover, in these cases, it is not possible to increase the RWHS reliability by combine them with other water saving measures as suggested herein.

As the cistern is the most expensive RWHS component, size optimization before implementing these systems is crucial for their performance and economical reliability. There is a wide range of RWSH sizing methods however, there is no unanimity among experts which is the best methodology [17,19,20,23]. Simplified sizing methods are approximate approaches useful for the first phase of RWHS design [12]. Thus, as the present case is an exploratory analysis, implementing this RWHS is still hypothetical, and the flushing cisterns' water consumption is uniform over time; choosing a simplified method was considered appropriate [43], despite not considering the variability of heavy rain falling or drought periods [20]. The projected 50 m^3 volume cistern will allow for a total rainwater harvesting of 821.31 m^3 (83.1% efficiency) (Table 5). However, the reliability of the RWHS is smaller in the summer months due to the low precipitation. From June to September, flushing cisterns are connected to the public water supply. Therefore, one of the strengths of this study is the proposal of a combination of RWHS with measures to reduce water consumption (scenarios 1 and 2). Indeed, this combination minimizes the effects of low precipitation periods on the RWHS reliability and building water consumption. Detailed sizing methods would eventually allow the simulation of a cistern with a larger volume, predicting the use of the overflow resulting from extreme precipitation events. However, these methods tend to oversize the cistern volumes [19,20]. Therefore, the question is whether increasing cistern volume is economically worthy and significantly improving system efficiency. Indeed, [20] verified that the influence of storage volume on the system's efficiency is very significant until up to a given limit. Then, above that limit, the increase in efficiency is insignificant, whereas the economic costs increase. Besides, similarly to other territories influenced by the Mediterranean climate, most precipitation occurs between October and March in a very irregular pattern from one year to another, and the summers are dry [40]. Therefore, the probability of occurring significant overflow rates is highly variable, depending on if the winter is dry or wet. Moreover, the climate change predicted impacts on the precipitation regime [55] anticipate further random variation in precipitation amounts, making difficult the sizing cistern task and implying continuous adjustments of volume optimization over time.

Flushing cistern water has quality requirements [46]. Nevertheless, roof runoff can be contaminated by a wide range of (micro) pollutants, some in concentrations exceeding water quality standards [56]. The sources of contamination are the roofing material and atmospheric deposition [56–58]. In addition, dust [59,60] and feces from rodents, lizards, and birds, which can be the main source of pathogens [58], can accumulate on roof tops during dry periods, affecting the harvested water quality. In areas of low industrial activity, such as the Bragança region, the observed phosphate is of natural origin (bird and rodent feces, moss, lichens, and plant remains). In contrast, nitrate and nitrite can be products of road traffic [58]. Furthermore, the Iberian Peninsula is affected by Saharan intrusions due to its proximity to Africa. These dusts can also be carriers of minerals, pollutants, and biological substances such as pollen grains, spores, or bacteria [59,60]. The highest values for the conductivity, turbidity, TSS, nitrite, nitrate, and phosphate observed in the first sample are similar to the results obtained by [58] after a dry period. Therefore, these preliminary results indicated that it is necessary to dispose of at least the first rainwater after a long dry period (first flush), as recommended by [43]. Several studies have suggested different values for the first flush volume [17]. Nevertheless, ideally, this volume is a trade-off between reducing the contaminant load and keeping the RWHS as full as possible.

As mentioned previously (item 3.2), the RWHS's economic reliability was not evaluated. However, despite this limitation, the obtained results showed significant water savings and water bill reductions (scenarios 3 and 4; Table 6), which are in line with other research outcomes carried out in commercial buildings in Portugal [12,34–36] and elsewhere in the world [4,8,16,28,29,33].

5. Conclusions

The main strength of this preliminary research is the direct determination of water end-uses in a commercial building, allowing the proposal of realistic measures to improve the water saving and reduce water bills, implemented in conjunction with the RWHS or alone. Although the method for sizing the RWHS has given a first view of the ideal volume to be efficient, more research is needed to optimize its volume dealing with the climatic uncertainties that influence the precipitation amount and timing. Moreover, determining the first flush volume and evaluating the installation costs of the RWHS are other research priorities. Nevertheless, the proposed measures are easily replicated, inspiring municipal and other public and commercial building managers to implement and replicate them in other commercial or public buildings.

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Appendix A

Survey

This survey distributed to Municipal Market and nightclub Customers, Third Age University students, Call Center and other store staff. Specific questions were addressed to Coffee shop, Restaurant, Nightclub and Cleaning Staff.

1. Gender: ☐ Male ☐ Female
2. Activity

   Market Customer ☐
   Nightclub Customer ☐
   Third Age University student ☐
   Call Center or Store Staff ☐

3. **Answer questions 3, 3.1 and 3.2 only if you are Third Age University students or Store staff.**

   3.1. Number of working days per week: __________.
   3.2. Daily workload: __________.

4. How often do you wash your hands? ___________.

   4.1 How many times you usually press the push bottom of the tap________.

Answer questions 5, 5.1 and 5.2 if you are male.

