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Environmental Sustainability for Infection Prevention and Control (IPC) in Healthcare Facilities

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Abstract
The emergence of the novel coronavirus, increase in microbial resistance and the scarceness of vaccines for the present pandemic have made it imperative to appraise the link between the sustainable built environment and Infection control as well as the strategies employed during the pre-antibiotic period. This paper aims to identify the nexus between a sustainable built environment and infection control in healthcare facilities with the view of developing guidelines and highlighting the role of architecture in curbing the pandemic. The study relied on existing studies, interviews, and interactions with healthcare workers. The findings showed that sustainable design strategies play a significant role in infection prevention and control and could as well be a panacea for curbing the spread of Coronavirus, especially in healthcare facilities. A sustainable environment for hospitals or healthcare facilities, apart from low energy and carbon emission, needs to integrate design strategies to confront the impact of healthcare-associated infections.

Keywords: Control; Environment; Facility; Sustainability; Infection.

1. Introduction

Infection prevention and control (IPC) is a scientific process and hands-on solution intended to prevent harm or health dangers originated by infection to patients and health workers (Kim, 1998). Human health and well-being are intrinsically linked to a sustainable built environment. Therefore, the purpose of sustainable design is to find environmental design responses that promote the well-being and coexistence of inorganic elements, living organisms, and humans that make up the ecosystem (Van-Khai, 2016). In addition, sustainable environmental design is the adoption of efficient energy and material resource in buildings, incorporation of the dwellers into micro-climate control within the building, and the natural environment. Health care settings in an environment where both infected persons and persons at increased risk of infection meet or congregate. Existing studies and investigations have constantly established that the healthcare environment can be a reservoir for organisms with the potential for infecting patients. For example, a study conducted in Iran by Tajeddin, et al., (2016) supports that a contaminated environment is a risk factor for hospital-associated infections (HAI). Moreover, In the epidemic of widely drug-resistant tuberculosis which occurred in Tugela Ferry, South Africa, in 2006, the architectural design of the hospital building took a significant share of the blame (WHO, 2020). Although improvements have been seen in overall rates of infection prevention and control in healthcare facilities, there has been an increase in Intensive Care Unit infections caused by drug-resistant pathogens, particularly those that contaminate the environment· (Weiner, et al., 2016). Hence, the need to understand the nexus between infection control (IPC) and environmental design. According to a recent report by the center for disease control (CDC) with regards to the mode of Covid-19 mode of transmission and in collaboration with Lateef (2009), achieving a balance between the concept of open access design and the need for control measures to decrease the rate of infections is imperative. Van-Khai(2016) added that the goal of sustainable environmental design for healthcare facilities, apart from low energy and carbon emission, must integrate design strategies to mitigate the effect of infectious diseases. Investigations revealed that climate change and unstable climate do not only influence the built environment but play a key role in driving the global emergence, resurgence, and redistribution of infectious diseases (Wu, Yongmei, Zhou, Chen, & Bing, 2016).

Although there is the quest for more ventilators, Personal Protective Equipment (PPE), extensive behavioral change, professionals of all credentials need to come together to fight the COVID-19 pandemic. There is a paucity of effective and contextual design strategies to support infection control and make healthcare workers much safer. In developing countries, the magnitude of the problem remains undervalued or even unidentified mainly because health-associated infection (HAI) diagnosis is multifaceted and surveillance activities to direct interventions need expertise and resources (Allegranzi & Pittet, 2008). For instance, Infection Prevention and Control (IPC) have been a neglected area in many health care facilities despite many policies related to IPC in Nigeria (Federal Ministry of Agriculture, Environment and Health, 2017) , and available local studies only focus on handwashing as IPC strategy (Bishara, et al., 2019). Njuangang, Liyanage, & Akintoye(2018) added that with most of the research on this topic carried out by clinicians, the role of the healthcare environment in infection prevention and control is under-researched. This has made it tough for research on non-clinical or environmental aspects of healthcare topics to be published in clinical domains (May & Pitt, 2012). However, according to Nejad, Allegranzi, Syed, Ellis, & Pittet, (2011) the relevance of HAI studies has started to gain recognition in Africa. An Algerian study by Atif, et al.(2006) documented how the introduction of a prevention program at the facility level in 2001 reduced the overall hospital-wide prevalence of HAI over five consecutive years (2001–2005).

