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Changes in the Water Footprint during COVID-19 at Santa Rosa Hospital Located In Metropolitan Lima City, Peru

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Abstract-This study aims to investigate the water footprint of Santa Rosa Hospital, situated in the city of Lima, Peru. The analysis period covers the years 2015 to 2019, before the onset of the COVID-19 pandemic, and the period from 2020 to 2022, after the COVID-19 pandemic. The primary objective is to understand how the health crisis has impacted water consumption and to identify measures taken to optimize its usage. The methodology involves the calculation of both blue and grey water footprints, with the green footprint excluded due to the absence of green areas in the hospital premises. Data essential for determining the water footprint were sourced from technical reports published by public scientific entities. The findings revealed an increase in the water footprint following the onset of COVID-19. A management study implemented significant savings for the year 2022. Through this analysis, the hospital aims to reinforce its commitment to sustainable water management, contributing to a healthier and more environmentally sustainable future.
Keywords**:** Water footprint, Santa Rosa Hospital, COVID-19, sustainable environment

1. Introduction

Water is considered a renewable natural resource, indispensable for life, vulnerable, and crucial for sustainable development [1]. In recent decades, the scarcity of freshwater in some cities around the world has been affecting the sustainable development of society. Various factors such as population growth, industrialization of final products, improvements in living standards, changes in consumption patterns, and the expansion of agricultural areas are some causes of the problem. According to [2], four billion people worldwide already face severe water scarcity, and Peru has cities along the Peruvian coast that would be the most affected. Additionally, issues associated with climate change and water pollution contribute to the decrease in both quantity and quality of water resources. In this sense, new concepts, management tools, and awareness regarding water use preservation have started to emerge. One of these concepts is the term Water Footprint (WF), introduced by [3], which is defined as a comprehensive indicator of water use, whether direct or indirect, required for the production and consumption processes of products or services. The WF is a volumetric measure of consumption and pollution; it is not a measure of the severity of local environmental impact of consumption and is determined multidimensional because it is defined for a specific geographical space and a specific time [3]. The water footprint consists of three main classifications: green WF, blue WF, and grey WF. Also, this indicator can be useful in studying the efficiency of water consumption concerning the availability of resources in a specific area [4].

In Peru, the largest water consumer is the agricultural sector, accounting for 89%, followed by the population sector with 9% of the total consumptive demand. Population water usage is projected to increase by 26% by the year 2035 according to government projections [5]. In line with this, the metropolitan city of Lima, the capital of Peru, which holds one-third of the national population with 10.4 million inhabitants (INEI, 2022), is the largest consumer of water, encompassing household consumption and other non-productive sectors such as the health sector. In recent years, several studies have shown that hospital operations entail high water, fuel, and energy consumption, leading not only to high consumption but also considerable environmental pollution, contributing to climate change. In practice, the government is promoting water management and conservation programs in various public buildings, including hospitals in Peru, with promising results. However, extreme situations can increase water consumption, as was the case during the COVID-19 pandemic (2019 - 2022) caused by the rapid and alarming spread of the SARS-CoV-2 virus. Many countries imposed health control measures to contain the spread, dramatically altering behavioral habits of people. Measures such as promoting frequent hand washing and surface disinfection were implemented in hospitals to prevent viral spread.

The primary motivation of this study is to aid in understanding the water footprint of Santa Rosa Hospital located in the metropolitan city of Lima, Peru. This involves quantifying the impact of COVID-19 on water consumption and pollution, analyzing monthly data over a five-year period (January 2015 to December 2019) and a three-year period (January 2020 to December 2022).

2. Study area

Santa Rosa is a hospital located in the Breña district in the Lima city (Figure 1), where the climate is around 17°C, and the annual precipitation is less than 15 mm. The hospital has a total area of 13,220 m^2, with 11,230 m^2 of constructed area dedicated to patient care services. It is a medium-sized hospital, structured with six floors and a basement across six blocks.