5. How often do you use the following per day/visit:

   Urinal: ___________ Toilet: ___________
   5.1 Indicate the number of flushes each time you use the urinal: _________
   5.2 Indicate the number of flushes each time you use the toilet: _________

Answer questions 6 and 6.1 if you are female.

6. How often do you use the toilet per day/visit? ___________

   6.1 Indicate the number of flushes each time you use the toilet: _________

Questions 7 and 8 are only addressed to store staff.

7. Please, estimate of the number of customers you serve on the Fridays. ____________
8. Please, indicate an estimate of the number of customers you serve during the other days of the week ______________

Questions 9 to 10 are only addressed to the hairdresser.

9. Please indicate an average estimate of the number of female customers you serve per day: ________________________
10. Indicate an average estimate of the time it takes to wash a woman's hair______________
11. Indicate an average estimate of the number of male customers you serve per day: ________________________
12. Indicate an average estimate of the time it takes to wash a man's hair______________

Questions 13 to 16 are only addressed to the restaurant staff.

13. Please estimate the average number of customers eating at the restaurant on Friday____________
14. Indicate an average estimate of the number of customers eating at the restaurant during the other days of the week ______________
15. Indicate the estimated time per day that you use the restaurant taps for:16.1. Prepare meals_____________________16.2. Wash the salads ___________________16.3. Wash the dishes ___________________
16. Does the restaurant have a dishwasher? ____________If so, how many times a day the machine works? _________

Questions 17 to 20 are only addressed to the coffee shop staff.

17. Please estimate of the average number of coffees you serve per day___________________
18. Indicate the estimated time per day that you use the restaurant taps._______
19. Does the Coffee shop have a dishwasher?
20. If so, how many times a day the machine works? ________

Questions 21 to 24 are only addressed to the nightclub staff.

21. How many days a week is the nightclub open? __________
22. Please the average number of customers per day. ________
23. Does the nightclub have a dishwasher?
24. If so, how many times a day the machine works? ________

Questions 25 to 28 are only addressed to the cleaning staff.
Market floor cleaning

25. How many times a day is the floor washed? ___________
26. How the market floor is washed?

    26.1 With mop? _______ How many times a day?_________
    26.2 What is the capacity of the bucket? _______
    26.3 How many times do you fill the bucket?_________
    26.4 With a cleaning machine? ________ How many times a week?_________
    26.5 What capacity has the cleaning machine? ___________
    26.6 How often is the machine filled?________

Nightclub floor cleaning

27. How many times a week is the floor washed? ___________
28. How the nightclub floor is washed?

    28.1 With mop? _______ How many times a day?_________
    28.2 What is the capacity of the bucket? _______
    28.3 How many times do you fill the bucket?_________
    28.4 With a cleaning machine? ________ How many times a week?_________
    28.5 What capacity has the cleaning machine? ___________
    28.6 How often is the machine filled?________
    28.7. With hose? _______ Approximately how long do you use the hose?________

Appendix B

Table A1. Rainwater parameters determined and analytical methodology.

Parameters	
Temperature	Digital Thermometer Summit SDT20
pH	SMEWW 4500-H + B (Electrometric method)
Conductivity (µS/cm)	SMEWW 2510 B
Turbidity (NTU)	SMEWW 2130 B
Alkalinity (mg $CaCO_3$/L)	NP EN ISO 9963-1:1994
Total solids (mg/L)	SMEWW 2540 B (Total solids dried 103–105 °C)
Total suspended solids (mg/L)	SMEWW 2540 D (Total suspended solids at 103–105 °C)
Hardness (mg $CaCO_3$/L)	SMEWW 2340 C (EDTA Titrimetric method)
Nitrite (mg/L)	SMEWW 4500 NO_2^- B (Colorimetric method)
Nitrate (mg NO_3^-/L)	SMEWW 4500-NO_3^- (Ultraviolet spectrophotometric screening method)
Ammoniacal nitrogen (mg/L)	SMEWW 4500-NH_3 (Direct nesslerization method)
Phosphate (mg PO_4^{3-}/L)	SMEWW 4500-P E (Ascorbic acid method)
Chloride (mg/L)	Mohr Method
Sulphate (mg/L)	SMEWW 4500-SO_4^{2-} E (Turbidimetric method)
COD (mg O_2/L)	SMEWW 5220-C (Closed reflux, Titrimetric method)
Total microorganisms 22 °C (CFU/mL)	ISO 6222:1999
Total microorganisms 37 °C (CFU/mL)	ISO 6222:1999
Total coliforms (CFU/mL)	ISO 9308-1:2000

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