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Effect of Healthcare Facilities on Climate Change: A Systematic Review of the Carbon Footprint of the Nigerian Healthcare Sector

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Climate change has continued to pose a global concern, as the resulting effect of the increase in greenhouse gas (GHG) emissions continues to have significant consequences on the planet and its inhabitants.
One of the major sectors contributing to the greenhouse effect is the healthcare sector, however, it is one of the sectors that has been overlooked and under reported.
Objective: This article aims at reviewing the carbon footprint of healthcare facilities in Nigeria and its impact on climate change, while highlighting important and effective strategies towards addressing it.
Methods: Data was obtained through a systematic review of available research articles obtained online via PubMed and Google scholar search engines, using the key words; climate change, healthcare facilities, global warming, and carbon footprint.
Results: Effective policy and regulatory frame works are essential towards addressing the carbon footprint of healthcare facilities; however a lot of gap still exists in curbing the effect of GHG emissions by healthcare facilities in Nigeria, as majority of healthcare facilities in Nigeria still rely significantly on the combustion of fossil fuels for generation of power due to its epileptic electrical power supply.
Conclusion: There is great need in addressing the effect of the carbon footprint of healthcare facilities on climate change. This can be achieved through the use of renewable energy technologies like solar and wind power, as well as the use of energy conservative measures such as the use of LED lighting and High-efficiency Heating, Ventilation, and Air Conditioning (HVAC) systems.

Keywords: Climate change; healthcare facilities; global warming; carbon footprint.

1. INTRODUCTION

Climate change is a global challenge that is driven by human activities, especially the burning of fossil fuels, industrial processes, and deforestation. The resulting increase in greenhouse gas (GHG) emissions has far-reaching consequences for the planet and its inhabitants, including rising temperatures, more frequent extreme weather events, and altered ecosystems [1]. One of the major under-reported sectors contributing to GHG emissions is the healthcare sector, particularly through its use of energy, transportation, and waste management [1].

Carbon footprint refers to the total amount of greenhouse gas emissions that are caused directly and indirectly by an individual or organization. In the case of healthcare facilities, this includes emissions from energy use, transportation, waste disposal, and the production and use of materials such as pharmaceuticals and medical devices [2]. Healthcare facilities in Nigeria are significant contributors to GHG emissions, and their carbon footprint has significant implications for climate change [2].

Nigeria has a population of over 170 million people with an estimated GHG of 492.44 metric tons (1.01% of the world's total). It is one of the world leading producers of bio-energy in the form of fuel wood, agricultural and forestry waste products, with oil, natural gas and biomass being the main source of energy, as less than 50% of the population have access to grid-connected electricity supply [3].

There has been a significant increase in energy emission over the years, mainly due to fuel combustion. The majority of Nigeria's GHG emission has been found to primarily originate through the land-use change and forestry (LUCF) sector as well as the energy sector, accounting for 38.2% and 32.6% respectively, while waste, agriculture and industrial processes contributes about 14%, 13% and 2% respectively [3]. Studies has shown that the global carbon footprint of the healthcare sector is estimated at 2.4 Gt of CO2; about 5% of total global emission [2]. The contribution of the Nigerian health sector plays a significant role through its cumulative energy, waste as well as industrial processes [2].

This review aims to examine the carbon footprint of healthcare facilities in Nigeria and explore methods in which the healthcare sector can reduce their contribution to climate change. It aims to highlight the importance of addressing the carbon footprint of healthcare facilities, while suggesting effective strategies to reducing it.

Data was obtained through a systematic review of 28 research articles obtained online via PubMed and Google scholar search engines, using the key words; climate change, healthcare facilities, global warming, and carbon footprint.

2. HEALTHCARE FACILITIES AND THEIR CARBON FOOTPRINT

2.1 Energy Consumption and Greenhouse Gas Emissions

In a study carried out to determine the energy indices for measuring energy consumption in Nigerian hospitals, it was found that an average hospital in Nigeria consumes energy as follows; a rural hospital building consumes 66.936kWh daily; an urban hospital building consumes 343.23kWh daily; a specialist hospital building consumes 454.872kWh daily while the average energy consumption of a teaching hospital building is 1,944.394 kWh daily. Lighting is responsible for 15%, 36%, 40.5% and 69.5% of daily energy consumption in rural, urban, specialist and teaching hospital buildings respectively [4]. Majority of Nigerian Hospitals rely majorly on the use of generators for generating electrical power [2].

