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Efficient water use in military installations. The students' accommodation building of the Military Academy in Amadora

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1 Introduction

Water is a natural resource which has an unquestionable environmental, social and economic value. For this reason, it is absolutely crucial to the existence of man and the Earth's ecosystems. Since the first forms of life emerged in the ocean, approximately 4 million years ago, that water is unique, fundamental and essential to the life of all living beings. Due to its unparalleled importance, and based on its abundance in nature, the concept that water was an infinite resource persisted for many thousands of years. According to Fagar (2011), nowadays, waste coupled with the increase in demand for this resource, has become a major problem, and deserves the consideration of all, due to the decreasing availability of drinking water on the planet.

The Military Academy is a public institution of higher education in which students live in a boarding school system in the early years of their courses. As any building with great human use, the daily expenses at all levels are very high, particularly with regard to water consumption.

The students' accommodation building is part of the vast complex that composes the Military Academy. This represents a considerable share of the total water consumption, since in this building, water is used with several purposes: for the about 150 students' personal hygiene, for clothes washing and for cleaning boots. Thus, this is an issue that should be addressed, attempting to find solutions that promote a more efficient use of water in this building.

This thesis aims to perform an estimate of water consumption in the students' accommodation building and also calculate the percentage it represents in the total monthly costs. After estimating these values and due to the current need to reduce water consumption, there will be presented two measures that promote a more efficient use of water. Basically, the main aim is to understand the future benefits that the implementation of these solutions can possibly bring.

2 The use of rainwater

According to Zhao and Xu (2012), the concept of using rainwater is ancient and it has been promoted by several foreign countries, mainly due to industrialization. In countries with prosperous economies and higher rates of urbanization, such as Germany, the United States and Australia, there was a huge and fast development in this field.

Currently, in Germany, the country with the highest technical knowledge regarding the use of rainwater, the technology is in a phase of standardization and industrialization. In Potsdam Platz, in Berlin, there are numerous green roofs that allow storm water retention, which causes the water level in the soil surface to be lower. On the other hand, the most common type of coverage, which only has water collection systems, forwards water to water tanks and also to artificial lakes. (Zhao and Xu, 2012).

Zhao and Xu (2012) also reported that in the United States, the technology used for the storage of water descendant from the covers, the system of collectors and irrigation system (covering the infiltration basin) the grass and permeable paving, are studied and implemented mainly by improving the infiltration capacity of the plants. In Portland, reconstruction and design are based on the concept of "Green Street", which has its genesis in the use of rainwater and flood prevention. In the United States, there is a clear concern, not only with regard to the evolution and development of engineering measures, but also on the preparation of legislation to support the use of rainwater.

3 The use of water from a hole or private well

When one thinks of using a hole, the water that one wants to capture is the one circulating in the interstices of the geological formations (rocks or land). So, for this to be possible it is necessary that these formations constitute aquifers. In turn, these voids must enable the storage, movement and exploitation of water for the satisfaction of human needs, on economically advantageous terms. (Ferreira et al., 2012)

When performing a hole, it is essential at an early stage, to try to estimate the volume of water that can be extracted from it. Water quality is also a very important factor and therefore, should ensure if it fits or not the purpose for which it is intended. (Ferreira et al., 2012)

As part of this dissertation, it is not intended that water from a hole is used for human consumption, but for other types of use. However, if the intention was to use the water for human consumption, one should have in mind the contents mentioned in the Decree-Law No. 306/2007 of 27 August. This was drawn up in order to establish the water quality regime for human consumption, having in view the health protection of its users. It also sets as a priority to ensure the availability of clean water and balanced in its composition.

4 Portuguese legislation

Once one of the goals is to implement an alternative water supply system, taking advantage of rainwater and holes, it is important to take into account some restrictions that the Portuguese legislation imposes.

The General Regulations of the Public Systems and Building Services of Water Distribution and Wastewater Drainage, approved by Decree No. 23/95 defines several rules alluding to the use of alternative systems of water supply for domestic use, namely:

Article 82 - System separation

The building systems fed by the public should be independent of any water distribution system with other sources, including wells and private holes.

Article 85 - Prevention of contamination

It is not allowed the connection between the land network of water distribution and gross water networks of wastewater disposal.