Therefore, the paper aims to examine how the space we occupy can be made safer from an architectural design perspective with the view of developing guidelines for policymakers and highlighting the architect's role in tackling the infections. The objectives include; to examine the evolution of medical architecture and the nexus between infectious diseases and architectural space and suggest design approaches for infection prevention and control (IPC). The study relied on existing works of literature, interviews, and interactions with health workers Without a doubt the present or current pandemic has revolutionized our thoughts with regards to design and planning of healthcare environment.

2. Material and Methods

The health care environment does not just describe the structure of the hospital but comprises or includes the fixed apparatuses within the facility with which health care workers, patients, and visitors interrelate being a share of the health care procedure (Zimring, et al., 2013) . The hospital environment serves as an ecological forte in which healthcare workers and patients as well might become infected with hospital-associated infections also known as nosocomial. The Centres for Disease Control and Prevention - CDC (2003) posited that the way hospitals are designed and built significantly affects rates of hospital-associated infections. Therefore, conceptual and empirical literature were reviewed to ascertain the link and evolution of the built environment and infection control.

2.1 Evolution of environmental design and Infection Control

The history of medical architecture spans many centuries. The evolution of medical architecture and infection control could be seen as comprising initial, formative, and advanced stages, corresponding to the pre-modern, modern, and contemporary eras (Njuangang, Liyanage, & Akintoye, 2018). According to Marlene (2015) and NCDC (2019), there exists a long-recognized relationship between healthcare and architecture, they added that the relevance of suitable building in the healing process is well known to both medical and architectural professionals.

In the early Middle Ages, hospitals were dominated by social functions as against medical, after the fall of the ancient states, owed to the low level of medical knowledge (Guenther & Vittori, 2008). Nevertheless, in Western Europe, between the 6th and 8th centuries, numerous hospitals were launched. Well along, the understanding of classical and Eastern healers began to infiltrate Europe around the 12th-13th centuries. The earliest chronicles of health-care in Egypt and Greece are knotted to spiritual tenets with priests and sanctuaries playing key parts in an attempt at disease identification, analysis, and care. Many of the early hospital designs resembled schools structured around a courtyard often located at the edge of villages or cities and monastic orders were the caretakers of the sick (Cameron, 2010; Tesler, 2018). A good example of such a building is "Schola Medica Salernitana founded in the 9th century under auspices of the monastic hospital in Italy" (Guenther & Vittori, 2008). Tesler (2018) added that until the 13th century, this institute remains the pioneering epicenter for training healthcare personals, scientists, and the issuance of practice licenses in Europe. Costeira (2015) posited that the aspect of the contemporary hospital was configured between the 17th and 18th centuries in Europe. This is evident in the Hotel-Dieu, one of the earliest and biggest hospitals in Paris in the mid-1700s. The facility depreciated to horrifying conditions. The facility was characterized by dark, poorly ventilated, unsanitary, and ward frequently located head-to-head to other wards with infectious patients. A commission was, therefore, set up to examine architectural design suitable to the circumstance, directing studies and researches to find a decisive solution to the hospital (Retief, 2006). The confluence of events, the outcome of the commission, and the notable works of Dr. Tenon gave birth to a solution to the problem known as the "pavilion" plan, which was first applied in the Hospital Lariboisiere built in 1854 (Burpee, 2008).

Another crucial factor that revolutionized medical architecture was the discovery of the transmission of germs in 1860 (Retief, 2006). This resulted in the isolation of disease and patients in particular pavilions. The work of Louis Pasteur confirmed the need to tackle infection and disease transmission, with the separation of patients and sterilization of medical devices (Costeira, 2015). These philosophies, isolation of pathologies, lead to a true revolution in medical architecture. The emergence of the pavilion model and the rise of scientific medicine coupled with the specific task of giving attention to the environment of healthcare gave birth to contemporary hospital architecture. Worthy of mention is Florence Nightingale (1820–1910) –born in Florence- Italy. Through her revolutionary activities in nursing, writing, and statistics hospital development was significantly influenced (Gormley, 2010). Her experience in the Crimean War (1853-1856), established bases for healthcare with pavilion models that provides ventilation, circulation of patients, lighting, and hygiene. This further enhanced patient recoveries and lessened the rate of infections. This model retained the multiple-patient ward concept, which was often called the Nightingale Ward, and is still applicable in today's practice.

