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Killing the Planet but Saving the People: How the American Healthcare Industry Impacts the Environment

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KILLING THE PLANET BUT SAVING THE PEOPLE: HOW THE AMERICAN HEALTHCARE INDUSTRY IMPACTS THE ENVIRONMENT

By

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Thesis Summary

The American population is rapidly growing and aging. In order to accommodate such a large population and its associated challenges, the healthcare industry has had to continually expand and adapt. The United States healthcare industry is now one of the largest, most expensive components of the economy. As such, it produces vast amounts of waste. Healthcare waste can damage the environment and contribute to climate change, which in turn can contribute to worsening health outcomes in the population. This thesis aims to explore both the immediate and prolonged impacts of the American healthcare industry on the environment, as well as provide insight into possible remedies for current practices. It consists of a literature review conducted through the University of South Carolina library databases. It identifies various sources and types of waste produced by the healthcare system and links that waste to its environmental impacts. Additionally, this thesis compares the United States healthcare system to other countries in order to identify possible interventions that could reduce the industry's contributions to climate change.

Introduction

The United States healthcare system is one of the biggest industries in the nation. In fact, at 18% of GDP spent on health expenditures in 2017, the United States spends more than twice the average of other developed nations on healthcare (Committee for a Responsible Federal Budget [CRFB], 2018). The nation's healthcare spending continues to grow as a function of price, population, and demand. Expenditures can encompass costs such as workforce, resources such as linen and bedding, location, technology, pharmacy, and food (Moses et al., 2013). The healthcare system has had to continually expand to meet the demands of a growing population and an increased life expectancy. As a developed nation, the United States has undergone an epidemiologic transition, meaning the population has shifted from experiencing primarily infectious diseases to more chronic diseases. Chronic conditions, such as heart disease or asthma, cost more to treat and require long-term care, further contributing to healthcare expenditures. In addition, the United States healthcare system operates with a heavy emphasis on tertiary care. Because this approach focuses on treatment through drugs, surgery, or other tertiary measures, relatively little funding is targeted towards preventing the development of disease (Rice et al., 2013). As we work to increase resources dedicated to primary care, we will see a decrease in the effects of chronic disease. Prioritizing preventative care means encouraging a healthy lifestyle. A healthy environment plays an essential role in a healthy lifestyle, which presents an obligation to the healthcare system to preserve the environment.

Climate change is often attributed to the production of greenhouse gases. As of 2018, human activities have pushed carbon dioxide concentrations above 400 parts per million (ppm), leading to an increasing global average temperature (Wheeler & Watts, 2018). Direct effects of an increased temperature include extreme weather, changes to precipitation patterns, and disrupted environmental processes. Humans, as well as every other organism on the planet, are dependent on the natural environment for air, water, and food. As we continue to damage the earth, we directly threaten everything we need to survive. Scientists have identified three main ways that climate change will impact human health; these include a rise in extreme weather events, altered patterns of disease transmission, and disruptions to food supply. An increase in frequency and intensity of extreme weather events, such as heat, drought, and hurricanes, directly threatens the health and well-being of every human on earth. (Wheeler & Watts, 2018). Within the first months of 2021, the United States has already faced extreme weather such as an unprecedented snowstorm across the Midwest. The significant loss of power and heat during this winter weather has highlighted the fragile infrastructure that is unprepared for the effects of climate change. Families were forced to ration oxygen tanks for their premature babies and the elderly, and many communities who rely on electricity for their stoves could not boil water to make it safe for drinking (Zdanowicz, 2021). This is a public health emergency, and its effects are both immediate and long-lasting.

Another way climate change will affect human health is seen through altered patterns of vector-, water-, and food-borne diseases (Wheeler & Watts, 2018). As temperate climates begin to heat and formerly warmer areas cool off, vectors such as mosquitos migrate and bring malaria and other diseases to new places. Many scientists now attribute the COVID-19 pandemic to climate change, and warn that this is only the beginning of the new infectious diseases we will face. Lastly, climate change has the potential to disrupt the social institutions that provide reliable access to resources such as food. This instability can contribute to a rise in undernutrition, mental health problems, violence, and conflict. Some demographics are particularly vulnerable, including children, elderly, and low-income communities (Health Care Without Harm, 2021).

