

**A6 - SUSTAINABILITY IN THE USE OF RAINWATER. STUDY CASE****F. MELO, S. LUCAS, A. SILVA AFONSO****Abstract**

Whether by human causes or natural reasons, the earth seems to go through a period of strong and rapid climate change, with particular salience in relation to water scarcity, which reinforces the need to implement on a global scale and countries level, appropriate policies to manage resources, particularly water resources. In this context, the rainwater comes as one of the most viable alternatives to resolve this shortage in many places of the planet. This process has advantages not only from the standpoint of environmental and economic, but also in reducing flood peaks in urban areas, as part of the rainwater is recovered, not being conducted for the urban storm drainage network. In this communication we describe the study for the infrastructure of the "Estádio da Luz" (Benfica Stadium), characterizing the system of rainwater harvesting and proposed referring the procedures adopted in its design, taking into account the seasonality of precipitation and consumption needs.

It is essential that a stadium with specific water consumption very high, there is a system of rainwater harvesting to reduce consumption of potable water and drain to the outside volume of which rain water can replace the existing drinking water consumption.

At first sight, the rainwater can be used in watering the lawn and washes the benches, where needs are met with a lower quality water.

This system allows a rational and efficient use of non-potable water, with the implementation of a sustainable strategy for a resource available on the stadium site and treating it in their own stadium.

In this context a survey was developed which allows the measurement in the population with regard to knowledge and dissemination in relation to the problem of water scarcity, the process of raising awareness about rainwater harvesting, advantages and implementation.

**Keywords**

rainwater, sustainability, rainwater systems

**1 Introduction**

The evaluation of the environmental parameters under large-scale infrastructure in operation presents with high relevance, not only with regard to the improvement of the various environmental aspects, but also, in many situations, with regard to the improvement of the economic.

So, knowing that the leisure practices of the population are very much linked to the sport spectacle, especially football, it is important to analyze the feasibility of rainwater harvesting in their infrastructure in order to optimize the building's water cycle. Remember that, globally, it is considered that 75% of sports infrastructure consumption point of water have very high due to its size and characteristics of influx of users

In Portugal, the risks of water stress in the short term, the sustainability of water use is concerns that must be present in general, establishing good conservation practices, reduce consumption and rational use of this feature. This applies, for example, a sport infrastructure for large, the "Estádio da Luz" (Benfica Stadium) was built for Euro 2004, with regard to the importance of studying systems of rainwater harvesting, not considered the initial project, aimed at reducing or even eliminating, in some uses where the needs can be met with a water that may have a lower quality.

The rainwater that falls on the roof of the stadium will be collected in tanks and, with proper treatment, re-used for functions that do not require drinking water. As drinking water is a scarce resource, and considering that a time will be greater the number of people sharing this facility, it is important to implement systems for recycling rainwater, which can be integrated into existing infrastructure and through this make-up water achieve a level of quality that meet everyday needs. This water does not present, so no problems to human health, since the recycling systems in its last phase of treatment, ensure the elimination of bacteria. This whole process of research and adaptation to the solution is being studied, and future prospects are foreseen for the use of rainwater collected.

**2 Objectives**

Based on the object of study is possible to establish some criteria and describe some measures which fall under the main objectives of this study.

The main objective of contributing to the development and management of sustainable water, knowing reliably and equitably the needs of water for present and future generations by optimizing the efficiency of water use and keeping efforts in preserving and restoring natural ecosystems.



4.1.1. Draft Climate

Lisbon is a city of hills and open valleys of the river, presents itself as the city's most pleasant of Europe, an abundance of flora and fauna with a temperate climate (according to the climatic classification of Koppen-Geiger ) strongly influenced by the Gulf Stream . Spring is cool to warm (8 °C to 26 °C) with sun and some showers.

Summer is usually hot and dry and temperatures between 16 °C to 35 °C. The October is mild and unstable, with temperatures between 12 °C and 27 °C and winters are typically rainy and cool, and also presented some sun (temperatures between 3 °C and 17 °C). The lowest temperature recorded was -2.2 °C and the highest was 43 °C.

The fact that drinking water is not distributed uniformly around the Planet, is an important factor of social inequality and social conditions the development of vast regions of the world. In Portugal, the situation begins to be alarming due to prolonged periods of drought experienced in recent years and it is essential that we start to change their behavior so as not to waste a finite resource that is the essence of life.

