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Healthcare in the Time of COVID-19: An Environmental Perspective on the Pandemic's Impact on Hospitals

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Featured Application: Healthcare organisations should encourage the implementation of more environmentally friendly purchasing processes. The implementation of policies that improve hospital management and transform the working culture of healthcare professionals, orienting them towards an appropriate use of equipment and resources, will facilitate the adoption of measures that reduce hospital expenditure and their environmental impact.

Abstract: Hospitals have demonstrated their enormous capacity to adapt to the rapidly changing situation imposed by the pandemic: increasing the number of intensive care units and intermediate and inpatient beds, with the corresponding human resources, services and facilities required. Internationally, the enormous demand to manage the COVID-19 pandemic has challenged hospitals in terms of staffing, supplies and equipment. This article analyses the effect of the COVID-19 pandemic on hospital activities, from the perspective of its environmental impact. It compares a year of normal hospital activities, 2019, with data on hospital activities from 2020. The aim of this research is to analyse the changes produced by the pandemic in the regular activities of the hospital and to determine the environmental impact, which allows reflecting on the exceptional situation generated. The results show that the hospital's environmental impact increased significantly in 2020 compared to 2019, with a 17.2% increase in overall environmental efficiency indices. The main contributors to this increase were waste generation and medical gas consumption, which are critical aspects of hospital activities during the pandemic.

Keywords: environmental indices; government hospitals; environmental efficiency; LCA; public health

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1. Introduction

The emergence of the SARS-CoV-2 coronavirus hit the world population unexpectedly and left governments with the task of confronting an unusual challenging scenario. The huge spreading capacity of this disease and its global impact led the WHO, on 30 January 2020, to declare the outbreak of the new coronavirus a Public Health Emergency of International Concern (PHEIC) [1]. This new virus spread rapidly throughout the world. As a result, WHO declared COVID-19 a pandemic on 11 March 2020 [2]. As of January 2022, there were 364,741,509 confirmed cases and 5,649,533 worldwide deaths due to the COVID-19 coronavirus outbreak [3].

According to the Spanish Government's Strategic Plan for Health and Environment [4], the health crisis caused by COVID-19 placed public health protection at the centre of public concerns. For their part, both the United Nations Convention on Biological Diversity and the World Health Organisation have nonetheless recognised the interrelationship between biodiversity and human health.

Along the same lines, at European and international level, there are some initiatives, directives and regulations on the different environmental aspects that can affect health, with the aim of promoting healthy environments that help to achieve the population's health objectives. In this sense, preventive and protective measures have been proposed before, such as the 2015 Paris Agreement [5], under the United Nations Framework Convention, which set ambitious goals to combat climate change. Another case is the WHO's Draft Global Strategy [6], from 2018, on health, environment and climate change, promoting the necessary transformations to sustainably improve living conditions and well-being through the creation of healthy environments.

1.1. COVID-19 Lockdown and the Environment

In response to the pandemic caused by COVID-19, governments in all countries saw the need to adopt complex, extraordinary and forceful measures. Such was the nature of restrictions on the movement of people, the closure of schools, the quarantine of geographical areas, restrictions on international travel, or the reduction in productive and social activity to essential minimums, which was based exclusively on health criteria and the protection of human lives [7–9].

The decrease, and in some sectors, a total halt, in productive activities during the lockdown and the idling during the following months had a positive effect on atmospheric and biodiversity conditions, which up to that point had been the main victims of the prevailing model of social and economic development commonly associated with capitalism. In those countries that implemented full lockdown, energy demand was reduced by around 25% on average. In those areas with partial lockdown, however, this reduction was estimated at 18% on average [10]. These energy demand reduction values had not been seen for decades and, as a point of comparison, are estimated to be seven times greater than the demand reductions observed during the great recession of 2009.

This drop in the energy demand led to a worldwide reduction in CO_2 emissions. CO_2 emissions, in particular, are estimated to have declined by 8.8% in the first half of 2020 compared to the emissions from the first half of 2019 [11]. This amounts to approximately 2 billion tons of CO_2, equivalent to about two times the annual emissions of Japan [12].

According to the study by C. Le Quéré et al. [13], the lockdown measures considerably reduced travel, commuting and energy demand, thus revealing a reduction in daily CO_2 emissions by 17%. Similarly, NO_2 emissions decreased significantly in 2020 compared to the same period in 2019. Bauwens et al. [14] estimates reductions of 40% on average in Chinese cities, 38% in the United States and 20% in Europe [14,15]. These results suggest that the global lockdown, resulting from the terrible coronavirus crisis, had a positive impact on the environment.

In contrast, a recent EEA report proposes a more balanced view, highlighting that the coronavirus crisis has also led to a considerable increase in the global consumption of disposable plastic products [16].

Other researchers [17,18], have concluded that the coronavirus crisis had a worldwide economic impact as well as serious effects on people's health. On the other hand, they also highlight that the sharp increase in the consumption of plastics has a clear impact on the environment, which may endanger global environmental sustainability.

This pandemic has affected the way people behave in terms of consumption, leading to behaviours such as hoarding and panic buying [19]. In addition, there has also been an increase in the plastic packaging of products that previously could be sold in bulk or other packaging [20]. The pandemic has also led to an increase in the home delivery of food and other products. Products that typically use plastic containers for ease of storage and transport. Other products with a high plastic content that have also increased their consumption are gloves, masks or hydroalcoholic gels. In general, the pandemic has led to a significant increase in the use of plastics, with single-use plastic containers being the main source of plastic waste during the pandemic [21].