Human activities contribute to the greenhouse gases present in the atmosphere through the burning of fossil fuel and carbon dioxide; they both increase the amount of heat present in air, adversely affect human health as well as the ecosystem [2]. Nigeria is one of the world's top producers and consumers of fossil fuels [5]. The air pollutants are known to have negative impacts on human health particularly on the children population due to their vulnerable state. Gaseous substances such as ozone and nitrogen dioxide can worsen respiratory infections such as asthma attacks. Other diseases such as cardiac death and lung infections can be attributed to greenhouse emissions [6].

2.2 Waste Management and Disposal

Healthcare wastes are materials generated by healthcare facilities such as hospitals, laboratories, research centers, autopsy centers and blood banks. They cover a wide range of substances such as infectious wastes, pathological wastes (fluids, human tissues), pharmaceutical wastes (vaccines) and radioactive materials. Only 15% of these wastes are considered hazardous and may pose risks to

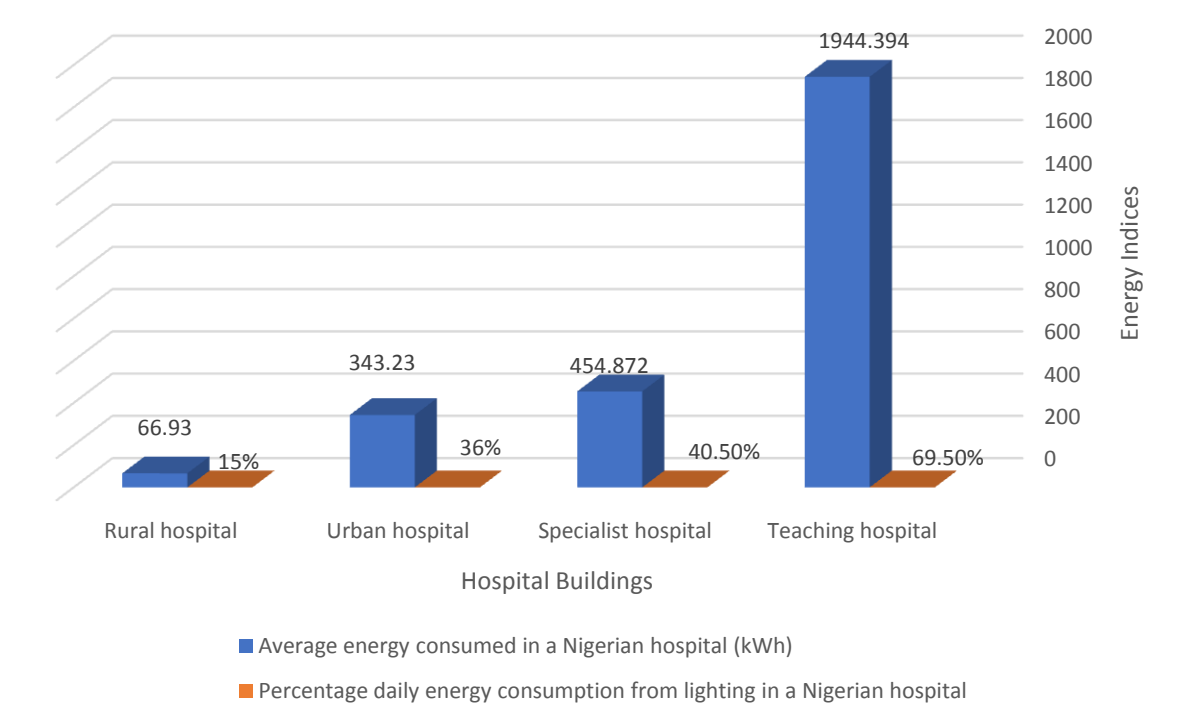

Fig. 1. Energy performance indices for hospital buildings in Nigeria.
Source: Nwanya et al., 2016 [4]

the people and environment while 85% are generally non-hazardous [7]. The World Health Organization has highlighted the proper guidelines of healthcare waste disposal which include; segregation, collection and storage, treatment and transportation, and of generation, segregation, collection, storage, transportation, treatment and disposal [8]. Incineration is the major method of disposal in Nigeria and this can pose health risks to the population if the appropriate technologies are not employed [9]. Some of the challenges of healthcare waste disposal in Nigeria include inadequate financing, lack of training and sensitization, unavailability of data, weak policy frameworks, and inefficient waste management methods [10]. The Mechanical Biological Treatment Technology is a low-cost technology that was specifically built for low and middle-income populations. This technology was designed to recycle wastes and convert them to energy available as fuel, and is ideal for a developing country like Nigeria [10,11].