Figure 1. Typical Nightingale Ward (Berche, 2012)

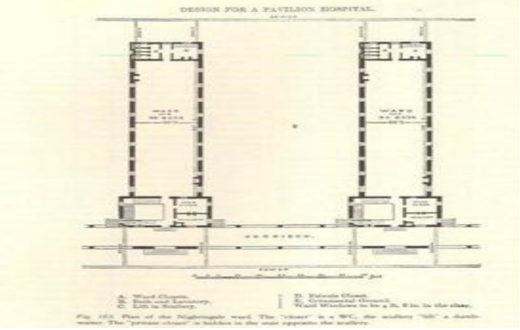

Figure 2. Pavilion model (Berche, 2012)

More studies on the works of Florence Nightingale revealed that in the military hospital in Turkey during the Crimean, the number of soldiers that died from Nosocomial infections (typhus, cholera, and dysentery) are than the number of soldiers who died as a result of injuries sustained in battle (Gormley, 2010). As a result of her discovery of the link between environmental/space factors and patients' healing, death rates were drastically reduced (from 42% to less than 3%) (Berche, 2012).

Interestingly, although the causes of diseases were primitively and non-scientifically explained, early healthcare practitioners and architects need to be applauded for establishing a nexus between the environment and the incidence of hospital-associated infections. According to Njuangang, Liyanage, & Akintoye (2018) to clarify the contagiousness of diseases, 18th-century physicians categorized 'bad air' into two groups: 'inanimate human contagions' and 'inanimate non-human miasmata. As reported by Alexander (1985) contagious stemmed from patients suffering from such diseases as smallpox and spread to those around them. Miasmata, on the other hand, were believed to originate from non-human causes such as swampy ground and to cause febrile diseases such as typhoid, malaria, and yellow fever. Alexander (1985) added that it was believed that the air contained unseen minute poisonous particles (miasmas) which when inhaled into the body can cause illness. This led to the consideration and emphasis on ventilation for new healthcare institutions (Platt, 1978).

Three epidemics of the recent past (TB, SARS, and CORONAVIRUS), to some degree, have some things to explain to us with regards to how architecture can be integrated into the fight against the spread of Coronavirus.

2.2 The Nexus Between Healthcare Environment and Infection Control

The Centres for Disease Control and Prevention - CDC (2003) posited that the way hospitals are designed and built significantly affects rates of hospital-associated infections. Interestingly, healthcare facilities in developing countries or low-income and medium-income countries are often not purpose-built and may have experienced wide-ranging changes in layout and clinical activity over the years (Ogunsola & Mehtar, 2020).

In the outbreak of Tugela Ferry, South Africa, in 2006, the hospital management reported that the health facility was not designed to handle airborne infection, rather it was designed with blood-borne infections in mind. As a result, it never had an airborne infection control policy at the time XDR-TB surfaced in patients (WHO, 2020). Such a report underscores the distinctive part architecture plays in contributing to healthcare delivery. Previous studies by Rubin et al., (1998), Ulrich, et al.(2008), and Jamshidi, Parker, & Hashemi(2020) posited that there are expressive suggestions that features of the designed environment have a significant influence on clinical outcomes for patients". Xiao, Jones, Zhao, & Li,(2019) used simulation to examine how Methicillin-resistant Staphylococcus aureus (MRSA) is transmitted across various surfaces in a medical ward in a Hong Kong hospital. Using graphics to illustrate the network in which MRSA travels, they found that apart from surfaces of the adjacent and the index patients, the public surfaces were found to have higher MRSA concentrations and these public surfaces are; surfaces of toilet door handles, toilet lids, the nurse station desk and the water dispenser. In another study by Rimi, et al. (2014) of a healthcare facility, high concentrations of airborne bacteria were found in densely populated locations such as the pharmacy, lobby, and other areas with densities of 0.5 to 1 cfu per m^{-2} of air inward areas and these concentrations increased in proportion to the number of people in the room resulting in a weightier bioburden. According to Ulrich, et al.(2008) and Kramer, Schwebke & Kampf(2006), healthcare centers could be a probable reservoir of nosocomial pathogens and such pathogens could have the ability to survive for a few days to several months. Such contaminated floors, walls in toilets, water taps, door handles, and rallies, could be potential spots for settlement of pathogens and transmission through hand contact of diseases such as cholera (Goh, Lam, & Ling, 1987), hepatitis A (Rajaratnam, Patel, Parry , Perry , & Palmer , 1992), vancomycin-resistant enterococci (Noble, et al., 1998) and puerperal fever