1.2. COVID-19 and Environmental Efficiency in the Hospital Sector

Healthcare organisations and workers have proved themselves to be crucial in responding to the COVID-19 situation. They are indeed a crucial and strategic factor in the fight against the pandemic, which had to be adapted and focused on a surge in the responsiveness of the health care system to treat people infected by COVID-19. Internationally, the enormous demand to manage the COVID-19 pandemic has challenged hospitals in terms of staffing, supplies and equipment [22]. Since the beginning of the pandemic, the WHO has made several announcements with recommendations on the use of face masks and other PPE (personal protective equipment) as part of transmission precautions for health workers caring for COVID-19 cases [23]. Along with these recommendations, the WHO made an estimate of the expected consumption of this type of protective equipment by healthcare workers. Specifically, it fixed values of 1.6 million goggles, 2.9 million hydroalcoholic gels, 30 million gowns and 76 million gloves needed each month to protect health workers worldwide [23]. According to WHO reports, these figures will affect the global supply chain, leading to a 40% increase in the medical protective equipment supplies.

Plastic material, found in a variety of personal protective equipment (PPE) (see Figure 1) and other disposable devices used in the medical industry, has been the main barrier to protect healthcare workers during the coronavirus crisis. The specific properties of plastic materials, such as good strength-to-weight ratio, as well as its versatility and durability, made it one of the most widely used materials in a variety of common healthcare equipment and systems [24].

Figure 1. Personal protective equipment (PPE).

The WHO recognises that it is essential to provide healthcare workers with the correct PPE, and in addition, it deems decisive to achieve this while paying attention to the environment and the impact that the consumption of PPE can generate. In this regard, a WHO report [25] recommends the use of waste management best practices to combine safety and sustainability in the use of plastic materials, both for the duration of the pandemic and in the case of other future crises that may require the use of similar protective systems. A consequence of the use of PPE is that they are considered infectious waste and are managed as such, as provided for in the information published by the different competent authorities on health care waste. The medical waste generated has increased exponentially due to the coronavirus crisis. For example, in the case of Wuhan, China, there has been a 600% increase, from 40 to 240 tonnes of medical waste per day. This added an extra 190 tonnes to the maximum available incineration capacity of 50 tonnes per day [26]. Similarly, all the worldwide hospital activity resulting from the pandemic has led to the production of hazardous waste, which in many cases came from PPE, which could thus be infected. Therefore, managing this hazardous biomedical waste is a vital aspect of dealing with the coronavirus crisis. This should include not only the usual waste treatment chain, i.e., identification, collection, segregation, storage, transport, treatment, and waste disposal, but also more specific components associated with the pandemic, such as the training of healthcare personnel or the disinfection of equipment and facilities [27].

Oxygen, on the other hand, has been officially treated as a medicine, and has been the basis for the treatment of SARS-CoV-2 pneumonia. The use of oxygen in healthcare settings has been considered a key element in the treatment of patients with severe forms of coronavirus. According to the World Health Organisation (WHO), 15% of COVID-19 patients (one in five patients) require oxygen. The oxygen supply system in hospitals has been overwhelmed by the pandemic, experiencing an extraordinary growth in demand in the face of the unstoppable growth in COVID-19 infections. In many countries, the medicinal oxygen demand has been higher than the availability.

Conversely, although overall energy demand declined in 2020, due to the lockdown and closure of non-essential sectors, hospitals, as an essential sector, boosted their energy consumption. The high demand for care, in order to treat COVID-19 cases as a priority, made the use of mechanical ventilators—and other electro-medical equipment permanently connected to the patient—a crucial need.

The above has revealed that, in recent years there has been a notable increase in the number of studies analysing the impact of the pandemic and its consequences on society and the environment [28–32]. Key topics have been the lockdown's effect on the environment, changes in product demand, plastic usage, and the subsequent increase in waste. However, no studies have been found that address the environmental efficiency of hospitals during the pandemic. This study provides evidence of the impact of the pandemic on the environmental performance of healthcare facilities. In a previous study [33], the authors developed a tool to reliably compare environmental performance in healthcare organisations, proposing environmental performance indices in the hospital sector. This tool makes it possible to calculate a global environmental efficiency index and 11 environmental indices according to impact categories such as GWP (global warming potential) or HTP (human toxicity potential). The starting point for this is the inventory associated with six types of consumption specific to hospital activity: natural resources, medical gases, waste production, waste disposal, transport, and products and materials. These inventory data are processed using the ReCiPe and CML-IA environmental impact assessment methodologies to obtain the different environmental efficiency indices.

For its validation, a regional hospital in Spain was used as a case study, analysing consumption during its healthcare activities in 2019. Furthermore, other authors have examined this tool as part of their initial review of existing literature in this field, subsequently developing their own system for multi-criteria evaluation in German hospitals [34]. Based on this index proposal, from the perspective of life cycle assessment, this research analyses the impact of the pandemic on the environmental efficiency indices, using consumption data for the year 2020.

2. Materials and Methods

This article uses a Spanish hospital as a case study, which belongs to the national public health system. Due to its location, in a small autonomous community, this facility provides care to about 80,000 inhabitants from approximately 30 nearby municipalities. All the healthcare activities are conducted with a staff of 550 employees and 80 available beds, as well as operating rooms, emergency, maternity, radiology, rehabilitation, day care, haemodialysis and intermediate care. In addition to these healthcare activities, the hospital also develops various lines of research, knowledge dissemination and teaching activities.

The hospital is distributed over several floors of 6800 m^2, with a total area of about 20,000 m^2.

The study aims to analyse the environmental impact of the hospital during 2019 and 2020, to compare the evolution of the environmental impact indicators in these years and to determine the possible effect the COVID-19 pandemic had on them.

2.1. Methodology

The methodology used for this study has been structured in the following stages (see Figure 2).