The supply of drinking water to sanitary appliances must be carried out without jeopardizing its potability, preventing contamination either by contact or by residual water suction, in case of depression.

Article 86 - Use of non-potable water

The managing body of the distribution service may authorize the use of non-potable water, only for washing floors, watering, fighting non-food industrial fires and purposes, provided that safeguarded the defence of public health conditions.

Non-potable water networks and their use devices must be marked.

5 The efficient use of water in buildings

According to Neves and Martins (2009), the National Programme for the Efficient Use of Water has acted as a stimulus to the implementation of practices aiming the efficient use of water in buildings. However, it also refers that its object of study is not restricted to this sector.

Neves and Martins (2009) conclude that in economic terms, the most effective measures are based on water savings in the baths and cleaning toilets. The authors also enhance that the water savings in the baths should be seen as a priority because it also makes it possible to save energy.

There are numerous motivations to change the consumer behaviour. The tax incentives of the European Union for sustainable construction, which the Housing Cooperatives in Portugal benefited from, and also the certification of sustainability in buildings, are just two of them. The tax incentives set out in the Municipal Tax Code Real Estate (IMI) for buildings that use rainwater or make wastewater reuse are also two of these implemented motivations. (Neves and Martins, 2009)

6 The use of high efficiency equipment

Using advanced technology allows more efficient use of water, as mentioned below. It is also important to note that only the relevant equipment in the scope of this dissertation will be mentioned.

6.1 Flush toilets

According to Baptista et al. (2001), discharges of flushes are one of the uses with greater impact in domestic water consumption. However, though there are these also in most commercial, industrial or collective buildings, their relevance in terms of global consumption is less significant.

Baptista et al. (2001) state that most of the spending does not derive only from discharges associated with physiological needs, but also from improper use, such as solid waste dump in the toilet bowl and leakage due to poor device tightness.

The traditional toilets have capacities ranging between 7 litters and 15 litters per flush. Thus, it is clear that the use of flushes with 6 litters discharges contribute to increased efficiency in the use of water, compared to the traditional 10 litters.

Currently, there are more efficient apparatus with discharge volumes that hover around 6 litters and with minimal discharge of 3 litters (dual flush system). These devices, according to Baptista et al. (2001), function adequately, especially when linked to a lavatory bowl designed to maximize the cleaning and drag of these volumes of water. The discharge of larger volumes should be performed only in the situation where faecal matter exists.

6.2 Urinals

Urinals are devices that are mainly used in common use facilities, such as public bathrooms, offices, sports facilities, among others. Reducing wastage of water in these facilities can be achieved by providing automatic downloading of control systems with more efficient models, that is, models that consume less water or even models that do not use water at all. There are several types of automatic systems: the infrared systems, liquid sensors and magnetic systems associated with doors and thermostats. (Baptista et al., 2001)

6.3 Showers

According to Baptista et al. (2001), the devices primarily associated to the bath tub are the taps. On the other hand, the main factors influencing consumption are associated with the shower flow of the shower, the shower duration and the number of daily showers. The water consumption for this type of use is considerable (approximately 32% of the average daily consumption in housing), meaning that there is a significant savings potential. Nevertheless, the policy measures should aim at reducing the volumes spending without compromising user comfort.

However, not everything comes down to the use of more efficient equipment. Another determining factor for the achievement of the desired levels of savings is the changing of behaviour. The duration and number of showers are merely behavioural issues that can easily be changed.

6.4 Taps

As Baptista et al (2001) mentions, the taps are the most common devices in homes and collective facilities. Thus, the main factors influencing the consumption associated with faucets are the flow, time of use and the number of daily uses. The frequency of use and duration of use are difficult parameters to quantify, since they have large temporal and spatial dispersion. That is, they are closely related to behavioural factors. The duration of use may vary from few seconds to a few minutes.

In Portugal, the National Association for Quality of Building Installations (ANQIP) proposes the use of efficient taps with flow rates of less than 2 l/min for sanitary facilities, and flow rates of less than 4 l/min for kitchens.

6.5 Washing machines

Nowadays, the washing machines are household equipment for general use. For this reason, the development of equipment was quick, always seeking minimizing the consumption.