As the healthcare system prepares to treat more populations impacted by climate change, it is important to also consider the role of the healthcare system itself plays in climate change. The healthcare industry is such a large contributor to climate change that if it were its own country, it would be ranked 13th in the world for greenhouse gas emissions (Eckelman & Sherman, 2016). Furthermore, US healthcare services generate millions of tons of waste each year. This can include hospital, medical (regulated and non-regulated), infectious, pathological, and hazardous waste (Burke & Ester, 1994). Hospitals and other clinical settings use vast amounts of energy and water per unit areas, produce tons of plastic waste from sterile and single-use packaging, and dispose of bodily fluids and other chemicals and solvents (Molero et al., 2021). Without proper waste management, there is a risk of contaminating the environment and damaging resources such as fresh water sources and food supplies. However, waste management presents its own set of unique problems. For example, incinerating medical waste can keep harmful chemicals out of the water supplies intitally, but the toxins then enter the atmosphere as carbon dioxide and eventually are absorbed by the oceans (Davies & Lowe, 1999). Because of the sheer mass of waste produced, no realistic solution to safely and efficiently process all of the waste produced by the United States healthcare system exists. It is therefore important to adopt a preventative philosophy for managing the healthcare sector in order to reduce the amount of waste produced. Potential interventions can target reducing test redundancy (Bejjanki et al., 2018), on-site recycling programs and paperless policies (Esmaeili et al., 2018), and designing hospital construction to encourage efficiency (de Fatima Castro et al., 2013). The healthcare system has the potential to make an important difference in the country's contribution to climate change, and subsequently keep our population healthy without ever having to step foot in a hospital.

This thesis aims to explore both the immediate and prolonged impacts of the American healthcare industry on the environment and provide insight into possible remedies for current practices. First, I will investigate the various sources and types of waste produced by healthcare with the goal of linking that waste to its environmental effects. Next, I will analyze how those environmental effects in turn impact the healthcare sector. Specifically, I will investigate climate change repercussions including infectious disease and chronic disease due to pollution. Finally, I will identify the most problematic and changeable healthcare policies, as well as possible solutions. This thesis will consist of a literature review conducted using the University of South Carolina library to access databases including PubMed, GeoRef, and Web of Science Core Collection. I will also pull relevant current event articles and reference nonprofit organizations such as Healthcare Without Harm.

The Problem

As the healthcare industry has grown in recent decades, experts have had to broaden the simple definition of waste to encompass the various byproducts associated with healthcare facilities. Hospital waste can be defined as the waste, either biological or not, that is discarded and not intended for further use. This can be further divided into infectious waste, which is the portion of medical waste that has potential to produce infectious disease. This differs from general medical waste, which is a result of patient diagnosis, treatment, or immunization. Medical waste can also be regulated into seven different classes, including laboratory cultures, pathological specimens, human blood or blood products, sharps, animal wastes, isolation wastes, and unused sharps. Pathological wastes encompass any part of the human body that could potentially be infectious, such as bodily fluids, and excludes things like hair and nail clippings. Additionally, waste can also be classified as hazardous, defined as waste that can contribute to an increase in mortality, illness, or otherwise pose a risk to human health or the environment if improperly dealt with (Burke & Ester, 1994).

With so many varying classifications of healthcare waste, it is no surprise that hospitals, which are already overwhelmed and often understaffed, have not prioritized sustainability. One reason why healthcare waste is so hard to manage is the prioritization of single-use items for sanitation reasons. With the emergence of COVID-19, there has been a surge in the demand for personal protective equipment (PPE). Due to the composition of most types of PPE, they are not compatible with the most available methods of sterilization, so they are typically thrown away after one use (Rowan & Laffey, 2021). Just a few months into the pandemic, shorelines were already littered with discarded PPE. Marine scientists have found a sharp increase in marine life, including birds and aquatic animals, with latex gloves and face masks in their stomachs. Animals such as crabs and birds can easily become tangled in the strings of face masks or mistake discarded plastic for food (Fadare & Okoffo, 2020). The World Health Organization (WHO) has estimated that supplies of PPE must increase 40% monthly in order to supply our populations with the necessary protection throughout the pandemic. This translates to 89 million medical masks, 76 million pairs of gloves and 1.6 million pairs of goggles. The growth in PPE demand is expected to sustain even beyond COVID-19 with an estimated compound annual growth of 20% in facial and surgical mask supply from 2020 to 2025 (WHO, 2020). The plastic waste produced by this surge of PPE only adds to the plastic waste hospitals routinely produced before the pandemic. Surgical kits and other materials are often individually packaged for transportation and sterilization purposes. These plastics are identified as single-use polymeric material and are the leading sources of microplastics pollution globally (Fadare & Okoffo, 2020). In addition to the immediate environmental concerns of plastic pollution, scientists are also concerned about the link between plastic waste and food supply. As fish ingest microplastics, those materials are amplified up the food chain and pose a threat to human food safety. Plastic particles are also known to propagate microbes such as invasive pathogens, potentially acting as a medium for disease outbreak (Marimuthu & Paulose, 2016).