(Teare, Smithson , Efstratiou , Devenish , & Noah, 1989). For ease of understanding the nexus, it is important to appraise the modes of disease transmission in the healthcare environment.

2.3. Means of Infectious Diseases Transmission in Healthcare Environment

Transmission of Microorganisms in health care facilities is through several routes, and the same microorganism may be transmitted by more than one route. The five main modes of transmission are: The three (3) key methods of transmission are:

1. Airborne and Droplet;
2. Contact (Direct and Indirect);
3. Waterborne (Common Vehicle).

2.3.1. Airborne and Droplet

Built environments, such as homes, offices, schools, workplaces, hospitals, and transport terminals have potentially harmful pollutants (Currie, 2007). Airborne transmission happens when fine microbial particles comprising of pathogens stay suspended in the air for a long period, or dust particles containing the infectious agent and then are spread extensively by air currents and inhaled which may cause infection when a vulnerable person inhaling the infectious airflow (Lateef, 2009). Airborne transmission is very hard to control, this is because it requires the regulation of airflow through special ventilation systems. There is concern that the coronavirus is aerosolized, meaning, like the bacteria that causes TB, it can remain suspended in the air and be inhaled by susceptible persons. Viruses are small (20-400 nm), obligate intracellular parasites and they exemplify a common cause of infectious disease acquired indoors, as they are easily transmitted mainly in crowded, inadequately ventilated spaces or environments (Young, De Smith, Chambi, & Fin, 2011; Guiseppina, Marta, Simonetta, Marcello, & Michelo, 2013).

Droplet transmission occurs when viruses travel on relatively large respiratory droplets (> 10 µm) that people sneeze, cough, or exhale during conversation or breathing - primary aerosolization (Currie, 2007) and talking during the performance of certain procedures such as suctioning and bronchoscopy (Ministry of Health, Ghana, 2015). Guiseppina, Marta, Simonetta, Marcello, & Michelo (2013) added that a single cough in a corridor, lobby, or passage can discharge hundreds of droplets, a single sneeze thousand (up to 40 000) at speeds of up to 50-200 miles per hour, each droplet containing millions of viral particles. Droplet transmission is not the same as airborne transmission, droplets do not remain suspended in the air and aerosol droplets travel only short distances (1-2 meters) before settling on surfaces (Verreault & Moineau, 2008). For transmission to occur, the source and the susceptible host need to be within approximately 1 meter (3 feet) of one another (Ministry of Health, Ghana, 2015).

2.3.2. Contact or Surface Transmission

Contact or surface transmission is the most significant and most frequent mode of transmission of hospital-associated infection and can be categorized into two groups: direct-contact transmission and indirect-contact transmission.

Direct contact refers to a person-to-person spread of diseases through physical contact between an infected person or infectious agents including contaminated hands, gloves, or mucous membranes of the recipient (Lateef, 2009). Direct transmission can also occur between two patients, with one being the source of the infectious microorganisms and the other a susceptible host.

Indirect-contact transmission involves contact of a susceptible host with a contaminated intermediate object, often inanimate. Examples of such intermediate objects include contaminated instruments, needles, or dressings, or contaminated unwashed hands and unchanged gloves. Some organisms can live on objects for a short time. For instance, coronavirus (Covid-19) can live for 72 hours on a plastic surface, 24 hours on a cardboard surface, and a Copper surface for 4 hours (Verreault & Moineau, 2008). The implication is that, if you touch an object, such as handrails, doorknob, or handles, shortly after an infected person, you might be open to infection. However, transmission occurs when you touch your mouth, nose, or eyes before washing your hands.