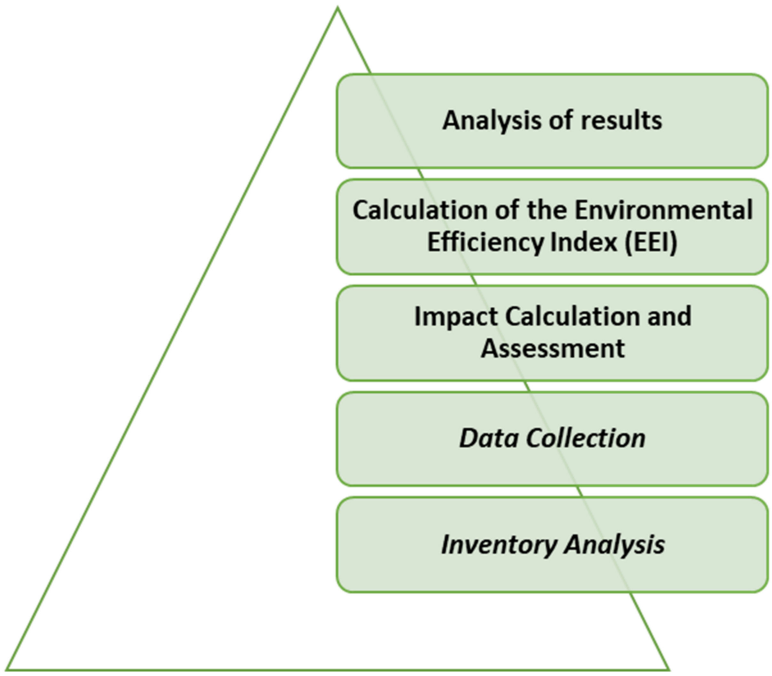

Figure 2. Research methodology.

2.1.1. Inventory Analysis

This stage of the study has been devoted to identifying and analysing the different environmental aspects involved in the activity under study. In this case, the direct and indirect environmental aspects derived from the hospital activities, during 2019 and 2020, were identified and evaluated from the perspective of life cycle assessment.

Figure 3 identifies and shows the environmental aspects considered in the study:

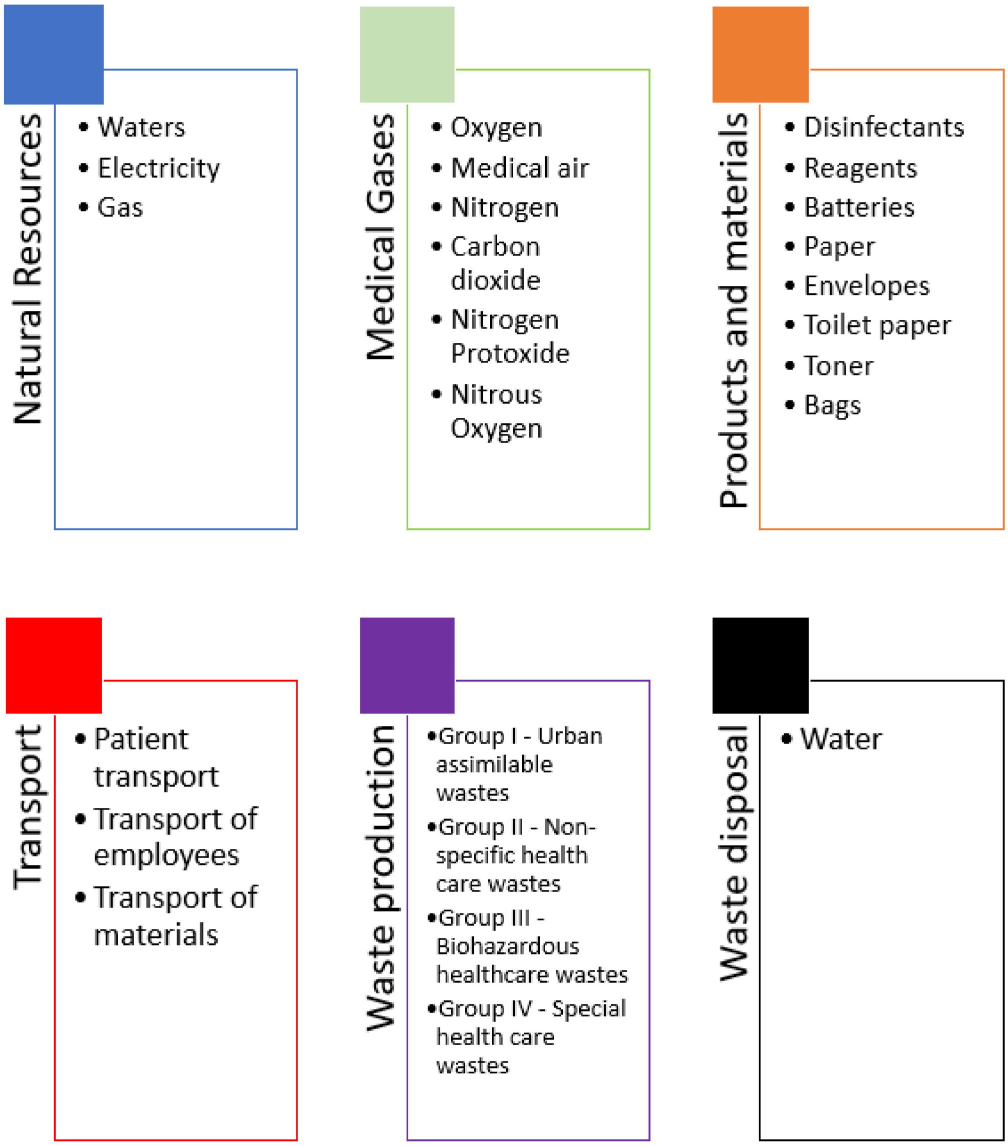

Figure 3. Environmental aspects considered in the study.