It is equipped with three flood-rate meter and for this study, and it was used as consumption data from these three supplies (Table 1). The potable water supplied to the hospital originates from the Potable Water Treatment Plant, sourced from the freshwater of the Rímac River, which flows through the metropolitan city of Lima. Monthly volumetric water consumption data from 2015 to 2022 was obtained through potable water receipts provided by the *Servicio de Agua Potable y Alcantarillado de Lima* (SEDAPAL).

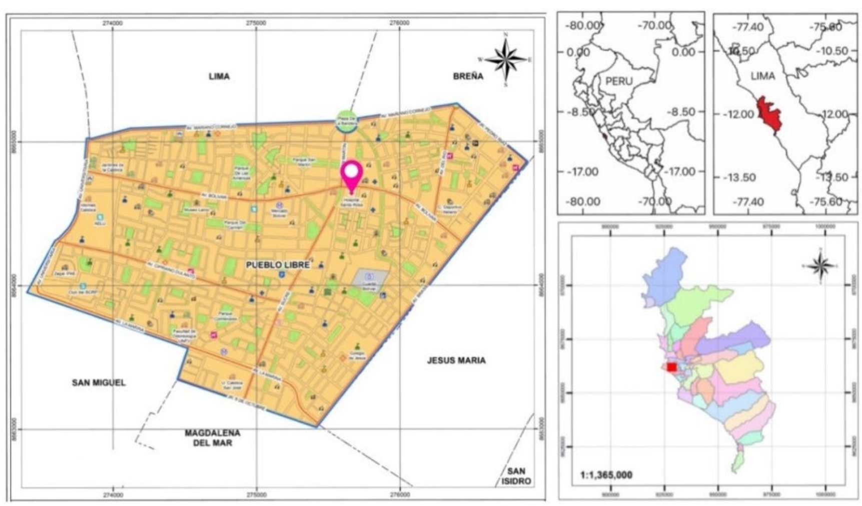
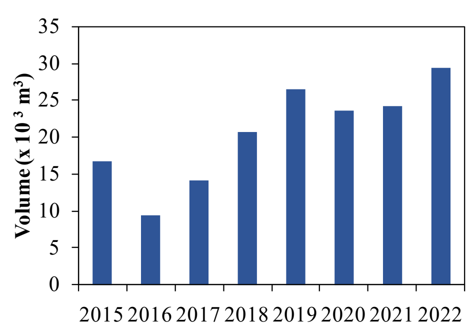


Fig. 1: Localization of the Santa Rosa hospital in the Lima city.

Table 1: Annual drinking water consumption at Santa Rosa hospital from 2015 to 2022.

Month	2015	2016	2017	2018	2019	2020	2021	2022
Jan	1116	1116	1116	1116	1116	1116	1116	1116
Feb	1713	1713	1713	1713	1713	1713	1713	1713
Mar	1857	1857	1857	1857	1857	1857	1857	1857
Apr	1182	1182	1182	1182	1182	1182	1182	1182
May	773	773	773	773	773	773	773	773
Jun	1855	1855	1855	1855	1855	1855	1855	1855
Jul	1628	1628	1628	1628	1628	1628	1628	1628
Ago	1394	1394	1394	1394	1394	1394	1394	1394
Sep	1414	1414	1414	1414	1414	1414	1414	1414
Oct	1551	1551	1551	1551	1551	1551	1551	1551
Nov	1279	1279	1279	1279	1279	1279	1279	1279
Dec	1025	1025	1025	1025	1025	1025	1025	1025
Total	16787	16787	16787	16787	16787	16787	16787	16787



3. Methodology

The water footprint is calculated based on [3] and is defined as the sum of its components: green (WF_{green}), blue (WF_{blue}), and grey (WF_{grey}), as depicted in the general Equation (1). The unit of measurement is volumetric per unit of time. WF_{blue} serves as an indicator of the consumptive use of fresh surface or groundwater and can be measured both directly and indirectly. It encompasses water that evaporates and the water utilized for all processes related to various unit operations (such as chemical and energy consumption, transportation, and sludge treatment) during wastewater treatment.

