EVALUATION OF THE IMPLEMENTATION OF A RAINWATER USE SYSTEM FOR NON-POTABLE USES IN A PORT STORAGE AND LOADING UNIT

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Developing and improving techniques for the use of rainwater is increasingly necessary, since over the years there is less availability of water resources and more and more consumption. This work analyzes the economic viability of implementing a rainwater system for non-potable uses in the area of storage and loading of solid bulk in the port terminal of Aratu/BA. Data collection was carried out on water availability, and the rainfall in the region for the preparation of the project’s economic feasibility study. The results indicated the feasibility of using rainwater for non-potable in terms of economy. A total of 12% of the drinking water economy was observed whereas the payback was estimated to be 4 years. Practices and methodologies that contribute to the conscious use and/or reduction in the use of resources are important and must be adopted by companies as an economic, environmental and technological strategy integrated into their processes and products.

Keywords: Use of rainwater, Economic viability, Use of resources, Sustainable.
1. Introduction

The indispensable resource for the survival of every living being is water. It is known that approximately 70% of the Earth is covered by water, but that about 1% is potable (CNA, 2023). Climate change, urbanization, and maintenance are present and future challenges for urban water infrastructure (OBERASCHER, 2021). Currently, there has been a gradual reduction in the quality and availability of water resources on the planet, mainly due to the sharp increase in world population and the increased consumption of drinking water (MARINOSKI, 2008). Although water availability is decreasing worldwide, the use of rainwater has been suggested to promote drinking water savings and alleviate water availability problems (GHISI, 2006). According to data from the National Department of Works Against Drought (DNOS, 2023) 12% of the world's water share is in Brazil and is suitable for human consumption, with 70% of this fresh-water concentrated in the Amazon Basin. The Northeast has only 5% of Brazil's freshwater reserves, and a large part of this volume is underground and high in salt content.

Graywater recycling and rainwater harvesting at the building level are alternatives that can provide water for non-potable uses (WANJIRU, 2018). The collected rainwater can be used for flushing toilets, cleaning, car washing, and garden irrigation.

This study aims to evaluate the potential for drinking water savings through the implementation of a rainwater harvesting system for non-potable use, verifying the economic feasibility of the project in the magnesium oxide loading area at the port terminal in Aratu/BA.

2. Literature review

2.1. Water availability

A watershed is an area where water flows into a main river and its tributaries. The area is delimited by relief and local geography. The basin is formed from higher to lower areas and separated from the others by a watershed, a relief formation - usually the crest of land elevations. The four main river basins in Brazil are the Amazon, the Tocantins, the Platina (Paraná, Paraguay, and Uruguay), and the São Francisco River, which together cover about 80% of the Brazilian territory (BHRC, 2019).

The Paraguacu River is the largest genuinely Bahian river. Its name is of indigenous origin and means "big water, big sea, big river" (NURP/MPBA, 2023). In 2006 the Paraguacu River Hydrographic Basin Committee - CBHP was created and, according to the National Water Agency, among its functions are the approval and follow-up of the elaboration of the Basin
Water Resources Plan, which gathers strategic information for the water management in each basin, arbitration of conflicts over the use of water (in the first administrative instance) and the establishment of mechanisms and suggestion of charging values for the use of water. From a series of criteria the control points for the Paraguaçu River basin were defined, the Paraguaçu River Planning and Water Management Region (RPGA) subdivided into ten Balance Units, based on the adopted control points. Salvador and the metropolitan region are in Balance Unit 9 - Upstream of Pedra do Cavalo Reservoir, as shown in Table 1.