2.1.2. Data Collection

The next phase, after identifying and defining the environmental aspects to be analysed, is the compilation of all the information relating to them and their standardisation for subsequent processing. For this study, the data were collected, for 2019 and 2020, for each of the environmental aspects defined (see Table 1).

During the pandemic, the consumption of natural resources decreased. This is because standard hospital activity was affected during 2020. All scheduled surgical activities were suspended; consultations, rehabilitation activities and all non-urgent healthcare activities were cancelled.

In contrast, the consumption of medical gases and materials and the production of waste increased considerably in 2020. During 2020, healthcare mainly focused on patients affected by COVID-19. Medical gases, and more specifically medical oxygen, have been the most significant medicine for severe and critical COVID-19 patients.

Table 1. Environmental aspects inventory data for 2019 and 2020.

Item	Item	Unit	Quantity	
			2019	2020
Natural Resources	Water	m^3	29,917,000	27,129,000
	Electricity	MWh	2865.29	2785.74
	Natural gas	MWh	2767.35	1885.78
Medical Gases	Gas	m^3	60,123.54	64,193
Waste production	Waste	kg	179,991.49	204,239.49
Waste disposal	Water	m^3	29,038	26.919
Transport	Employees	km	6,648,422.4	6,925,440
	Patients	km	8,274,345.4	7,659,151
	Materials	km	37,101.6	39,063
Products and materials	Disinfectants	kg	2146.6	9541.25
	Reagents	kg	1323.2	873.1
	Batteries	kg	106.56	101.36
	Paper	kg	15,033	15,200
	Toner	kg	244.8	225.6
	Plastic bags	kg	5483	6369
	Masks	kg	456	5792
	Goggles	kg	4.8	966
	Gloves	kg	11,275.5	25,176
	Hats and stockings	kg	524	1305
	Aprons	kg	8	82

Waste generated during the care of a person infected or with symptoms compatible with COVID-19, such as gloves, masks, gowns, protective clothing and the like, are considered hazardous health care waste. In addition, all the waste generated during the cleaning and disinfection of potentially contaminated surfaces or because of the application of other hygienic measures in any place in contact with COVID-19 is managed as hazardous health care waste, according to the provisions of the regional regulations on health care waste.

The data obtained show an increase in the production of hazardous healthcare waste, with 92% of the waste generated in this hospital in 2020 coming from materials in contact or possible contact with COVID-19.

In addition, during 2020, the number of total patient trips to the hospital decreased compared to the previous year. In cases not affected by COVID-19, telemedicine measures were implemented to diagnose and provide care to patients in order to avoid travel and possible contacts.

With regard to the consumption of materials, it was the use of disinfectants that increased by an unprecedented amount. Environmental cleaning and disinfection procedures, together with the application of commonly used hospital disinfectants, have become essential and indispensable procedures to combat the spread of COVID-19.

2.1.3. Impact Calculation and Assessment

Finally, once the data were gathered, as the third phase of the study, the calculation of the environmental impacts was made.

The overall impact of the hospital activity is calculated using the ReCiPe method [33]. In addition, the CML-IA baseline V3.05/EU25 methodology is used to assess the environmental impact in the 11 impact categories listed below: AD (abiotic depletion), ADF (fossil depletion), GWP (global warming potential for a 100-year time horizon), ODP (ozone layer depletion), HTP (human toxicity potential), FWAE (fresh water aquatic ecotoxicity), MAETP (marine aquatic ecotoxicity), TE (terrestrial ecotoxicity), POCP (photochemical oxidant creation potential), AP (acidification potential), and EP (eutrophication potential).

The modelling of hospital activities has been performed with SimaPro v.9.1®. This software allows modelling a product or process throughout its life cycle and assessing the environmental and social impact associated with it.

2.1.4. Calculation of the Environmental Efficiency Index (EEI)

For each category and year, the different environmental efficiency indices [33] have been calculated and the results have been normalised, based on the specific hospital complexity unit (HCU) of each year and of the hospital under study:

$$EEI = \frac{I}{HCU} \quad (1)$$

where:

I = calculated environmental impact;
HCU = annual hospital complexity unit (annual activity).

3. Results

The results obtained are presented in two different ways. First, they appear as an overall value of the impact, and second, as detailed results presented for each year, in each of the eleven impact categories studied.

The overall efficiency indices calculated include all the environmental impacts derived from those defined in the inventory: natural resource consumption, medical gases, generated waste and its treatment, material consumption and transport.

In addition, the environmental efficiency indices are also presented by eliminating all the transports considered in the system; in other words, transport related to patients, employees and materials used in hospital activity.

3.1. Global Efficiency Indices

3.1.1. Single-Value Global Environmental Efficiency Index

Table 2 shows the value obtained, using the ReCiPe methodology, for the single-value environmental impact index, for each aspect analysed for 2019 and 2020.

Table 2. Global environmental efficiency index (2019–2020).

Item	GEEI 2019	GEEI 2020	% Variation
Natural resources	1.39×10^2	1.52×10^2	9.35%
Medicinal gases	2.91×10^2	3.74×10^2	28.52%
Wastes	2.99×10^3	4.43×10^3	48.16%
Discharges	1.69×10^2	1.90×10^2	12.43%
Means of transport used	2.21×10^4	2.68×10^4	21.27%
Transport of patients	3.48×10^4	3.91×10^4	12.36%
Consumption of materials	1.57×10^1	2.52×10^1	60.51%

The measurement of this index has resulted in a single-value representing the environmental impacts for 2019 and 2020

$$GEEI\ 2019 = 6.06 \times 10^4$$

$$GEEI\ 2020 = 7.10 \times 10^4$$

Obtaining these single-values facilitates the analysis and makes it possible to compare the environmental impact produced by hospital activity in 2019 and the impact of the COVID-19 pandemic on the same index, during 2020.