According to Baptista et al. (2001), different models of washing machines have very different consumption values, with these ranging between 35 and 220 litters of water per wash. Generally, it is assumed an average value of 90 litters per wash, for a device with 5 kilograms of laundry load capacity. These devices have a useful life of between 8 and 16 years, which varies depending on the quality of the equipment and the frequency of use.

The factors that determine the most the volume of water used in each wash, are the characteristics of the equipment: its age, the available washing programs and the amount of clothing that is placed in each wash. So, for one to achieve a more efficient use of water in each wash, machine models with lower consumption should be used. Also, warning consumers about the correct procedures to adopt would be a plausible approach. The user, should therefore, choose a suitable washing program depending on the amount of laundry and the required washing time for it. (Baptista et al., 2001)

Nowadays, it is possible to acquire more efficient equipment, which consumption is approximately 45 litters per wash.

7 Case study – The students' accommodation building

The case study is the students' accommodation building of the Military Academy. This building is a collective and symmetrical dormitory building, with two floors and about 13 meters of height. It is located in Portugal, more specifically in the city of Amadora. The building being studied is part of a larger complex that composes the Military Academy.

The floors have a similar organization, except for the ground floor which has some peculiarities. On this floor, apart from the rooms, there are also offices, storage rooms and common areas, intended for laundry cleaning.

The building comprises a total of 87 rooms, 6 areas for offices, two common areas for cleaning clothes and two areas for the storage of material.

7.1 Experimental determination of water consumption in the building

The need to estimate the water consumption in the building, arises due to the fact that the Military Academy does not have a counter for each building, but a general counter. The objective involves determining the daily and monthly consumption in the building, concluding which is the impact of this on the total costs. Thus, it will be possible to conclude whether there is a margin to implement measures which can make this building a more efficient one. The used values are based on the daily habits of most of the military academy students.

For the experimental determination of the consumption, we used a container with one litter volume and clocked the time required to fill it to the top. In Table 1 we can observe the values of the consumption in the building.

Table 1. Estimate of the consumption in the students' accommodation building of the Military Academy.

Total consumption (litters/day/person)	233,00
Total consumption (m^3/day/person)	0,23
No. of people	150
Total consumption (litters/day)	34975,71
Total consumption (m^3/day)	35
Total consumption in the building (litters/month)	1050000
Total consumption in the building (m^3/month)	1050

Once the water consumption was estimated, it was possible to convert the cubic meters of water used in Euro. (Table 2)

Table 2. Estimated cost of water supply and of wastewater sanitation.

Monthly price of water supply (€/month)	4101,73
Monthly price of wastewater sanitation (€/month)	4395,47
Total (€/month)	8497,20

In summary, the consumption in the building is about 1050 m3 per month, which translates into an expense of €8497. The invoice of water for the month of January 2016, shows a monthly consumption of 2041 m3 throughout the Military Academy, which corresponds to an expense of €23586.79. Thus, based on the previous estimate, one can affirm that the building represents about 36% of the total costs. Hence, it is concluded that this building in particular plays an important role when it comes to the monthly costs with water. Therefore, it is clear that any adopted measure to promote efficient use of water can be beneficial, as shown below.

7.2 Solutions to implement to promote the efficient use of water

7.2.1 1st Hypothesis

A first option to reduce the water consumption and promote an efficient use of water could be achieved by undertaking awareness campaigns, as well as by replacing the sanitary equipment. For this, it is assumed that users have an exemplary behaviour, which means, using a glass of water for brushing their teeth, filling the sink to shave, which minimizes the maximum time of open taps and using properly the toilets and urinals. It is further considered that a more efficient equipment would be installed. Table 3 shows the consumption values after the implementation of the described measures.

Table 3. Estimate of the consumption in the students' building after the implementation of more efficient equipment and adapting behaviours.

Total consumption (litters/day/person)	100
Total consumption (m^3/day/person)	0,10
No. of people	150
Total consumption (litters/day)	15000
Total consumption (m^3/day)	15
Total consumption in the building (litters/month)	450000
Total consumption in the building (m^3/month)	450

Based on the table above, it is possible to estimate the cost to be paid after the implementation of the previous suggestions. In Table 4 one can see the results obtained.

Table 4. Estimated cost of water supply and wastewater sanitation after the implementation of more efficient equipment and adapting behaviours.