2.3 Transportation and Supply Chain Emissions

The increasing rate of urbanization in Nigeria has led to more travel demands, which are highly dependent on automobiles. This has also resulted in more gridlock, hazardous gas emissions and numerous road injuries. Studies have shown that greenhouse emissions from automobiles account for over one million deaths globally. The transportation sector is largely responsible for the emission of greenhouse gases (GHG) and carbon dioxide which are toxic to human health [12].

2.4 Drivers of Carbon Footprint in Healthcare Facilities

2.4.1 Infrastructure design and building materials

The construction industry accounts for a significant proportion of the world's energy consumption and carbon emissions, of which the construction and operation of buildings represent 36% of the total final energy use, and nearly 40% of the greenhouse gas (GHG) emissions [13]. Consequently, minimizing the energy consumption and carbon emissions of buildings has great significance for environmental protection and sustainable development [14].

Each construction product has an impact on the environment. It is associated with all stages of a production, from raw materials through processing, manufacturing, distribution, use, maintenance, and recycling. The phase of producing these materials is characterized as initial embodied energy (acquisition of raw materials and production), indirect energy (energy transport costs) and direct energy (transport of finished products and assembly in the building). Considering the embodied energy, construction materials can be classified as.

- Low energy building materials (e.g. sand, gravel, timber, concrete)
- Medium energy (e.g., brickwork, lime, cement, mineral wool, glass)
- High energy (e.g. steel, zinc, copper, aluminum)

Rapid construction of healthcare infrastructure puts a great burden on the local and indigenous building material supplies and methodologies beyond their sustainable capacities [15]. Healthcare facilities can become environmentally sustainable by siting hospitals near public transportation routes, using local and regional building materials, planting trees on the site, and by incorporating design components like day lighting, natural ventilation, alternative energy source, water harvesting and green roofs [16]. The use of natural indoor ventilation is especially paramount as Nigeria has a tropical climate and air conditioning contributes immensely to the carbon footprint of hospitals especially in urban centers.

2.4.2 Medical equipment and technology

Recent studies carried out show the average carbon emission from medical equipment used in carrying out diagnostic investigations for patients [17]; the carbon footprint of an MRI scan is 17.5kg CO2 which is the same as driving a car for 145km, while the CO2 equivalent for a CT scan is 9.2kg CO2 which also translates to driving a car for 76km. Studies were also done on the much more common imaging tests like the X-rays and ultrasound machine. The X-ray had a carbon footprint of 0.76kg CO2, while that of the ultrasound was 0.53kg CO2; both were equivalent to driving for 6km and 4km respectively [17]. Blood tests were not left out and emitted 49g-116g per blood test, the figure is almost intangible but becomes substantial considering the hundreds of blood tests ordered for each day in health care facilities in Nigeria.

Dialysis is the most common means of renal replacement therapy for end stage renal disease.

Table 1. The average carbon emission from running medical equipment and diagnostic procedures

Medical equipment	Kg of CO2 equivalent	Metric tons of CO2 equivalent
MRI Scan	17.5kg	0.0175
CT Scan	9.2kg	0.0092
X-ray	0.76kg	0.00076
Ultrasound	0.53kg	0.00053
Blood tests	49g-116g	0.000049-0.000116

In Nigeria, as of 2018, about 3000 people were on haemodialysis and the number has continued to increase [18]. Dialysis is a power-hungry procedure and uses a large quantity of water and electricity. It also generates a lot of waste. In a typical 4-hour dialysis session, 240 liter of source water is required to prepare the dialysate [19]. It was estimated in one study that each haemodialysis treatment generates 2.5 kg of hazardous waste, of which 38% is plastic [20]. Another study reported up to 8 kg of waste per treatment, of which less than one-third was potentially recyclable [21].

2.4.3 Operational practices and management

Metered-Dose Inhalers (MDIs), which are used for the treatment of asthma and other respiratory conditions in Nigeria, use hydrofluorocarbons as propellants. These gases are highly potent greenhouse gases, with warming potentials between 1,480-2,900 times that of carbon dioxide [22]. The full global emissions from MDIs can be expected to be substantially greater than this figure, and while anti-asthmatics are included on the World Health Organization (WHO) essential medicine list, alternative delivery mechanisms to MDIs, such as dry powder-based inhalers, are available which provide the same medicines without the high global warming potential propellants [22].

Importantly, direct atmospheric emissions from inhaled anesthetics also make up a sizeable fraction of healthcare's total climate footprint. Wastes from anesthetic gases account for 2.5–3.0% of total carbon emissions of the UK's National Health Service [20]. Desflurane and nitrous oxide are the gases that make up most of the anesthetic footprint [23]. Several initiatives have already demonstrated significant reductions in facility-level GHG emissions, achieved simply through substituting sevoflurane for desflurane, as well as reducing fresh gas flow rates, and avoiding nitrous oxide usage [24,25].