2.3.3 Waterborne Transmission (Common Vehicle)

Common vehicle transmission applies to microorganisms transmitted by contaminated items such as Diseases related to water are classified into four groups: water-borne, water-washed, water-based, and water-related diseases (Baker, Stevens, & Bloomfield, 2001). Waterborne transmission is a highly effective means for spreading infectious agents to a large portion of the population. There are several water-related modes of transmission of infectious diseases. Large quantities of an enteric organism can be introduced into the aquatic environment through the discharge of infected persons’ feces into the sewer or unprotected waterways (Doremalen, et al., 2020). Secondly, infectious agents from bedridden infected persons can play a role in waterborne disease transmission because pathogens in soiled bedding and clothing may be released into the water during laundry activities (Gleick, 2002).

3. Results and Discussion

3.1. Design Strategies for Infection Prevention and Control

One of the ways space can promote or aid the inhibition of infectious diseases is when infection prevention and control concepts (IPC) are integrated into space conceptualization and designed process. This was first experimented with by Florence Nightingale, when she launched the hospital ward model, stated that natural daylight and cross ventilation are significant components to disinfect and lessen the infection occurrence in hospitals (Young, De Smith, Chambi, & Fin, 2011). Below are some design strategies to be employed in adapting our domestic, commercial, residential, and hospital spaces for infection, prevention, and control.

a) Design for social distancing

Provide adequate spacing in consulting rooms, waiting for areas, corridors, hallways, stairs, and entrance lobby to support social distancing or the safe distancing of at least 1,000mm apart as required by CDC. This will not only reduce contact transmission but will create safe distancing since current research reveals that aerosol droplets travel only short distances of 1,000mm to 2,000mm before settling on surfaces (Baker, Stevens, & Bloomfield, 2001). Corridors should be designed to discourage informal conversations by eliminating nooks with benches or ledge. The ledge corridor design was earlier introduced to hospital design by Carthey(2008) to encourage interactions among team members.

Avoid closed-end lobbies, waiting areas, double bank corridors, and other spaces designed with little or no airflow.

It has become obvious that corridor and lobby design considerations need to be reviewed to accommodate not only wheelchairs, crouches, trolleys, and beds but also safe distancing as required by CDC. As seen in figure 3, a corridor width of 1,500mm recommended by the UK Department of Health (UKDH, 2013)] is inadequate with regards to safe distancing within hospital space. Hence, this study suggests a minimum of 2,600mm width for corridors as analyzed in figure 4. This is to allow for 1,000mm minimum interval in social distancing and over 500mm as bilateral freeboards since human movement is not exactly in a straight line.

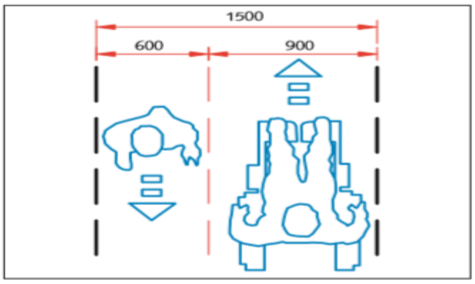

Figure 3. Corridor width as recommended by (UKDH, 2013)

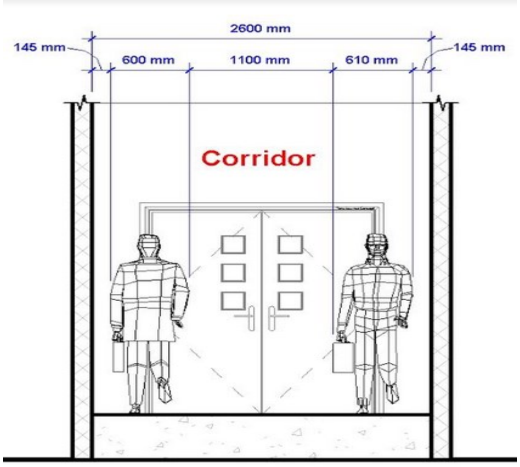

Figure 4. Suggested minimum Corridor width (Author)