Monthly price of water supply (€/month)	1767,68
Monthly price of wastewater sanitation (€/month)	1874,68
Total (€/month)	3642,36

By analysing the previous tables, it is possible to realize that by changing some daily habits and by the replacement of old equipment with a more a modern one, a reduction of approximately 57% of the costs and water consumption is observed.

7.2.2 2nd Hypothesis

The second hypothesis suggested, is only an improvement of the first hypothesis. This second solution, suggests the combination of all the measures and changes that were reported previously, together with a rainwater utilization system. It also has as an objective to capture and store water from a hole to increase the volume of water available.

The implementation of a rainwater system, will have as main objective the supply of equipment, in which the quality of water does not need to be high - water not used for human consumption. That said, it is worth mentioning that the equipment intended to be fed with this system are toilets and urinals.

Table 5 presents the consumption associated with the implementation of the measures described above.

Table 5. Estimate of consumption in housing building of students after implementation of more efficient equipment, fitness behaviours and implementation of SAAP.

Total consumption (litters/day/person)	90
Total consumption (m^3/day/person)	0,09
No. of people	150
Total consumption (litters/day)	13070
Total consumption (m^3/day)	13
Total consumption in the building (litters/month)	392110
Total consumption in the building (m^3/month)	392

Based on the table above, it is possible to estimate the cost to be paid after the implementation of the previous suggestions. In Table 6 one can see the results obtained.

Table 6. Estimated cost of water supply and wastewater disposal after the implementation of more efficient equipment, fitness behaviours and implementation of SAAP.

Monthly price of water supply (€/month)	1558,72
Monthly price of wastewater sanitation (€/month)	1649,47
Total (€/month)	3207,71

The analysis of the table above allows us to see that the change of some daily habits together with the replacement of old equipment with a more modern one and the implementation of a SAAP, enables a reduction of approximately 62% of the costs and water consumption.

8 Future benefits

As expected, both hypotheses presented have advantages and disadvantages. However, one of the solutions will have a greater long-term impact, especially when it comes to the spared volumes of water. In this chapter, a comparison of the suggested hypotheses will be made. In this way, it will become more noticeable the investment that needs to be made in each case, which is the volume of water that each solution allows to be saved, and also the return time of investment.

Knowing that the implementation of the 1st hypothesis requires an investment of approximately €15242, in Figure 1 it is possible to see the payback period of this investment and the money saved over a year.

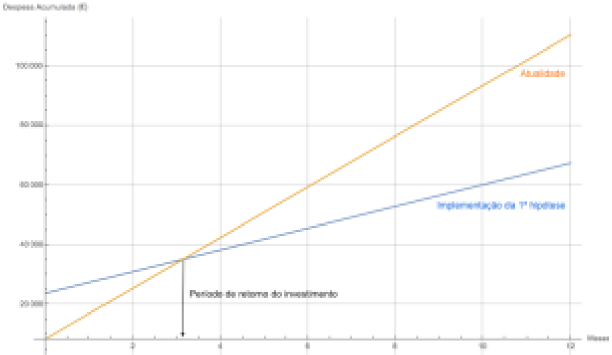

Figure 1. Payback period of investment and money saved after the implementation of the 1st hypothesis.

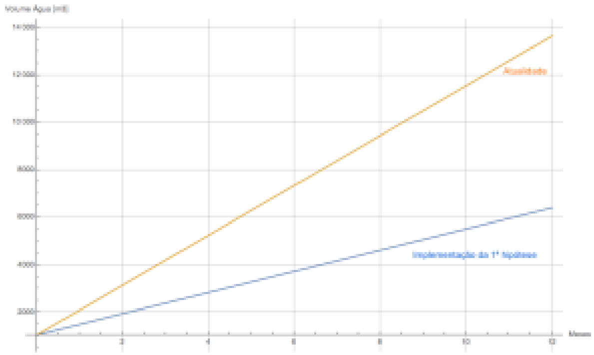

Figure 2. Volume of water saved after the implementation of the 1st hypothesis.

The analysis of Figure 1 allows to realize that it is possible to recover the investment in just three months. Moreover, it can also be seen that at twelve months it was possible to save about €45000.