2.5 Implications of Healthcare Facilities' Carbon Footprint

2.5.1 Impact on climate change and public health

The carbon footprint of healthcare facilities is an important issue that calls for concern and requires attention of both healthcare providers and policy makers. Carbon footprints of individuals and organizations around the globe are fueling the current climate change trend leading to enormous negative effects on human health and the ecosystem. The carbon generated by humans and their activities are heating the earth making it unsustainable and the evidence is well established in the literature [26].

Reducing the carbon footprint of healthcare facilities can have a positive impact on climate change and public health, while reducing financial costs and improving sustainability. Nigeria is a developing country with a population that is growing exponentially and has significant healthcare infrastructure deficit, which implies that healthcare facilities have a long way to meet the pressing needs of the growing population. Healthcare facilities in Nigeria depend largely on fossil fuels for power due to the epileptic power state in the Nation; the fossil fuels contribute largely to greenhouse gas emissions and climate change.

Nigeria is currently experiencing the effects of carbon emission from different industries including the healthcare systems especially hospitals, some of these effects include the rising of environmental temperatures especially in urban areas, leading to urban heat island effect causing heat stress, it can also lead to vector-borne diseases like Lyme disease and West Nile virus, droughts, and flooding which are all of public health concerns. The effects of climate change from carbon footprint can also lead to air pollution which can result from the use of fuels for heating, cooling, and electricity generation. The relationship between carbon footprint and public health is conceptualized as a continuous

cyclic interaction, continuously bringing troubles to man. Carbon footprint impact on public health can have direct or indirect effects. The direct impact of carbon footprints on public health was explored under five thematic areas, which are: impact on extreme weather events (hurricanes, storms, and floods), impacts on temperature, impacts to air pollution, impacts to water- and foodborne diseases, and impacts to vector and rodent-borne diseases, while the impact of a carbon footprint on the economy was seen as an indirect impact on humans and a huge change in human lives [27].

Exposure to air pollution can cause respiratory problems such as asthma and chronic obstructive pulmonary disease (COPD), also increase the risk of heart disease and stroke. Health facilities can contribute to water pollution through disposal of carbon waste in water bodies; it can affect the quality of drinking water and increase risk of waterborne diseases. Climate change effect on infectious diseases is complex and varied; alteration of ecosystem can lead to displacement of animal populations, which can cause shifts in the types of infectious diseases and additional measures to prevent spread of diseases like malaria and dengue fever.

2.5.2 Economic costs and benefits of reducing carbon footprint

Reducing the carbon footprint of healthcare facilities in Nigeria will have both direct and indirect economic cost implications. Direct costs will include the investment required to switch to methods that are energy- efficient like solar panels or wind turbines, retrofitting existing health centers and use of renewable energy sources. Indirect costs would include changes in operating procedures required to reduce carbon emissions. For instance, transitioning to a paperless system may require the implementation of new technologies, which could result in temporary disruptions to work flow [28].

A “Power Down” initiative in a hospital in the United States decided to turn off all anesthesia and operating room (OR) lights and equipment not in use which resulted in saving $33,000 and 234.3 metric tons of CO2 emissions reduced per year. Converting from soap to alcohol-based waterless scrub demonstrated a potential saving of 2.7 million liters of water annually. Formation of an OR committee dedicated to ecological initiatives can provide a significant opportunity to improve health care's impact on the environment and save money [29].

While these investments may be beneficial over time in reducing carbon footprint, climate change and public health burden, it represents a significant up-front cost. The reduction of carbon in health systems in Nigeria have potential benefits, which include investing in renewable energy technologies can create new jobs stimulating economic growth, reducing carbon footprint can help to mitigate climate change impact, leading to decrease in economic costs, such as damage to infrastructure, and better healthcare costs. There are also significant health benefits, by reducing air and water pollution reducing incidence of respiratory and cardiovascular disease, which can save lives and reduce healthcare costs.

2.5.3 Policy and regulatory frameworks to address carbon footprint in the healthcare sector

Effective policy and regulatory frameworks are essential to address the carbon footprint of healthcare facilities. In Nigeria, the National Policy on Environment and Health provides a framework for integrating environmental considerations into healthcare practices, including the reduction of GHG emissions. The Nigerian Energy Support Program (NESP) was also established in 2013 by the German Agency for International Cooperation (GIZ) to support the development of renewable energy projects and promote energy efficiency measures in various sectors, including healthcare [30].