Other forms of hospital waste follow a similar journey to the oceans. Few unified regulations exist concerning waste treatment. In 1988, the federal government passed the Medical Waste Tracking Act to regulate medical waste. However, this act expired in 1991, and waste has primarily been regulated by state environmental and health departments since. Federal agencies such as OSHA and the CDC still offer regulations regarding medical waste, but these typically only provide an overarching framework and leave local governments to fill in the details (MedPro Disposal, 2021). Standard waste procedures often include off-site treatment of potentially contaminated objects such as sharps because it is more cost-effective for hospitals. Hospitals collect their biohazards and store their waste in an autoclave, which sanitizes the material with steam. Then the hospital either employs a truck service to transport their waste, or they utilize the US Postal Service to ship materials to a waste facility. Hospital waste is then treated by incineration, microwaving, or chemical and biological methods. Recent regulations limit incineration to use only for pathological wastes because it releases harmful toxins and byproducts into the air. Methods centered on autoclaving or microwaving waste work by sanitizing materials to then be disposed of normally in solid waste landfills (Klemes et al., 2020). No matter how the waste is dealt with, it will impact the environment. Very few waste management practices focus on reducing or recycling waste, which would be more effective in protecting the environment.

In addition to the solid waste produced by hospitals, it is also important to consider the energy burden of the healthcare system. Hospitals are typically large buildings, open and lit up 24 hours a day, kept at cool temperatures all year, and requiring vast amounts of energy to heat water and power medical equipment. In short, hospitals consume more energy than any other nonresidential building per square meter of floor space (Brown et al., 2012). Healthcare associated emissions can contribute to large percentages of greenhouse gases in the atmosphere, acid rain, and photochemical smog (Eckelman & Sherman, 2018). It is estimated that the US healthcare system is responsible for 12% of acid rain, 10% of smog formation, and 9% of air pollutants such as ground-level ozone, particulate matter, lead, sulfur dioxide, and more. The indirect health burdens that result from this pollution contribute to the estimated 98,000 hospital deaths each year from preventable medical errors (Senay & Landrigan, 2018).

Once in the environment, this waste can have detrimental effects. Untreated healthcare waste in landfills can lead to contamination of drinking, surface, and ground water. Chemical disinfectants used in the treatment of waste can be released into the environment and damage ecosystems. Incineration releases pollutants into the air and generates ash. Many documented pollutants such as materials treated with chlorine can generate carcinogens or heavy metals (WHO, 2018). Of the most concern to human health is the pollution of air and water. The United Nations World Water Development Report indicated that in the next 20 years, the quantity of water available per individual will decrease by 30% (United Nations World Water Development Report, 2015). This will have profound health impacts both for individuals struggling to access clean water, and for hospitals that require water for the vast majority of their operations.

Microplastics and chemicals in aquatic environments contribute to loss of biodiversity and decline in the safety of the water and food supply. Microplastics can also serve as a vector of contaminants to organisms following ingestion, spreading disease worldwide. The effects of microplastics and various chemicals can target the genes, cells, or tissues of plants and animals (Li et al., 2020). Due to the lack of long-term data, it is difficult to completely analyze the effects these toxins have on humans. However, it is already evident that microplastics can impact the food supply and therefore can affect human health through malnutrition and food insecurity. Malnutrition, which encompasses both obesity and undernutrition, affects approximately 2 billion people worldwide (Dietz, 2020). Climate change will continue to disrupt our food, agriculture, and transport systems and exacerbate issues of malnutrition, potentially reaching new communities.