b) Design to enhance natural ventilation

Ventilation is the movement of air within a space, often shaped by variance in air pressure. Ventilation is very critical in mitigating nosocomial and other infectious diseases. Ventilation procedures are well-defined in terms of air volume per minute per occupant and are based on the hypothesis that occupants and their actions are accountable for most of the contaminants in the conditioned space (HEB., 1997) . Ventilation rates for health-care facilities are often expressed as room ACH (Air Change per Hour). Peak efficiency for particle removal in the air space occurs between 12 ACH–15 ACH (Nath, et al., 1994; Hermans & Streifel, 1993; Memarzadeh & Jiang, 2000). Recent studies have shown that an appropriate ventilation rate can effectively decrease the cross-infection risk of airborne infections in healthcare facilities and public spaces (Zhao, Zuo, Wu, & Huang, 2019; Hua, et al., 2010). Natural ventilation can provide a higher ventilation rate than power-driven ventilation in an energy-efficient manner. A study of isolation wards in Chinese hospitals revealed that those with a high percentage of openable openings were found to be better in preventing the plague of SARS among health workers than other available designs (Wang, et al., 2003) . The ventilation rate requirement-ACH by CDC is 12ACH (Ninomura & Bartley, 2001), the implication is that when the ventilation rate increases, the infection risk would be significantly reduced.

A Study by Hua, et al., (2010) revealed that the decay of droplet nuclei concentration is significantly influenced by ventilation rate. Hua, et al.(2010) with the concentration decay equation, observed that it requires 20 min to lessen the concentration to 1.8% with 12 ACH, on the other hand only 10 min with 24 ACH.

In another study, Escombe, Eduardo, Victor, Manuel, & David (2019) adopted the carbon dioxide tracer-gas technique to analyzed the pre-and post- modification scenarios of a room. The aim was to examine the change in TB transmission risk in the consulting room and waiting room. The result indicated an average 72% decline (interquartile range 51–82%) in estimated TB transmission risk for patients and healthcare personals. Thus, adequate ventilation could be a panacea for curbing the spread of infectious diseases such as covid-19 in hospitals, schools, offices, and other public spaces. Moreover, providing clean, filtered air (High-Efficiency Particulate Air filters - HEPA) and efficiently controlling indoor air pollution through natural ventilation are two vital features of maintaining good air quality. According to Anjali (2007) HEPA is at least 99.97% efficient for removing particles ^{3}0.3 µm has proven effective in stopping the occurrence of infection among immunocompromised and high acuity patients.

Also, the study suggests the following design measures;

- Adequate cross ventilation in healthcare facilities is necessary.
- Corridors should have an open end to ensure an appropriate ventilation rate as shown in figure 5. As much as possible, corridors or hallways with a closed end should be avoided. Provide an upper ventilation window on the dividing wall in the hallway and a ventilation louver on the doorstop to lessen hot air circulation.
- Integrate the courtyard design to establish a cohesive ventilation passage, use the courtyard space as the ecological interchange space, conduct overall design on building structure layer/open space and create an integrated ventilation channel to enable the natural ventilation of hospital building as shown in figure 6. The design approach (open-end corridor and court-yard) increases ventilation rate (ACH- air change per hour) thereby reducing the risk of infection significantly. Where natural ventilation is inadequate, mixed-mode (Hybrid) approach and approved mechanical ventilation should be adopted.

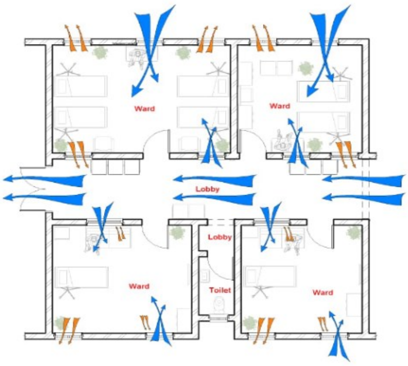

Figure 5. Example of Open-end Corridor

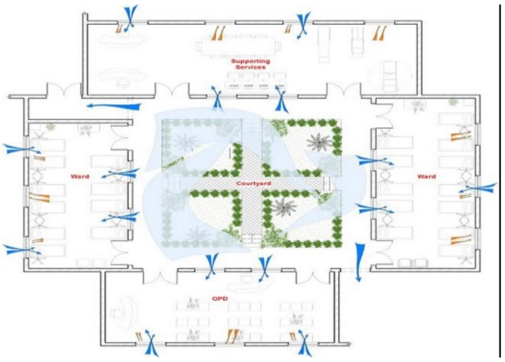

Figure 6. Example of Court-Yard approach

However, there is no proof that mechanical ventilation has aided the spread of infection in houses even though a wide variety of micro-organism is said to have been found in vent outlets (Escombe, Eduardo, Victor, Manuel, & David, 2019).