2.6 Best Practices and Strategies for Reducing Carbon Footprint in Healthcare Facilities

2.6.1 Renewable energy sources and energy efficiency measures for reducing carbon footprint in healthcare facilities

Healthcare facilities can implement a range of strategies to reduce their carbon footprint. It has been suggested that implementing energy efficiency measures such as upgrading lighting and Heating, Ventilation, and Air Conditioning (HVAC) systems and using high-efficiency medical equipment can reduce energy consumption and carbon emissions [31]. Similarly, reducing waste and improving waste management practices such as recycling and composting can help to reduce carbon

emissions. Using more sustainable materials such as renewable plastics and biodegradable materials can also contribute to reducing the carbon footprint of healthcare facilities.

Encouraging sustainable transportation is another important strategy for reducing carbon emissions in healthcare facilities. This can include promoting cycling and public transport for staff and patients, as well as electric or hybrid vehicles for hospital fleets. Additionally, investing in renewable energy such as solar and wind power can significantly reduce the carbon footprint of healthcare facilities. It has also been suggested that healthcare facilities in developing countries like Nigeria can implement renewable energy technologies such as solar and wind power to power their operations. Energy efficiency measures such as upgrading to LED lighting and installing high-efficiency HVAC systems can also significantly reduce energy consumption and GHG emissions [32].

2.6.2 Sustainable waste management and recycling practices for reducing carbon footprint in healthcare facilities

Sustainable waste management comprises of various steps to ensuring safe disposal of waste generated from healthcare facilities. The steps involved include proper waste management, transport segregation, recycling and offsite disposal [33]. In most African countries including Nigeria, 90% of healthcare wastes are disposed by incineration which is associated with release of greenhouse gases into the atmosphere [34]. This can be averted by the use of air pollution control technology like biofiltration which is the biological removal of organic or inorganic air contaminants [35]. Alternative disposal methods of healthcare waste asides incineration such as autoclaving, thermal pyrolysis, microwave treatment, shredding and recycling can be adopted [36].

Recycling of medical waste is essential, as its plastic content is quite significant. This can help reduce the volume of plastic that will eventually be incinerated and result in the increase of the toxic greenhouse gases released in the atmosphere. Recycling of these plastics will also help in reducing the cost of their disposal, saving landfill space and preserving some of earth's natural resources [37]. Recycling of plastic waste can be in the primary, secondary, tertiary or quaternary forms. Only the secondary (mechanical) and tertiary (chemical) recycling methods are suitable for medical wastes [38]. Medical waste bottom ash following incineration can also be recycled into concrete for construction purposes [39].

2.6.3 Green transportation and supply chain management for reducing carbon footprint in healthcare facilities

Telemedicine contributes significantly to green transportation. If implemented, telemedicine has the potential to reduce the rate of patients' physical presentation to health facilities. Hence the volume of fuel burnt and greenhouse gases emitted reduces [40].

Some other forms of green transportation relevant to healthcare will include micromobility, and use of cable cars. Micromobility which involves bikes and scooters does not result in release of greenhouse gases [41]; and they can be used in the delivery of small and lightweight healthcare equipment. Drones can also be utilized to this effect as they are associated with limited amounts of carbon dioxide emission [42]. Implementation of cable cars as a mode of transportation of larger equipment and for ambulance services can also be useful in reducing fossil fuel consumption [43]. The barrier to the implementation of this will be the insufficient power supply in Nigeria.

Green Supply Chain Management is defined as ‘integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its use [44]. The principles of green package design- reduce, reuse and recycle, should be applied in the production of healthcare supplies. Substituting traditional raw materials with green and recyclable ones and in less quantity will reduce the eventual volume of waste generated and disposed [45]. Increasing the use of multiple-use medical devices rather than single-use ones, under effective sterilization technique and biogas plant installation in secondary and tertiary hospitals are important recommended green logistics practices [46].

3. CONCLUSION

Nigeria as a developing country has a healthcare system that still relies significantly on fossil fuels for power generation, due to its epileptic

electrical-power supply, contributing largely to greenhouse gas emissions and climate change.

The carbon footprint of healthcare facilities in Nigeria is an important issue that calls for concern and requires urgent attention of both healthcare providers and policy makers, as reducing the carbon footprint of healthcare facilities would have a positive impact on climate change as well as public health.

This review shows the importance of integrating sustainable waste management and recycling practices as well as the use of renewable energy technologies like solar and wind power in effectively managing the carbon footprint of healthcare facilities in Nigeria towards the regulation of climate change.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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