Table 1 - Balance Units of RPGA X

<table>
<thead>
<tr>
<th>Balance Sheet Unit</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>UB9 - Pedra do Cavalo Reservoir upstream</td>
<td>The UB9 covers the sub-basins of the tributaries that drain directly to the reservoir of the Pedra do Cavalo dam, except for the main course of the Paraguaçu and Jacuípe rivers. BU9 contains the Pedra do Cavalo reservoir and dam. The reservoir has a volume of 4,630.96 km3 and a regularized flow of 58.3 m3/s, generating important interference in the basin's water availability. The reservoir of the Pedra do Cavalo dam extends over two branches, a stretch over the channel of the Paraguaçu River and another over the Jacuípe River, which after confluence form the final course of the Paraguaçu River. The main direct tributaries to the reservoir are: the Ribeirão do Cavaco and the Aguilhadas Creek on the right bank of the Jacuípe River branch; the Curumutaí River on the left bank the left bank of the branch over the Paraguaçu River and the Jenipapo River on the right bank. The UB9 has a total area of 2,015 km2, where rocks of the crystalline basement occur. The headwaters of the Curumutaí and Ribeirão do Cavaco rivers are in an area with a semi-arid climate, however, as one gets closer to the reservoir of the Curumutaí as one approaches the reservoir of the dam, the annual precipitation increases, reaching 1,000 mm. Part of the urban area of the city of Feira de Santa occupies the UB9, but agricultural activity predominates the land use. The surroundings of the Pedra do Cavalo dam reservoir have a high degree of environmental degradation. In this UB are located the captures carried out in the reservoir of the Pedra do Cavalo dam that supplies water for the human supply of the</td>
</tr>
</tbody>
</table>
Due to increasingly reduced water availability, there is a need for management and rational use of this resource in all sectors. Developing strategies that contribute to increasing efficiency in the use of raw materials, water and energy, integrated into its processes and products, is of interest to industries, in addition to bringing economic, social and environmental benefits.

### 2.2. Cleaner Production (CP), management and rational use of water in industrial areas

An organization's ability to capitalize on its innovative capabilities develops over time and largely depends on the sustainable practices it chooses to adopt (DIXIT, 2021). For Rocha (2010) the permanent evolution of preventive practices requires a discussion about the desired speed for this evolution and the real possibility of reversing the process of environmental degradation only from technological evolution.

The Cleaner Production methodology is the result of a joint effort by UNIDO (United Nations Industrial Development Organization) and UNEP (United Nations Environment Programme) on waste management, energy and material waste and waste (KIPERSTOK et al., 2002). The United States Environmental Protection Agency (EPA) states that adopting simple changes in habits aimed at using water more efficiently results in water savings and money to pay the bill. (EPA, 2008).

In Brazil, the National Plan to Combat Water Waste - PNCDA conceptualizes the management of water demand as any measure that aims at the final consumption of water by system users, without prejudice to the hygiene and comfort provided by the original system (PNCDA, 2008). Kiperstok et al (2009) state that whatever the type of building, before adopting any action aimed at implementing the rational use of water, it is necessary to control the building’s water consumption, which is done considering three factors: the existing measurement of the consumption, awareness and/or consumer demand. The consumption of water (and/or energy) in buildings stems from a series of aspects that must be analyzed to organize actions to minimize them, as shown in Figure 1.
Santos (2010) argues that in Brazil, there are still few examples of incentives for the implementation of programs for the rational use and conservation of water in buildings, either by municipal authorities or by state sanitation companies. And this scenario remains pretty much the same. There are efforts by the government to take care of water, but they should act with greater impetus and austerity. Water rationalization programs are only adopted by sanitation companies in Brazil when there are emergencies, such as problems in the water distribution networks or due to climatic factors such as, for example, periods of severe drought, when advertisements about the need for water rationing.

2.3. Rainwater harvesting

According to the Technical Standard that deals with the use of rainwater from roofs for non-potable purposes - Requirements (NBR 15527: 2019) there are some conditions it applies to non-potable uses in which rainwater can be used, for example, discharges in toilet bowls and urinals, irrigation for landscaping purposes, vehicle and floor washing and ornamental use. There are also NBR 10844:1986 - Building installations for rainwater and NBR 5626:2020 - Building installation of cold water for your service.

Each hydraulic building system has a specific NBR, but they can be integrated with other systems. NBR 10844 establishes rainwater drainage requirements on roofs and the project ensures acceptable levels of functionality, safety, hygiene, comfort, durability and economy.
NBR 5626, on the other hand, establishes requirements and recommendations related to the design, execution and maintenance of cold water building installation.