It is known by "Matriz da Água de Lisboa", the total consumption of drinking water in Lisbon, estimated at about 74.5 million m<sup>3</sup>, representing 13% of the total consumption of drinking water in Portugal. Each habitant of Lisbon, has a daily consumption of drinking water per capita of 367 gallons of water, which exceeds the national average and the European Union. [4]

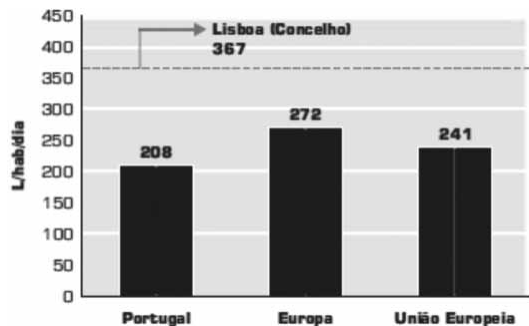


Fig.3: urban daily consumption of water per capita in the municipality of Lisbon compared to National and European consumption [4]

In terms of climate presents values of temperature and precipitation characteristics distinctly Mediterranean, has multiple climatic variations, subject to the influence of continental polar air masses. These variants result in three basic types of time: in the wet winter and unstable in hot, dry summers. [5]

In a more detailed level and study parameters, it is noted the levels of precipitation, obtained through the National System of Water Resources due to its location, was considered the station of S. Julião do Tojal 20C/01C. The series was used between 2000 and 2011, considering that this period has consistent data.

Station Identification	
Code:	20C/01C
Name:	S.Julião do Tojal
Basin:	Tejo
[M; P] (m):	[114090;208796]
Altitude (m):	6

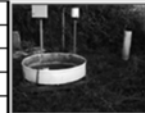


Fig.4: Identification of the monitoring station [6]

From the index rose in the period 2000 to 2011, we calculated the mean monthly precipitation, involving the production, with such results, the graph below:

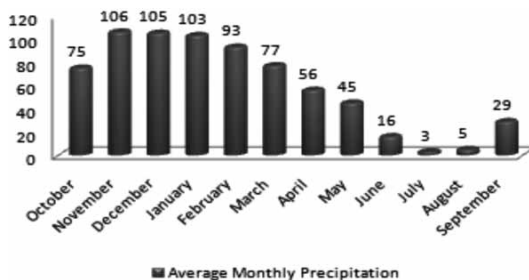


Chart 1: Analysis of the average monthly rainfall between 2000 and 2011

Through analysis of average monthly rainfall indices will reveal the highest rainfall in the months November to March (wet period), and decreased precipitation from April to September (dry season).

The annual rainfall variability is the main characteristic of the rainfall, in the case of a mild climate. The rates of precipitation 600 to 900 mm were more frequent in a period from 2000 to 2011. However, other indices showed small differences of occurrence: rates exceeding 900 mm occurred in three years, in three years the annual totals were below 600 mm. Another index proved to be quite rare, in just two years the index was above 1000 mm.

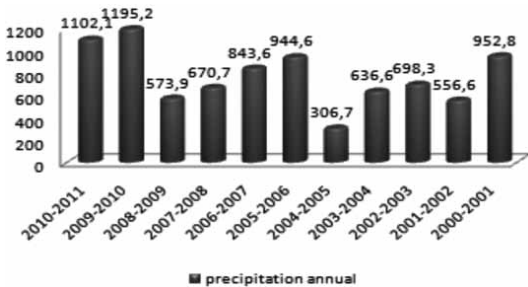


Chart 2: Precipitation annual variability between 2000 and 2011

The average annual rainfall was 713 mm, the minimum annual precipitation was 29.7 mm and maximum annual rainfall was 2 578 mm.

Statistical analysis of dry periods allows us to assess / identify the maximum number of consecutive days without rain each year, thereby adjusting the distribution of extreme size and allow the volume of the storage reservoir.

Currently there is use of rainwater from the cover for a reservoir located in the basement which supplies 3 Fire Network, but that can not be considered as a system of rainwater harvesting, there is a drainage network and storage.

#### 4.2 Assessment of consumption

The main water consumption and analysis so far, takes place through the daily watering of the lawn and washing the benches. Based on the reading held at the “Estádio da Luz”, water consumption between 04 a 12 May 2011 used to wash the floor 0 countertops, a floor 1and floor 3, it is possible to estimate a volume of water spent on drinking water for consumption-washing benches is the order of 73m<sup>3</sup>.

The deployment of the system of rainwater harvesting, makes it possible, to reduce the amount of water used for washing the stadium from the stands, it also allows a reduction in the release of CO<sub>2</sub>, they are just being consumed large quantities of water treated to a so it is entirely dispensable.