$$WF = WF_{blue} + WF_{green} + WF_{grey} \tag{1}$$

In the hospital, direct measurement includes the consumption of drinking water for various services, which is accounted for by the three flood-rate meters installed at the hospital's main entrances. On the other hand, the indirect measurement is found in the virtual water used to generate energy for the hospital.

$$WF_{blue} = WF_{drinking} + WF_{energia} \tag{2}$$

The WF_{green} serves as an indicator of human usage of green water. Green water refers to a portion of the water that falls on the earth's surface as precipitation, which is stored in the soil or temporarily remains on the soil surface or in vegetation. Eventually, that portion of the precipitation either evaporates or is transpired by plants. In the case of Santa Rosa Hospital, this component is not considered due to the absence of garden areas and the nearly negligible precipitation in the city of Lima. The water footprint for energy, $WF_{energia} = 0$, is not taken into account, as the hospital is not considered an industrial local.

The WF_{grey} serves as an indicator of the degree of water pollution associated with the operational stage of the Hospital. It is defined as the volume of water required to assimilate the sewage load based on concentrations under natural conditions and existing environmental standards. This applies to polluted point sources.

$$WF_{grey} = \frac{V_f . c_{efl} - V_a . c_{afl}}{c_{max} - c_{nat}} \tag{3}$$

where, V_f and $V_a$is the volume [$m^3.month^{-1}$] effluent and influent, respectively. c_{efl} is the pollutant concentration [$kg^3.month^{-1}$] effluent. c_{afl} is the influent concentration. c_{max} is the concentration of the environmental quality standard, an value of maximum acceptable concentration. c_{nat} is natural concentration of water receptor corresponds to the concentration that would occur if there were no human interventions.

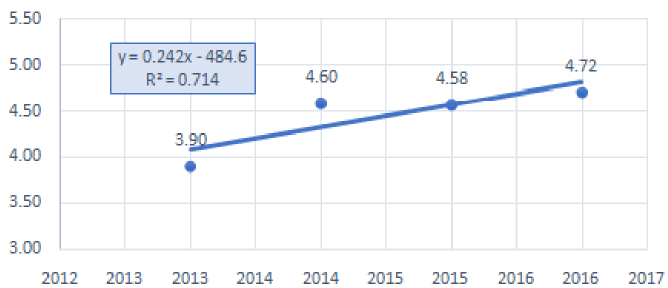
The procedure to calculate the total water footprint (WF) in Santa Rosa Hospital is the sum of the green, grey and blue water footprints. Here, due to the absence of green areas and low precipitation in the city of Lima, that value is not considered in the calculations. Therefore, the WF of Santa Rosa Hospital is summarized by calculating the grey and blue footprints. The blue WF equals the water consumption recorded by the 3 flood-rate meters. For the calculation of the grey WF, due to the lack of actual measurements of the effluent volume in the hospital, V_f is considered as a percentage of the recorded volume. 80% is the fraction of the recorded volume.

The effluent concentration (c_{efl}) is considered as 266.5 mg/L, a value obtained based on the information provided by the public hospital of Lima. The maximum concentration (c_{max}) is the maximum allowable value for the concentration of parameters established in the regulation provided by [6], which is 500 mg/L. The influent concentration (c_{afl}) is 3 mg/L. The reference concentration used for DBO5 comes from the Environmental Quality Standards (ECA) provided by MINAM (2017), which is 3 mg/L. All that was previously mentioned is summarized in the Table 2.

Table 2: Drinking water consumption at Santa Rosa Hospital from 2015 to 2022.