3. Methodology

For the elaboration of this work, the following structure was used: - Strategy: Case study, Bibliographical research and Documentary analysis (NBRs); - Procedure: Survey of secondary data to carry out feasibility analyses, Result analysis, Application of Cleaner Production (CP) methodology, Discussion about the results.

The storage facilities at the Port of Aratu, located in the municipality of Candeias/BA, metropolitan region of Salvador (RMS), are made up of warehouses, patios, tanks and silos. These facilities are leased to private companies, except for the solid bulk yard, which is public and operated by Companhia das Docas do Estado da Bahia (CODEBA). To carry out this work, the storage and loading area of Company “K” was used as a case study, which has a leased warehouse in a public port area, in which it operates solid bulk cargo, resulting from the sintering of magnesium oxide. Data from the rainfall index of the National Institute of Meteorology (INMET) were used to evaluate the implementation of a rainwater harvesting system for non-drinking purposes, verifying the economic viability of the project in the area. Cleaner Production is the methodology that proposes strategies to companies to avoid wasting raw materials and energy, waste of any kind, being responsible for additional costs to production processes and generating environmental problems.

The Brazilian Association of Technical Standards (ABNT) created NBR 15527 - Use of roofs in urban areas for non-potable purposes, which guides the requirements for the use of rainwater reuse systems for non-potable purposes, as well as its design guidelines definitions and maintenance of the system, gutters and conductors, reservoirs, building installations, water quality.

4. Results and discussions

4.1. RMS climate and weather conditions

According to data from the National Institute of Meteorology (INMET, 2023) in Salvador, the summer is hot and the sky is partially cloudy. Winter is warm, with precipitation and almost cloudless skies. Throughout the year, in general, the temperature varies from 22 °C to 31 °C, as shown in Figures 2 and 3.
It is observed that the average minimum temperature (°C) jumped from 24.04 to 25.14 between April 2018 and April 2019, reflecting the consequences of global warming.

Figure 3 presents information on the rainfall index for the Metropolitan Region of Salvador (RMS). The A456 automatic meteorological station, located at the Aratu naval base, was installed in 2018 (INMET).

It is observed that the months between April and July are the rainiest periods in the RMS, with average indexes of 200mm. The months of December to February are less rainy, with an average of 80 mm. An increase in the rainfall trend can also be seen, resulting in an increase of 12.24% between March 2018 and December 2021.
4.2. CP implementation opportunity applied to the port logistics sector

The CP strategy identified in the company related to Good Operational Practices (BPO) was the implementation of a rainwater harvesting system for non-drinking purposes, verifying the economic viability of the project.

The area for storing magnesium oxide at Company “K” has an available roof of approximately ~ 5,000 m². The implementation of this system was recommended so that the water is used for flushing toilets, cleaning the administrative area, cafeterias, and common areas, washing vehicles and superstructures, fighting fires, irrigating the garden, uses covered by NBR 15527, and currently fresh drinking water is used.

The feasibility of using rainwater for non-potable uses depends on the amount of water that can be collected from the system, which varies according to the catchment area and the volume of rainwater storage, and is also influenced by the region’s rainfall and the coefficient of surface runoff. The equation can be used: \( Q = 10^{-6} \cdot C \cdot I \cdot A / 36 \) [m³/s], which varies according to the catchment area \( A = [m^2] \); the Surface Runoff Coefficient \( C = [%] \) and the Rainfall Index of the Region \( P = [mm] \), since the Intensity of the equation can be calculated by \( I = P / D \) [mm/h]. It is noteworthy that the required volume of storage \( Vol = [m^3] \) is given by the product of the design Rainfall Height \( P = [mm] \) pela Area \( A = [m^2] \) of capture.

From the consumption information of the company “K”, the costs with the implementation of the project were calculated, in Table 2.

| Table 2 - Data on consumption, cost and savings of the project to capture and store rainwater at Company “K” |
|-----------------------------------------------|-----------------|------------------|
| Information                                   | Value           | Unit             |
| Consumption                                   |                 |                  |
| Average monthly consumption of drinking water | 17              | m³/ month        |
| New average monthly drinking water consumption| 15.0            | m³/ month        |
| Costs                                         |                 |                  |
| Current average monthly cost of drinking water| R$ 1,454,17     | R$/ month        |
| New monthly drinking water cost               | R$ 1,279,67     | R$/ month        |
| Average monthly cost of operating the system* | R$ 1,000,00     | R$/ month        |
| System implementation cost                    | R$ 4,840,00     | R$               |
| Economy                                       |                 |                  |
| Drinking water saving potential               | 12.0            | %                |
| Total savings generated                       | R$ 174,50       | R$/ month        |

Source: Authors (2023)

* Company “K” offers maintenance services/materials. Some items were already available in the warehouse.