c) Design to Enhance Daylight or Sunlight

There are indications that good fenestrations and daylight in structures can sway the spread of airborne pathogens. The average annual temperature of tropical West Africa rainforests is above 20 °C with lots of sunshine (about 12 hours of sun a day) due to their location around the earth's equator. Evidently, before the advent of antibiotics, ventilation, and sunlight were thought to be significant safety measures against infectious diseases (Nightingale, 1868). Solly (1897) added that direct sunlight through glass may well kill bacteria bacillus in a few minutes or hours subject to the thickness of the layer of bacteria exposed, moreover, diffuse sunlight found near windows in buildings may well kill bacteria in five to seven days. Advanced studies indicated that sunlight can kill a variety of bacteria such as anthrax, tuberculosis, etc. (Hockberger, 2000). A more recent study by Strong(2020) posited that a diffused sunlight or daylight over two layers of glass from a north window was discovered to be very effective in killing hemolytic streptococci within thirteen days without antibiotics, with the similar strain surviving in the dark, at room temperature for one hundred and ninety-five (195) days. Another study by Yajia, Li, Zhang, & Liu(2020) found a potential relationship between latitude (as an indicator of sunlight) and vitamin D standing, and the number of COVID-19 cases and associated mortalities. Daylighting is a good germicidal factor and can inhibit infection (Lateef, 2009). Lytle & Sagripanti (2005) added that sunlight or, more specifically, solar radiation (UV) acts as the principal natural virucide in the environment. The standard for measuring daylight or sunlight is UV index and the germicidal effectiveness of UVC peaks at about 260-265nm (Rauth, 1965; Ayse & Sanlidag., 2020). It is important to note that the most effective and commonly used wavelength for ultraviolet germicidal irradiation (UVGI) is ultraviolet C (Kowalski, 2009). Unfortunately, only a small percentage of it reaches the Earth's surface as most are absorbed by the ozone layer (Pozo-Antonio & Sanmartín , 2018). It simply follows that as part of infection prevention and control, there should be adequate openings that will allow daylight into hospital wards, rooms, offices corridors, stairwell, and balcony. Designing buildings with better exposure to sunlight and outdoor air may inhibit the survival and transmission of infectious diseases with resulting in health benefits for dwellers.

d) Design with adaptive finishing materials

Surfaces in healthcare facilities such as floors, walls, door handles, etc. are very critical in infection prevention and control strategy. Recent studies on coronavirus(covid-19) suggest that the virus behaves differently and possesses different life span with different material surfaces. A study by Doremalen, et al.(2020), shows that coronavirus is steadier on plastic and steel (up to 3 days) than on spongy fabrics like cotton, leather, even cardboard (<24 hours) while the same strain of the virus only survives for four (4) hours on copper surfaces as seen in figure 8. Thus, architects must rethink the material selection process, material specification writing, and treatment of surfaces. An earlier study by Nightingale(1868) revealed that the plaster used in construction, which has many tiny voids, was believed to be the breeding zone and spread of pathogenic elements.

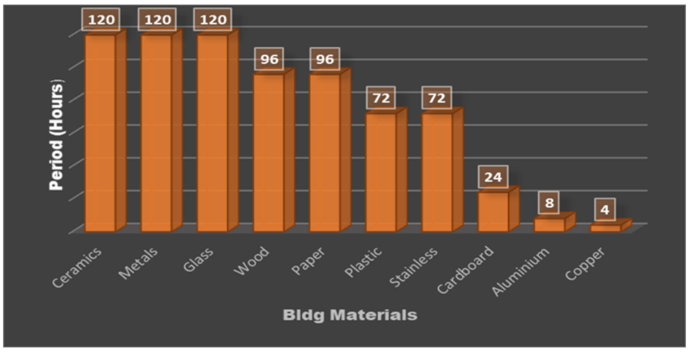

Figure 8. Coronavirus survival on different surfaces. Source: (Singh, 2021)

Based on the above findings, the study proposes the following;