Characteristics	**Symbol**	**Value**	**Source**
Maximum concentration	c_{max}	500 mg/lt	[6]
Effluent concentration	c_{efl}	266.5 mg/lt	[7]
Influent concentration	c_{afl}	3 mg/lt	[8]

The natural concentration (c_{nat}) record is available from 2013 to 2016 in the annual statistical report (SEDAPAL, 2017). An lineal regression analysis is conducted to extend the data until the year 2022, as depicted in Figure 3.



Year	c_{nat}
2016	4.72
2017	3.56
2018	4.10
2019	4.04
2020	3.98
2021	3.93
2022	3.87

Fig. 2: Regression analysis for calculate natural concentration (c_{nat})

4. Results

Due to an impractical water consumption, a survey was conducted to assess the current state of the sanitation facilities in the hospital. A pre-audit was carried out concerning the current state of the sanitation facilities in the staff quarters located in different blocks, focusing on exploring the bathrooms in the staff quarters and barely usable sinks. This helped identify potential issues in facilities where there may be no replacement but repairs can be made to prevent water leaks. The WF is calculated by month and it is divided in seven groups within heat map as despite in the Fig.3.A dashed black horizontal line represents the beginning of the COVID-19. This map shows that red and green colors presents higher and lower of WF, respectively.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	1590	2440	2645	1684	1101	2642	2319	1985	2014	2209	1822	1460
2016	1508	736	1148	1637	1537	1107	1215	1144	1206	744	802	734
2017	838	767	1487	1297	2716	2376	3154	2665	1082	1566	992	1248
2018	3367	3283	2339	1938	1841	2554	2843	2614	2371	1988	2188	2080
2019	3172	3528	5762	4324	4297	3800	2433	1855	1822	2075	2332	2295
2020	2358	2633	2658	2391	3997	1988	1794	1852	2188	3884	3925	3873
2021	4169	4058	3646	2580	2225	2435	2793	1990	2163	2689	2249	3461
2022	3499	3771	3394	3005	5584	3907	3334	4527	2024	2594	2901	3233

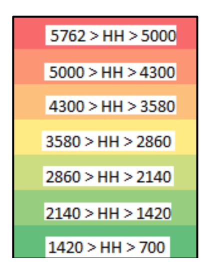


Fig. 3: Heat map of Water Footprint

4.2 Water resources Management of Santa Rosa Hospital

A management plan for sustainable water use is crucial in the hospital. After identifying the number of sanitation facilities, the monetary saving are calculated using the following equation:$\text{saving} = 2.516.\text{V}_{\text{water}} + 1.099.\text{V}_{\text{alcanta}}$. This equation shows the monetary saving in function the water volume. These calculations were obtained based on information from SEDAPAL. The water and sewer rates are derived from the data on SEDAPAL receipts, and the savings will be applied to the volume of water intake at the hospital. The table 3 shows the savings in water consumption at the hospital over period 2015 to 2022, there is a saving of S/. 43297 PEN in 2022.

Table 3: Savings in water consumption at the Hospital Santa Rosa over 2015 to 2022.

Year	Total savings (PEN)
2015	15019
2016	10783
2017	17380
2018	25311
2019	33371
2020	30235
2021	35711
2022	43297

4. Conclusion

The water footprint for Santa Rosa Hospital was calculated in the context of COVID-19, determined as the sum of blue and grey footprints. The blue footprint reflects water consumption behavior pre and post-pandemic. Results indicate a tendency for the calculated water footprint to increase over time, with an average annual growth of 5,300 m^3. A management plan suggests implementing water-saving devices in sanitation facilities, resulting in substantial savings, particularly by 2022.

This study identified critical points contributing to potential impacts linked to the water footprint in one of the three supplies, constituting 79% of the total water footprint. Furthermore, a correlation was observed between the economic aspect and changes in water footprint values, indicating improved resource management. Despite an increase in the water footprint during the COVID-19 pandemic, it is asserted that this rise is not significantly higher than the average value.

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