In Figure 2, one can see the volumes of water that the implementation of the 1st hypothesis allowed to spare. The analysis of Figure 2, allows to conclude that at twelve months it is possible to save about 7300 m^3 of water.

The implementation of the 2nd hypothesis, on the other hand, requires an investment of approximately €32085. In Figure 3, one can see the payback period of the investment and the money saved during one year.

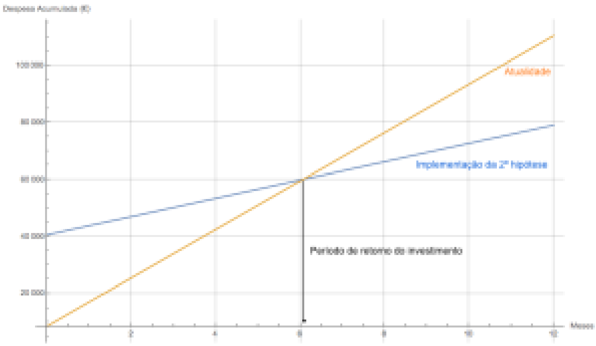

Figure 3. Payback period of investment and money saved after the implementation of the 2nd hypothesis.

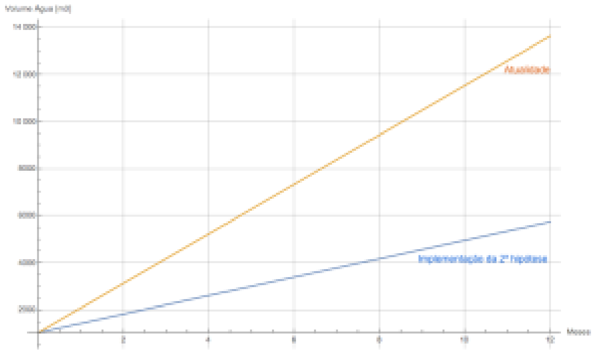

Figure 4. Volume of water saved after the implementation of the 2nd hypothesis.

In Figure 3, one can see that the payback period of the investment will be a little more than six months. It is also possible to realize that at twelve months it is possible to save €30000.

The Figure 4 shows the volume of water saved twelve months after the implementation of the 2nd hypothesis. The Figure 4 also shows that at twelve months it is possible to save about 7900 m^3 of water.

The transition from the current reality to a reality where the measures suggested in the 1st hypothesis were implemented, allows to realize that drinking water consumption in the building will be lower. On the other hand, the 2nd hypothesis suggested is an improvement of the 1st hypothesis. In this case, not only the drinking water consumption would be even lower, but also, one would be opting for unsafe sources of drinking water, which means, water that is not paid.

Summarizing, the 1st hypothesis suggested that a volume of 7300 m^3 of water would be saved after one year. After five years the amount would be 36,500 m^3 and after ten years 73000 m^3 would have been spared. On the other hand, the 2nd hypothesis would allow to save 7900 m^3 of water in the first year, 39500 m^3 after 5 years and 79000 m^3 after ten years.

9 Conclusions

This dissertation aspired to propose solutions that would minimize the consumption of drinking water in the students' accommodation building of the Military Academy and, consequently, the monthly expenses that this would entail.

In order to proceed to an analysis of the consumption in the building under study, an experimental determination of the flow rates of the various equipment existing in the building, was made. This, together with the personal experience of four years of living daily in the same place, allowed to conclude that currently, the consumption per student is of approximately 233 litters per day. It was also concluded that the students' accommodation building, with 150 inhabitants, is responsible for 36% of the total water costs in the Military Academy of Amadora.

The implementation of the first hypothesis formulated, reduces the per capita water consumption by 58%, which translates in 99 litters per day. In this case, the investment would be of about €15244. However, after approximately six months, this value would have already been retrieved and after twelve months, it would have already been saved €30000. After a year it would have been spared about 7300 m^3 of water.

From an economic point of view, it would be advisable to opt for the 1st hypothesis, since it would allow to save more money. However, from an environmental perspective, it would be more advantageous to opt for the 2nd hypothesis, as it would save more than 600 m^3 of water per year than the 1st hypothesis.

Concluding, no matter the choice made is, between the two cases presented, the need to intervene is indisputable, since any changes to the current system would bring tremendous benefits, both environmental and economic.

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