The resulting index obtained for 2020 shows the increase in the impact this hospital had on the environment, compared to 2019.

3.1.2. Environmental Efficiency Index per Category

The results obtained with the CML-IA methodology for the environmental efficiency indices in 2019 and 2020 are presented in detail in Table 3, for each of the eleven impact categories studied.

The results obtained show an increase in the environmental impact of the hospital under study as all indices have increased in 2020 compared to 2019, by an average of 9.42%.

For the index associated with global warming potential, $EEI_{GWP100a}$, a value of 6.80×10^2 was obtained in 2020, which represents an increase of 9.25% compared to 2019.

Amongst all the aspects analysed, the hospital waste production during 2020 represents the greatest increase in impact, with respect to the indices obtained in 2019. That is particularly valid for the EEI_{AD}, EEI_{ADF}, EEI_{ODP}, EEI_{POCP} and the EEI_{AP} indices, in which the contribution of waste production has increased by more than 100%, with respect to 2019. COVID-19 resulted in a doubled production of waste in the hospital in 2020. This translates into a significant change for both the internal hospital waste management and for waste management in the treatment plants. The environmental impact of healthcare waste during COVID-19 makes it clear that better, safer and more environmentally sustainable waste management practices are needed and, above all, good preparation for future pandemics is necessary. Banciu et al. [35] studied the impact of the pandemic on hospital wastewater and concluded that the increase in antimicrobial drug compounds had significantly changed the structure and dynamics of the microbial population in wastewater. In light of the pressing urgency to address environmental sustainability, some good practices to ponder are the use of environmentally friendly packaging, as well as the procurement of safe and reusable PPE (e.g., surgical gloves and masks) and recyclable or biodegradable materials. Quintana-Gallardo et al. [36] analysed the environmental impact of different types of hospital gowns and implemented a pilot circular economy model using non-sterile surgical gowns as the core element of the project. Likewise, one could add the investment in non-burn waste-treatment technologies, such as autoclaves and reverse logistics, to ensure that materials such as plastics can have a second life.

The consumption of medical gases has also been a contributing factor to the overall increase in all indices, increasing by 28.26% in 2020 compared to 2019. Medical gases, particularly oxygen, have been essential in the treatment of complications in people hospitalised with coronavirus. Oxygen is manufactured by an industry characterised by a high electricity consumption, as the main element in its production, which increases its environmental impact. Faced with this situation, the best solution would be to produce energy in a more sustainable way.

Patient transport was the only aspect that—in 2020—saw a reduced impact on all the indices studied. During the pandemic, the hospital's normal activities were reduced, relegating face-to-face activities and patient monitoring to a minimum due to the high demand for care of patients with possible COVID-19. As a result, most consultations and tests were cancelled in order to minimise patient travel and avoid contact with the hospital environment. In Spain, specific telephone numbers were made available to the public for consultation on COVID-19, in addition to the international emergency number 112. This possibility of virtual health contact became a very significant opportunity for patient relations. The possibility of non-face-to-face care reduces travel and sometimes represents an added advantage related to avoiding the need for family members or companions to request permission to leave their jobs for a few hours, which is a social or work-related advantage.

Table 3. Global environmental efficiency index classified by impact category (2019–2020).