The results presented in Table 3 are in relation to the net present value, the investment return time and the monthly internal rate of return.
Table 3 - Calculation of the project's NPV for capturing and storing rainwater at Company "K"

<table>
<thead>
<tr>
<th>Period</th>
<th>Investment</th>
<th>Tax (Hurdle rater)</th>
<th>Sum Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>R$ (4,840,00)</td>
<td></td>
<td>R$ (4,840,00)</td>
</tr>
<tr>
<td>1</td>
<td>R$ 1,279,67</td>
<td></td>
<td>R$ 1,163,33</td>
</tr>
<tr>
<td>2</td>
<td>R$ 1,279,67</td>
<td>10%</td>
<td>R$ 1,057,58</td>
</tr>
<tr>
<td>3</td>
<td>R$ 1,279,67</td>
<td></td>
<td>R$ 961,43</td>
</tr>
<tr>
<td>4</td>
<td>R$ 1,279,67</td>
<td></td>
<td>R$ 874,03</td>
</tr>
<tr>
<td>5</td>
<td>R$ 1,279,67</td>
<td></td>
<td>R$ 794,57</td>
</tr>
<tr>
<td>NPV</td>
<td>R$ 10,94</td>
<td></td>
<td>R$ 4,850,94</td>
</tr>
</tbody>
</table>

| NPV (VP of flows + Initial investment) | R$ 10,94 |

Hurdle rater 10%
NPV R$ 10,94
PAYBACK 3.78
IRR 10%

Source: Authors (2023)

For this study, a monthly tax (Hurdle rater) of 10% was considered. It is observed that the return on investment is estimated at 4 years, IRR 10% considering the project viable for capturing and storing rainwater at Company “K”. There is an even greater potential for saving potable water through the implementation of a rainwater harvesting system for non-potable uses, given that the catchment area of Company “K” is large and rainfall in the region occurs regularly.

Training with employees on the correct use of water for the bathrooms, showering time at the end of the shift, cleaning the area and vehicles, and use in gardening, among others, was prepared, in addition to the implementation of a schedule for maintenance/replacement of toilet bowls (discharge valve).

5. Conclusions

When thinking about sustainability, it is necessary to identify strategies to increase the eco-efficiency of processes and products by several orders of magnitude. Currently, concern and care for the environment are part of the values of companies. In order to prevent impacts, companies seek to implement environmental practices through methodologies in their businesses, considering the socio-environmental points in their standards, commitment and awareness of their employees. And the market values those who dedicate themselves to caring for and preserving the environment.

Cleaner Production is a methodology that uses technicians who aim to preserve or reduce the use of these resources. The implementation of BPO was used and suggested for the capture and
storage of rainwater, “taking advantage of water that would be discarded or disposed of”, for a new use, reducing the consumption of potable water. By collecting data on water availability and rainfall in the region, an economic feasibility study was prepared for the project, which indicated savings of 12% in the use of drinking water, with an estimated return on investment of 4 years.

Company “K” cares about its partners and the community, and one of its principles is to create a fairer, more resilient and sustainable society. In this sense, it has been developing projects in recent years related to the Sustainable Development Goals (SDG). SDG – 9 - Industry, Innovation and Infrastructure is already part of its portfolio. Thus, target 9.4 – Brazil – “By 2030, modernize infrastructure and rehabilitate economic activities to make them sustainable, focusing on the use of renewable resources and greater adoption of clean and environmentally appropriate technologies and industrial processes”.

Among other actions and practices that Company “K” already practices and with the implementation of the CP program, it will also contribute to the standards and good practices that today characterize a company with environmental, social and corporate governance (ESG).

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