I. Specify Copper-infused or plated materials for frequently touched surfaces such as staircase handrails, balcony rails, bed rails.
II. Design and situate sinks to enhance ease of cleaning and to prevent waste from spilling into sensitive care areas.
III. Plaster with a mixture of de-coagulant in cement screed for high solidity and smoothness. Apply POP screed after plastering with cement to enhance smoothness and eliminate tiny voids on the wall surface or use covering materials such as special paints, use of textured paints with fine sand should be discouraged.
IV. Entrance doors and curtains to hospitals and public spaces with high traffic should be designed with sensors to enhance automatic opening and closing. This will drastically reduce contact with the doorknob and hence prevent transmission.
V. Multiple entrances into public spaces should be minimized, this is to enable effective monitoring of compliance to CDC rules.
VI. Sinks with motion sensors also eliminate some possibilities of transmission. Controls and equipment should be specified with a smaller number of flat surfaces where particles can land as well as negligible crevices and crannies where debris can gather.
VII. Reducing the number of horizontal surfaces such as ledges can help reduce the spread of infection.

e) Flexible design with sustainability features.

Provide well-organized and sufficient workspace to carry out medication-related tasks. The design should not be rigid. But should be flexible enough to match with the changing health care demands and respond to up-to-date regulation from healthcare equipment manufacturers /providers and healthcare regulators. It is important to know that the ordinary existence of doors and windows is no assurance that they will be frequently used to enhance air movement as hospitals cannot automatically keep windows open during unfavorable climatic circumstances (Aikinson, Chartler, & Pessoa, 2009; Hobday & Dancer, 2013). Hence, a flexible design should be able to adapt to changes and accommodate new challenges such as the novel covid-19 pandemic.

The emergence of the novel coronavirus, increase in microbial resistance and lack of a vaccine for the present pandemic have made it imperative to appraise the preventive strategies employed during the pre-antibiotic period (Gould, 2009). It is even more urgent as bioterrorism now poses an additional possible threat to public health indoors (Wallin, Lukslene, Zagminas, & Surklene, 2007; Fleck, 2003). Moreover, the modern architectural practice of designing healthcare buildings or hospitals for comfort and aesthetics favors pathogen persistence (Ayse & Sanlidag., 2020).

4. Conclusion

The paper surveys historical and contemporary proof supporting the influences of key design strategies -natural ventilation, daylight, and antimicrobial building materials in decreasing the threat of infection in healthcare facilities. The evolution of medical architecture, the connection between infectious diseases/architectural space, and suggested design and material specification approach for infection prevention and control (IPC) were considered.

Studies reviewed suggested that viruses are a common cause of infectious disease acquired indoors, because they are easily transmitted, particularly in crowded, poorly ventilated environments. Building materials were found to be significant in infection prevention and control hence, rethink material selection and treatment of surfaces. Use non-porous surfaces (e.g., stainless steel, plastic, composites) for infection control and ease of cleaning. Although the relevance of studies on hospital-associated infections (HAI) has started to gain recognition in Africa a change of culture is essential not only to respond to the understanding of the design process as set out in the building code but also to ensure that the planned and active participation of infection control teams in the entire design process, construction of new and refurbished healthcare facilities.

Design strategies can play a significant role in infection prevention and control (IPC). With the present effort to contend with the coronavirus (Covid-19) outbreak, it has become necessary that a multidisciplinary approach be adopted. It also proposes that architects, engineers, and allied professionals directly involved in designing or constructing healthcare facilities should be given a form of training in public health. This is because buildings designed with more or less daylight access could play a key role in influencing the microbial communities of indoor dust. Architects must rise to play their role in curbing the spread of coronavirus. This can be achieved at the early stage of design, specification writing, and construction. Daylight should be integrated into lighting design in hospital buildings, not only because it helps inhibit bacterial and virus infections but also because it will remove the need for artificial lighting, subsequently lead to energy conservation and contribute to environmental sustainability. Although UVC is the most effective wavelength for infection control only a small percentage reaches planet earth. The implication is that more daylight is needed in healthcare facilities, schools, and indoors. The paper also suggests the use of special ultraviolet radiation systems (ultraviolet Clamps, chambers) especially in healthcare facilities where sunlight cannot be guaranteed.

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Conflict of Interests

The Authors declare no conflict of interest.

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