Table 1 - Readings of water consumption for washing countertops Floor 0, Floor 1 and Floor 3

counter	Initial reading	Final reading	Consumption (l)
1	14294	41533	27239
2	30509	59.600	29091
3	3574	3574	0
4	2066171	2083009	16838
Total			73168

The quality of water is defined according to the type and amount of impurities present in it. The qualitative characteristics of water indicate that the most appropriate uses can be made and it can be translated in the form of water quality parameters.

Through analysis carried rainwater in the region of Coimbra, the quality of rainwater for non-contact with the ground or be directly exposed to the discharge of pollutants of anthropogenic origin, is presented with reasonable quality for different uses, and necessary to carry out a treatment to prevent malfunction of the system of utilization of rainwater. It is then possible to verify that the rain has sufficient quality for non-potable uses, as to make it drinkable is a need for finer filtration than not bacterization and removal of chemical elements. Thus, this water can no conditions, replace public drinking water in several applications: toilets, washing machines, watering lawns, washing and cleaning countertops.

#### 4.3 Catchment area

The system is characterized as a way to allow the use, retrieve and use rainwater collected on the slip down the stadium, as well as at a later stage, analyze the existing runoff in the area of the lawn. Here, it is important to analyze the drainage areas of sport green, being influenced by the characteristics and properties of the terrain and vegetation.

The control of water is the responsibility of the work, to ensure total protection, preventing the water reaching the critical locations and provide fast flow of water to the local storage structures without damaging the pickup, driving and unloading for processing and storage.

The quality of water collected depends on the material surface to capture, in other words, coverage of the stadium, weather conditions and the environment where it operates.

The material of the roof of the stadium consists of a membrane Lexan<sup>®</sup> Thermoclear high quality polycarbonate. These covers have a high stiffness and excellent long term resistance, good thermal insulation properties and good behavior in hot climates, since it prevents discoloration and degradation by the effect of ultraviolet light, impact resistant at temperatures up to 100 °C.

Comes in two types of color, transparent and opaque. The surface is smooth and horizontal, thus allowing a greater amount of rainwater captured.

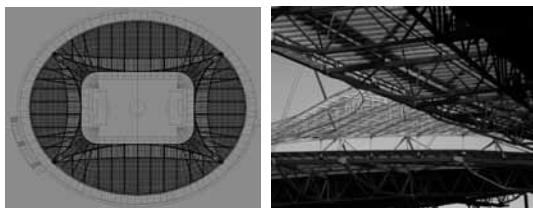


Fig.5 and 6: Plant and detailed coverage of the "Estádio da Luz"

The coverage area where you can collect rain water, has an area of about 26.000 m<sup>2</sup>.

**Table 2 - Catchment area - Largest and smallest of the "Estádio da Luz"**

catchment area			
smaller	5204,0743	5204,0743	
more	7947,4904	7947,4904	
total			26303,1294

Thus, it is possible to estimate the amount of rainwater to be collected, taking into account the variability of precipitation, whereas in this case, the average annual rainfall of 713mm can be a volume of rainwater captured in the order of 18.800 m<sup>3</sup>.

**Table 3 - Volume of rainwater captured estimated for the "Estádio da Luz"**

V= 0,713 m3	→	18.754.130,98	→	18.754,13 m3/ano
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Once this initial phase that is only to consider the collection of rainwater for washing stands, one can conclude that there is no need to use the total catchment area. It is therefore important to know the degree of frequency of washing and the most prevalent. This will be mainly during the games, or in winter, which is considered a vantage point for the collection of rainwater, as it is in winter that has a higher rainfall.

Also important to note that methods should be considered to prevent sediment and floating debris from being forwarded to the points of discharge, thus avoiding the risk of infiltration and malfunction of the system. The contamination on the surface of capture depends on the number of dry days (days without rain), which increases the number of waste material.

#### 4.4 Transport

Transport system is any system that allows you to collect rainwater from the catchment surface to the place of storage. Currently at the "Estádio da Luz" since there is a drain cover to the basement 3, which is established through the pillars where the reservoirs, but which is connected directly to the public, will thus be a link to this drainage to a the reservoirs, which currently is inactive.