Item	Natural Resources			Medical Gases			Waste Production			Waste Disposal			Transport Employees			Transport Patients			Consumption Transport Mat.		
	2019	2020	%	2019	2020	%	2019	2020	%	2019	2020	%	2019	2020	%	2019	2020	%	2019	2020	%
EEI_{AD}	4.42×10^{-6}	4.87×10^{-6}	10.18%	1.71×10^{-6}	2.19×10^{-6}	28.07%	6.06×10^{-6}	1.28×10^{-5}	111.22%	6.73×10^{-6}	7.56×10^{-6}	12.33%	2.69×10^{-3}	3.25×10^{-3}	20.82%	3.34×10^{-3}	3.34×10^{-3}	0.00%	7.51×10^{-5}	9.05×10^{-5}	20.51%
EEI_{ADF}	1.48×10^{1}	1.61×10^{1}	8.78%	3.30×10^{1}	4.23×10^{1}	28.18%	4.15×10^{1}	8.53×10^{1}	105.54%	1.39×10^{1}	1.57×10^{1}	12.95%	3.17×10^{3}	3.84×10^{3}	21.14%	3.95×10^{3}	3.94×10^{3}	−0.25%	2.58×10^{3}	2.35×10^{3}	−8.91%
$EEI_{GWP100a}$	1.35×10^{0}	1.47×10^{0}	8.89%	3.11×10^{0}	3.98×10^{0}	27.97%	1.43×10^{1}	2.64×10^{1}	84.62%	1.51×10^{0}	1.69×10^{0}	11.92%	2.31×10^{2}	2.80×10^{2}	21.21%	2.88×10^{2}	2.87×10^{2}	−0.35%	8.25×10^{1}	7.83×10^{1}	−5.09%
EEI_{ODP}	1.30×10^{-7}	1.42×10^{-7}	9.23%	3.14×10^{-7}	4.03×10^{-7}	28.34%	6.70×10^{-7}	1.47×10^{-6}	119.40%	1.07×10^{-7}	1.20×10^{-7}	12.15%	3.48×10^{-5}	4.22×10^{-5}	21.26%	4.33×10^{-5}	4.33×10^{-5}	0.00%	2.18×10^{-6}	2.75×10^{-6}	26.15%
EEI_{HTP}	7.08×10^{-1}	7.80×10^{-1}	10.17%	1.37×10^{0}	1.76×10^{0}	28.47%	4.57×10^{0}	6.31×10^{0}	38.07%	2.48×10^{0}	2.78×10^{0}	12.10%	2.02×10^{2}	2.45×10^{2}	21.29%	2.51×10^{2}	2.51×10^{2}	0.00%	8.32×10^{1}	7.50×10^{1}	−9.86%
EEI_{WAE}	8.15×10^{-1}	9.01×10^{-1}	10.55%	1.86×10^{0}	2.38×10^{0}	27.96%	2.51×10^{1}	3.00×10^{1}	19.52%	1.33×10^{0}	1.50×10^{0}	12.78%	1.30×10^{2}	1.58×10^{2}	21.54%	1.62×10^{2}	1.62×10^{2}	0.00%	9.14×10^{0}	9.88×10^{0}	8.10%
EEI_{MAETP}	2.08×10^{3}	2.30×10^{3}	10.58%	5.48×10^{3}	7.03×10^{3}	28.28%	5.92×10^{4}	5.87×10^{4}	−0.84%	2.14×10^{3}	2.40×10^{3}	12.15%	1.98×10^{5}	2.40×10^{5}	21.21%	2.47×10^{5}	2.46×10^{5}	−0.40%	3.18×10^{4}	3.40×10^{4}	6.92%
EEI_{TE}	1.39×10^{-2}	1.54×10^{-2}	10.79%	8.77×10^{-3}	1.12×10^{-2}	27.71%	1.90×10^{-2}	3.10×10^{-2}	63.16%	3.18×10^{-2}	3.57×10^{-2}	12.26%	3.57×10^{-1}	4.33×10^{-1}	21.29%	4.45×10^{-1}	4.44×10^{-1}	−0.22%	1.71×10^{-1}	1.99×10^{-1}	16.37%
EEI_{POCP}	4.06×10^{-4}	4.46×10^{-4}	9.85%	5.92×10^{-4}	7.60×10^{-4}	28.38%	5.66×10^{-3}	1.17×10^{-2}	106.71%	5.02×10^{-4}	5.64×10^{-4}	12.35%	5.88×10^{-2}	7.13×10^{-2}	21.26%	7.32×10^{-2}	7.31×10^{-2}	−0.14%	2.52×10^{-2}	2.52×10^{-2}	0.00%
EEI_{AP}	6.93×10^{-3}	7.66×10^{-3}	10.53%	1.62×10^{-2}	2.08×10^{-2}	28.40%	2.26×10^{-2}	4.77×10^{-2}	111.06%	1.30×10^{-2}	1.46×10^{-2}	12.31%	7.37×10^{-1}	8.94×10^{-1}	21.30%	9.18×10^{-1}	9.16×10^{-1}	−0.22%	2.72×10^{-1}	2.66×10^{-1}	−2.21%
EEI_{EP}	3.26×10^{-3}	3.60×10^{-3}	10.43%	1.04×10^{-2}	1.33×10^{-2}	27.88%	3.09×10^{-2}	4.90×10^{-2}	58.58%	4.05×10^{-2}	4.55×10^{-2}	12.35%	2.26×10^{-1}	2.74×10^{-1}	21.24%	2.81×10^{-1}	2.80×10^{-1}	−0.36%	5.92×10^{-2}	6.10×10^{-2}	3.04%

3.2. Study of Environmental Efficiency Indices of "Hospital Activity"

On the other hand, environmental efficiency indices have been calculated, excluding the environmental impact derived from the transport of patients, employees and goods. Calculating these indices will make it possible to show the real impact caused by hospital activity alone.

3.2.1. Single-Value Environmental Efficiency Index "Hospital Activity"

Table 4 shows the values obtained for the overall environmental efficiency indices specific to hospital activity.

$$\text{GEEI } 2019 = 3.60 \times 10^3$$

$$\text{GEEI } 2020 = 5.17 \times 10^3$$

Table 4. Single-value environmental efficiency index hospital activity associated with the hospital activities and services provided in 2019 and 2020.

Item	GEEI 2019	GEEI 2020	% Variation
Natural resources	1.39×10^2	1.52×10^2	9.35%
Medicinal gases	2.91×10^2	3.74×10^2	28.52%
Wastes	2.99×10^3	4.43×10^3	48.16%
Discharges	1.69×10^2	1.90×10^2	12.43%
Consumption of materials	1.49×10^1	2.36×10^1	58.39%

The calculation of these single-value global indices allowed verifying the 44% environmental impact increase the hospital will have from 2020 compared to 2019.

Waste generation and gas consumption during the coronavirus crisis are the aspects that have the greatest impact on the indices obtained.

3.2.2. Environmental Efficiency Index "Hospital Activity" per Impact Categories

Table 5 shows the environmental efficiency indices exclusively for hospital activity for each of the 11 impact categories analysed using the CML-IA methodology.

In this case, where the environmental efficiency indices typical of hospital activities have been calculated. For the global warming potential index ($EEI_{GWP100a}$), a value of 1.02×10^2 was obtained for 2019 and of 1.08×10^2 for 2020, which means an extra 5.59%. All the environmental aspects analysed have a substantial impact on this index, significantly highlighting the aspects related to consumption of materials and waste generation.

The consumption of materials in the hospital generates the environmental indices that affect the most in nine of the eleven categories studied. In some indices, such as the EEI_{ADF} and EEI_{HTP}, this consumption of materials can account for up to 90% of the total impact. It should be considered that some of these materials consumed in the hospital are toxic, e.g., disinfectants and cleaning products. During 2020, disinfectants were essential products to combat COVID, with the usual consumption rate increasing fourfold. The increase in the use of chemicals for disinfection requires an integrated management from purchase to final disposal, requiring a life cycle assessment of these products in order to select those that are effective and have a lower impact on the environment.