In the air, toxins directly contribute to climate change. For example, ground-level ozone is a pollutant gas that impacts the respiratory system, meaning it can exacerbate asthma, increase susceptibility to infection, promote chronic obstructive pulmonary disease (COPD), and otherwise reduce lung function (Demain, 2018). The US healthcare system is responsible for a large percentage of pollutants that contribute to the formation of ground-level ozone. Particulate matter, which is a mixture of organic and inorganic particles, is another damaging air pollutant posing significant health risks because it can harm both the respiratory and cardiovascular systems. The US healthcare system contributes to particulate matter primarily through incineration of waste. After producing these toxins, the healthcare system is then responsible for treating the populations that developed chronic disease from that pollution.

Of the nation's $3.8 trillion in annual healthcare expenditures, 90% of it is for treatment of people with a chronic health condition. This includes respiratory disease, cardiovascular disease, and mental health conditions (Centers for Disease Control and Prevention [CDC], 2021). Especially during the COVID-19 pandemic, levels of anxiety and depression among the American population are on the rise. In a recent study, 43.3% of young adults reported depression, 45.4% reported anxiety, and 31.8% reported PTSD symptoms. Many respondents cited COVID-19 specific worries, as well as climate change worries, as reasons for their anxiety or depression (Liu et al., 2020). As a result, prescriptions for antidepressants and other pharmaceuticals have also increased, and these will eventually end up in the environment as well (Lopes et al. 2020).

Chronic disease is not the only concern resulting from pollution. Centuries of documentation prove climate change affects epidemic infections as well. Infectious agents, including bacteria or viruses, as well as the disease vector, such as mosquitos or ticks, are heavily regulated by the climate. There is a limited range of climatic conditions, known as the climate envelope, that each infective or vector species can survive. This is evident each year as cyclical changes in the weather bring new diseases each season (Patz et al., 2001). Typically, warmer temperatures increase rates of survival, development, and replication of parasites and some vectors. As moderate climates warm, it is possible for vectors to expand their territory. It is also possible that the distribution of water-borne diseases will be altered as well (Ostfeld, 2009). There has been a global increase in the appearance of emerging infectious diseases (EIDs), such as the 2013 Ebola outbreak (Bernasconi et al., 2020). The COVID-19 pandemic has made it clear that our healthcare system is not equipped to handle a rise in infectious disease. With such vast impacts on human health, it should be the priority of the healthcare system to minimize its contribution to climate change.

From a fiscal perspective, it is also in the best interest of hospitals to minimize waste production in order to minimize costs associated with waste management. In 2004, the United States created over 3.5 million tons of medical waste per year, with an average disposal cost of $790 per ton. These numbers have only gone up in recent years (Windfeld & Brooks, 2015). By 2028, it is estimated that healthcare costs will rise to $2.9 trillion, or 9.7% of the economy (CRFB, 2018). Growth in the healthcare system will lead to increased waste and more money spent on waste management. In many cases, the cost of healthcare waste management can be reduced simply by disposing of the waste correctly. Some studies suggest that up to 92% of the weight of red bag (i.e. biohazardous) waste is discarded inappropriately, meaning it did not need to be classified as biohazardous. Disposal costs of biohazardous waste range from $0.19 to $0.40 per pound, while disposal costs of normal waste are only $0.02 to $0.06 per pound (Nussbaum, 2008). Properly sorting waste for disposal could drastically reduce costs associated with waste management. In addition, healthcare facilities across the US spend more than $8 billion each year in energy costs related on heating and cooling, water, and running medical equipment (Practice Greenhealth 2021a). As large, constantly operating facilities, designing hospital buildings to be more energy efficient or to utilize renewable energy could save billions every year in heating and cooling costs.