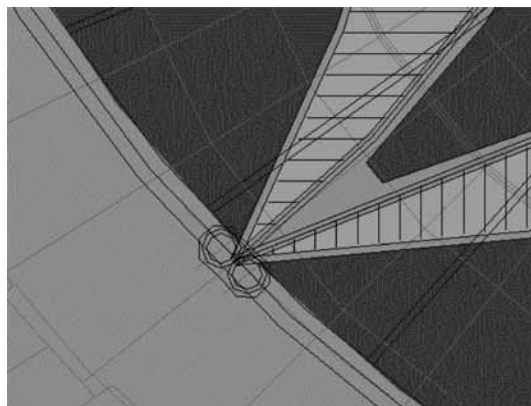


Fig.7: Location of the pillars where a connection of downpipes at the "Estádio da Luz"



Fig.8 and 9: Details of entry and exit system of the pillars of the "Estádio da Luz"

#### 4.5 Filtration and Treatment

The cover is a surface that is subject to dust, leaves, flowers, bodies of insects, animal feces and other waste transported by air. Thus, to prevent these pollutants reach the storage reservoir, we use components of filtration through sieves made of leaves, the first flow diverters and filtration devices. These are systems that require careful maintenance. The screens of leaves are used to remove larger debris and should be cleaned regularly to work effectively, because otherwise they can become clogged and prevent water reaching the reservoir rain and debris can harbor bacteria that ruin the equipment. The diverter of the first rains, allow us to reject minor contaminants. The first part of runoff is stored in a chamber where the water enters on the form of drops that fall slowly through a small hole, while the clean water on top of the camera goes into the storage reservoir. It is an example of a diverter on the market first rains Portuguese (Scheme 1) [7]. All filtration devices must be cleaned, so that does not obstructions and restricting the flow of rainwater, but to no growth of pathogenic microorganisms.



Fig.10: Schematic of a diverter first rains [7]

The mode of treatment of rainwater, depends on its quality when captured. In Portugal, it was established by Decree-Law No. 74/90 of 7 March 1990, a set of quality parameters to which the water should meet, based on the presence of certain substances that may be harmful. Decree-Law No. 74/90 fixed "the minimum requirements of a quality that water should meet, depending on their type of use." Are stipulated maximum recommended and maximum allowable values, above which water is considered unfit for consumption. These values vary depending on the use of water is for human consumption, irrigation, for washing or other purposes.

However, treatment of stored rainwater makes sense only if done correctly and that the collection and hygienic use of water to ensure that this does not suffer from further contamination. [9]

#### 4.6 Storage

The type of storage tank is used, and this is seen as the most expensive component of the entire system to use rainwater. It is important that they are opaque to inhibit algae growth, covered, ventilated and protected from direct sunlight to prevent the development of mosquitoes [7].

Currently the "Estádio da Luz" already has a double storage reservoir, which is currently, disabled, which will therefore be used for storing rainwater. This reservoir is located in the basement 3.

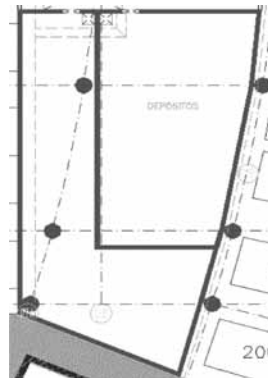


Fig.11: Plan of the double storage tank located in Cave 3



Fig.12 and 13: 3 deposits in the basement of the "Estádio da Luz"

The contamination in the storage tank depends heavily on the efficiency of water filtration that is made before reaching the reservoir. Thus, the more efficient filtration, sedimentation and introduction of lower organic matter will be inside the tank.

The reservoir must have opened to allow access for cleaning and equipped for proper restraint of coarse materials and disposal, extraction of sediment and sludge without having to drain the tank periodically. In order not to compromise the quality of stored water and the tank is important that regular cleaning is carried out of the reservoir [9].

### 5 Conclusions

This article presents a small intervention with regard to the water resource in relation to the “Estádio da Luz”, of constituting a basis for the definition of the intervention strategy and prioritization of actions required to contribute to the water and environmental performance of the Stadium.

The water system developed for this sports complex is to ensure the supply of water under normal conditions of comfort, featuring a system of simple design and a good economic efficiency. These interventions, and contribute to water conservation, reduced consumption of drinking water in places where it is unnecessary and creates conditions for a more efficient operation of drainage systems.

After compilation of the various technical possibilities which can be performed will be made a better definition of the technical solution that can be used both for the system to their accumulation and drainage network and storage, and these are the prospects for the near future. The choice has to do both in the choice of drainage areas most technically advantageous as that infrastructure of the stadium will use collected rainwater.

These systems are solutions already implemented in stages that received the German World Cup stadiums in Brazil and currently receiving certified “Green Goals” by the energy and water efficiency. With this, a stadium with consumption of very high water point, is clearly important to have a system rainwater harvesting, where rain water will replace the existing drinking water consumption. Rainwater, the recovery of the surplus of grass, either from rain or irrigation use water sustainably and project the club to a level of development within the Iberian Peninsula.

Subsequently, and from the definition of performance indicators, you can define the relevant targets and actions to fit which will, in an integrated manner, a rational water management, an integral part of the study to the water's Benfica Stadium.

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