The results obtained indicate that the environmental impact indices increased in 2020, with the exception of the EEI_{ADF} and EEI_{HTP} indices, which reduced their value by 8.18% and 7.61%, compared to 2019 (see Table 6). This decrease is due to the reduction in the consumption of some materials such as reagents, batteries and toners. Reagents used in hospitals for pathological anatomy processes mainly include alcohol, xylene or formaldehyde. These products, whose consumption has a negative impact on the ADF and TPH categories, are used in the laboratory to analyse and process biopsy, cytology and autopsy samples. These techniques were reduced to a minimum during the pandemic in 2020, with the focus of health activities mainly on COVID-19.

Table 5. Global environmental efficiency indices classified by impact category without transport (2019–2020).

Item	Natural Resources			Medical Gases			Waste Production			Waste Disposal			Consumption of Materials		
	2019	2020	%	2019	2020	%	2019	2020	%	2019	2020	%	2019	2020	%
EEI_{AD}	4.42×10^{-6}	4.86×10^{-6}	9.95%	1.71×10^{-6}	2.19×10^{-6}	28.07%	6.06×10^{-6}	1.28×10^{-5}	111.22%	6.73×10^{-6}	7.56×10^{-6}	12.33%	7.22×10^{-5}	7.49×10^{-5}	3.74%
EEI_{ADF}	1.48×10^{1}	1.61×10^{1}	8.78%	3.30×10^{1}	4.23×10^{1}	28.18%	4.15×10^{1}	8.53×10^{1}	105.54%	1.39×10^{1}	1.57×10^{1}	12.95%	2.56×10^{3}	2.29×10^{3}	−10.55%
$EEI_{GWP100a}$	1.35×10^{0}	1.47×10^{0}	8.89%	3.11×10^{0}	3.98×10^{0}	27.97%	1.43×10^{1}	2.64×10^{1}	84.62%	1.51×10^{0}	1.69×10^{0}	11.92%	8.17×10^{1}	7.40×10^{1}	−9.42%
EEI_{ODP}	1.30×10^{-7}	1.42×10^{-7}	9.23%	3.14×10^{-7}	4.03×10^{-7}	28.34%	6.70×10^{-7}	1.47×10^{-6}	119.40%	1.07×10^{-7}	1.20×10^{-7}	12.15%	2.06×10^{-6}	2.06×10^{-6}	0.00%
EEI_{HTP}	7.08×10^{-1}	7.80×10^{-1}	10.17%	1.37×10^{0}	1.76×10^{0}	28.47%	4.57×10^{0}	6.31×10^{0}	38.07%	2.48×10^{0}	2.78×10^{0}	12.10%	8.29×10^{1}	7.34×10^{1}	−11.46%
EEI_{FWAE}	8.15×10^{-1}	9.01×10^{-1}	10.55%	1.86×10^{0}	2.38×10^{0}	27.96%	2.51×10^{1}	3.00×10^{1}	19.52%	1.33×10^{0}	1.50×10^{0}	12.78%	8.95×10^{0}	8.88×10^{0}	−0.78%
EEI_{MAETP}	2.08×10^{3}	2.30×10^{3}	10.58%	5.48×10^{3}	7.03×10^{3}	28.28%	5.92×10^{4}	5.87×10^{4}	−0.84%	2.14×10^{3}	2.40×10^{3}	12.15%	3.12×10^{4}	3.09×10^{4}	−0.96%
EEI_{TE}	1.39×10^{-2}	1.54×10^{-2}	10.79%	8.77×10^{-3}	1.12×10^{-2}	27.71%	1.90×10^{-2}	3.10×10^{-2}	63.16%	3.18×10^{-2}	3.57×10^{-2}	12.26%	1.70×10^{-1}	1.92×10^{-1}	12.94%
EEI_{POCP}	4.06×10^{-4}	4.46×10^{-4}	9.85%	5.92×10^{-4}	7.60×10^{-4}	28.38%	5.66×10^{-3}	1.17×10^{-2}	106.71%	5.02×10^{-4}	5.64×10^{-4}	12.35%	2.49×10^{-2}	2.36×10^{-2}	−5.22%
EEI_{AP}	6.93×10^{-3}	7.66×10^{-3}	10.53%	1.62×10^{-2}	2.08×10^{-2}	28.40%	2.26×10^{-2}	4.77×10^{-2}	111.06%	1.30×10^{-2}	1.46×10^{-2}	12.31%	2.69×10^{-1}	2.47×10^{-1}	−8.18%
EEI_{EP}	3.26×10^{-3}	3.60×10^{-3}	10.43%	1.04×10^{-2}	1.33×10^{-2}	27.88%	3.09×10^{-2}	4.90×10^{-2}	58.58%	4.05×10^{-2}	4.55×10^{-2}	12.35%	5.82×10^{-2}	5.56×10^{-2}	−4.47%

Table 6. Total global environmental efficiency indices classified by impact category without transport (2019–2020).

Item	Total		% Variation
	2019	2020	
EEI_{AD}	9.11×10^{-5}	1.02×10^{-4}	12.32%
EEI_{ADF}	2.67×10^{3}	2.45×10^{3}	−8.18%
$EEI_{GWP100a}$	1.02×10^{2}	1.08×10^{2}	5.49%
EEI_{ODP}	3.28×10^{-6}	4.19×10^{-6}	27.99%
EEI_{HTP}	9.20×10^{1}	8.50×10^{1}	−7.61%
EEI_{FWAE}	3.81×10^{1}	4.36×10^{1}	14.60%
EEI_{MAETP}	1.00×10^{5}	1.01×10^{5}	1.07%
EEI_{TE}	2.43×10^{-1}	2.86×10^{-1}	17.43%
EEI_{POCP}	3.21×10^{-2}	3.70×10^{-2}	15.39%
EEI_{AP}	3.28×10^{-1}	3.38×10^{-1}	3.20%
EEI_{EP}	1.43×10^{-1}	1.67×10^{-1}	16.59%

The EEI_{ODP} index increased by 28% in 2020 compared to 2019, being the index that increased the most during the pandemic. This result is mainly due to waste generation and the consumption of medical gases.