Considering how much potential the US healthcare system has to help the environment, in addition to how much money it could save, it is important to consider why more changes have not already been implemented. The healthcare system began in 1798 when President John Adams signed the first federal public health law for the relief of sick and disabled Seamen. Throughout subsequent decades, the government made no efforts to subsidize funds or require insurance. This essentially left healthcare development up to individual state governments and private programs (Physicians for a National Health Program, 2021). As a result, the healthcare system has not developed cohesively across the country. The lack of a national mandate also means there is no long-term plan for the healthcare system. Instead, the industry shifts to try and meet the needs of the present population while the nation continues to grow and change. As private programs have influenced the development of the industry, it often encourages the production of inefficient and low-value services in order to produce a profit. However, what produces the most profit for some entities can cause widespread damages throughout the rest of the system (Bentley et al., 2008). The cheapest purchasing options available to hospitals are often the most wasteful and damaging to the environment. The initial cost of a machine capable of sanitizing PPE significantly outweighs the initial cost of purchasing additional PPE. However, the long-term costs associated with waste management vastly outweigh the upfront costs of committing to environmentally preferable purchasing options. Furthermore, the environmental movement is a relatively new initiative, and it is difficult to work with a system that was not designed with environmental implications in mind.

Efforts to move hospitals over to renewable energy, invest in better recycling programs, or simply update HVAC systems, are difficult to initiate because of challenges such as high costs of initial investment, unintended administrative complexities, and difficult to navigate trade-offs among patients', payers', and providers' interests (Bently et al., 2008). Throughout the United States healthcare system, there is a long history of mismanagement of resources and excessive spending habits. Approximately 25% of total healthcare spending is wasteful, representing up to $935 billion in unnecessary costs. Overtreatment and low-value care account for $75.7 billion to $101.2 billion of that wasteful spending (Shrank et al., 2019). Not only does overtreatment cost more money, it also produces more medical waste. Low-value care also produces more waste because patients often have to come back for more treatment. Healthcare spending and healthcare waste production are directly connected. Despite the opportunity to cut spending by almost 25%, the US has yet to implement widespread changes to accomplish this. This is because inappropriate healthcare spending comes from so many sources that no single policy is enough to address it, and no state governments have the means to overhaul a system as large as the healthcare industry. Introducing individual policies such as value-based payment programs has proved difficult and ineffective, and therefore new policies quickly lose momentum (Shrank et al., 2019). Changing healthcare operations requires a unified, comprehensive approach that is simply unrealistic without federal guidance and funding. Many government initiatives that have been introduced have stalled, largely because of political hurdles. Until the government is able to prioritize a cost-effective, renewable healthcare system, the industry will continue to resist change and produce damaging amounts of waste while losing tremendous amounts of money.

How Does the United States Compare?

Comparing waste management in the United States with other countries is an enlightening practice. It is already well-documented that the United States spends more on healthcare services than any other country, but how does that translate into healthcare waste management? Healthcare waste management varies by country based on factors such as socioeconomic conditions, regulations, level of education, available resources, treatment technologies, and the capacity to monitor and manage inadequate practices. Definitions of medical waste vary by country as well. The WHO defines all waste generated by hospitals, research centers, and laboratories as healthcare waste, while the United States' EPA uses terms such as hospital waste and medical waste to delineate hazardous waste (WHO, 2020; EPA, 2017). The variation in terminology can make international policies hard to regulate or enforce. Waste management can also vary based on rural or urban location, population, and local government. The World Bank of National Economies created a method to compare countries and their waste management based on income. This makes it possible to compare the United States with other high-income countries. A common global trend, no matter the country's income, is the emphasis on providing reputable healthcare services while neglecting healthcare waste management. Comparisons of healthcare waste management uncovered an overarching need for training and clear definitions of waste (The World Bank, 2020). Successful waste management systems incorporate personnel from every stage of waste production and train every worker to properly dispose of and sort waste. The most effective waste management systems are regulated on a national level to ensure continuity throughout healthcare systems, as shown by countries such as Germany or Austria (Caniato et al. 2015).