4. Discussion

This article analyses the effect of the COVID-19 coronavirus crisis on the different environmental efficiency indices studied in the hospital sector. The results were obtained by taking a regional hospital as a case of focus, analysing its hospital activities during 2019 and 2020 and evaluating the environmental impact of these activities.

The aim of this research has been to analyse the changes produced by the pandemic in the regular activities of the hospital and to determine the environmental impact, which allows reflecting on the exceptional situation generated.

The life cycle assessment methodology was used as the basis for the development of this research, by analysing the inventory, compiling the data and comparing the environmental impacts during the pandemic, in 2019 and 2020.

Hospital activity during the COVID-19 pandemic focused on the care of patients infected with the coronavirus, while continuing to care for other patients. This article shows the effect this change has had on the normal functioning of hospital activities from the perspective of its environmental impact. For this purpose, the life cycle assessment tool was used, as it provides a detailed analysis of the environmental impact of any process and serves as a reference for the development of strategies and decision-making, considering its environmental implications.

On the other hand, the pandemic provided a number of lessons learned for the future in terms of care practices, which also contributed to improving the environmental impact of hospitals.

Projects that had been worked on for a long time, such as telemedicine and telecare, became standard practice in healthcare within a few weeks, reducing bureaucracy and streamlining care in activities such as the renewal of electronic prescriptions.

Faced with insufficient resources and infrastructure, hospitals were forced to improve their care processes, allocating resources according to risk, redesigning services and streamlining the patient discharge process. These changes were forced by the pressing need for healthcare resources and made possible by the extraordinary efforts of healthcare professionals. Although it would be desirable for these circumstances to disappear as soon as possible, it should be analysed whether the effectiveness of the application of these improvements in healthcare practice, which were implemented during the pandemic, would compensate for their incorporation into routine practice, taking into account the lack of healthcare professionals at present or in the case of future epidemics.

The incorporation of new technologies in healthcare activity, in some cases with artificial intelligence, can benefit, among other things, the diagnosis of patients, favouring the reduction in time and an increase in the availability of resources.

The deployment and application of these practices can be favourable for both health purposes and the environment. An improvement of care processes, ensuring that medical or nursing visits are not used for otherwise purely administrative tasks, optimises care processes and also contributes to improving the environmental impact of the activities.

The COVID-19 crisis allowed hospitals to coordinate and organise themselves at high speeds to adapt to the new circumstances, ensuring that critical material is distributed rationally. Efficient management and use of resources, both human and material, must be maintained in order to optimise the use of resources.

The results show that the impacts arising from the transport of patients and workers, the consumption of materials and the production of healthcare waste were the most relevant for the environment. The healthcare system must be reinvented to transform it from a volume model to a value model. Reducing face-to-face visits—largely by taking advantage of technology—and in turn offering more effective and efficient care, will improve the conditions of the environmental and healthcare activities. The risk–benefit ratio for virtual healthcare during the COVID-19 pandemic changed enormously and all the existing barriers and bureaucratic processes were swiftly reduced. Therefore, this situation must be transformed into a great opportunity. Now is the time to take the great leap towards the incorporation of virtual healthcare.

The pandemic revealed that the traditional hospital-centric design of healthcare has much room for improvement and must evolve to become sustainable. The digital transformation of healthcare can empower people to access healthcare more efficiently, affordably and closer to home. The development of applications such as digital triage systems or remote patient monitoring can help lead this transformation.

Health transport must also evolve towards a progressive reduction in the emission of polluting gases and carbon footprint, adopting measures that favour sustainable mobility, such as increasing the use of electric, hydrogen or gas-powered ambulances. The optimisation of route management, linked to the activity of medical transport, could also be positive for the environment.

Another important aspect highlighted by the pandemic is the alteration in the dynamics of healthcare waste generation, especially that caused by the use of PPE. It is relevant to understand the impact generated by the materials used throughout their life cycle and to create strategies for the management and classification of this type of waste in order to reduce the environmental impact.

In relation to the above, another relevant aspect is to manage the purchase of sanitary materials, in a way that includes an environmental impact assessment or life cycle assessment. This will ultimately translate into reduced impact and improved environmental performance. Healthcare organisations should encourage the implementation of more environmentally friendly purchasing processes.

The implementation of policies that improve hospital management and transform the working culture of healthcare professionals, orienting them towards an appropriate use of equipment and resources, will facilitate the adoption of measures that reduce hospital expenditure and their environmental impact.

One of the possible lines for the continuation of this study is the analysis of the different COVID-19 variants and their effect on environmental impacts derived from pre-pandemic and pandemic hospital activity. This study analysed the changes produced in the environmental impact indices, generated by the different waves of the pandemic, which may lead to the need for the promotion of environmentally comprehensive and sustainable management that lasts over time.

5. Conclusions

This article analyses the effect of the pandemic on the environmental efficiency indexes of hospital facilities. The overall environmental efficiency index worsened during the pandemic by 17.2%. If the different indices are analysed by impact categories, an increase of 9.25% is observed in the EEIGWP100a. While other categories show increases of 11.7% (EEITE), 11.5% (EEIAP) or 11.4% (EEIPOCP).

These increases are even more remarkable if we specifically analyse the effect of the increase in hospital waste generated during the pandemic. In this respect, the EEIAD, EEIADF, EEIODP, EEIPOCP and EEIAP indices stand out, with values increasing above 100%.

These increases in all environmental efficiency indices during the pandemic demonstrate that traditional hospital-cantered healthcare system design needs to evolve in order to become more sustainable, for example, by undertaking a major digital transformation to make patients' access to healthcare more efficient, sustainable and closer to home.

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