Perhaps the best way to compare healthcare waste between countries is to quantify the amount of waste generated in a hospital by measuring total kilograms (kg) of waste generated per day divided by total number of beds occupied at the hospital. By using a kg/bed-day metric, waste generation is adjusted for the number of illnesses treated and the seriousness of illness. This is effective because number of beds in service has been found to strongly correlate with amount of medical waste produced by the facility. From here, it is possible to compare healthcare waste generation between countries with a similar GDP per capita. In the United States, the total healthcare waste generation is 10.7 kg/bed-day. This is significantly higher than comparable countries such as the United Kingdom and France, which both generate 3.3 kg/bed-day (Windfeld & Brooks, 2015). Plastic alone makes up nearly 25% of the waste generated in US hospitals (Practice Greenhealth, 2021b). Many scientists attribute this to what Janet Howard, director of engagement at Practice Greenhealth (2021b), coined the ‘ick factor.’ This refers to the concept that, in order to ensure a sense of cleanliness and sanitation, American patients expect everything to be freshly packaged and sterilized when they enter a hospital. Current recycling methods make it possible to sterilize and reuse much of our medical equipment, but consumers resist this idea. America’s “abundance of caution” approach to sterilization may be a large contributor to the reason we produce so much more healthcare waste than other countries (Windfeld & Brooks, 2015).

It is also important to compare how the generated waste is managed. The United States used to regulate its waste management through government agencies such as the Environmental Protection Agency (EPA). Since the Medical Waste Tracking Act expired in 1991, the EPA’s authority over medical waste management has significantly diminished. The EPA provides guidelines, but individual state environmental and health departments are primarily in charge of regulating medical waste (EPA, 2017). Using a vastly different approach, the European Union adheres to a unified methodology to healthcare waste management. The EU sets directives for regulations and standards, and each member nation creates legislation to support these guidelines. For example, the United Kingdom regulates its medical waste through the Environmental Protection Act, which requires a waste management license from every healthcare provider (Windfeld & Brooks, 2015). This ensures that all healthcare facilities follow the strict guidelines the government has put in place. This is a major reason why the UK has a much more effective waste management system than the United States.

A prime example of healthcare waste management in different countries is how each country has managed waste from COVID-19. This involves management of PPE, sharps from vaccinations, plastics from testing kits, dressings, blood products, pharmaceuticals, medical devices, and more. In the European Union, any healthcare solid waste generated during the pandemic is considered infectious waste. This designation recommends an increased capacity to manage any waste, so participating nations have prioritized providing suitable facilities for waste management. Waste must be stored in sealed containers and disinfected on outer and inner surfaces. Safety measures are strictly enforced and waste packaging follows firm plans outlining collection, separation, storage, and transportation. On the contrary, healthcare waste generated by COVID-19 patients in the United States does not receive a special designation and is considered the same as any other healthcare waste (Das et al., 2021). As a result, the excess waste generated by COVID-19 has overwhelmed and outpaced current waste management infrastructure. Other countries that have implemented specific COVID-19 waste management systems are better equipped to handle the surplus of PPE and other waste. It is important to note that proper healthcare waste management can help increase the proportion of recyclable waste and therefore reduce landfill waste, which can in turn help keep waste out of the environment.

Another consideration when comparing the environmental impact of healthcare facilities is their energy consumed. In the United States, hospitals not only require more energy than any other commercial building, but they also have higher energy intensities than in most other countries. This is because countries such as Spain and Japan, have adopted energy-efficient approaches to infrastructure and management. Healthcare facilities in the United States, despite accounting for only 4.8% of the total area of commercial buildings, are responsible for 10.3% of total energy consumption. This energy consumption is directly linked to environmental pollution and emissions, such as 12% of acid rain and 10% of air pollution recorded (Senay & Landrigan, 2018; Bejjanki et al., 2018). In all countries, hospitals require so much energy due to space heating, cooling, steam production, ventilation, lighting, equipment usage, and hot water. To compare energy consumption of healthcare facilities across countries, energy intensity (kilowatt hours, kWh) is measured per unit of area (meters squared, m^2). US hospitals average an annual energy intensity of 738.5 kWh/m^2, which is significantly higher compared to other countries. For example, the average annual energy intensity is 516.2 kWh/m^2 in the UK and as low as 228.2 kWh/m^2 in France. These differences could be due to variation in infrastructure, design standards, consumption culture, sophistication of equipment, and geographical conditions (Bawaneh et al. 2019; Bejjanki et al. 2018). As it stands now, the United States healthcare industry is responsible for 10% of the entire country's carbon emissions, largely due to the energy consumed in running our healthcare facilities (Senay & Landrigan, 2018). The good news is that other countries have proven it is possible to lower energy related emissions and have demonstrated best practices that the United States could adopt.

Possible Solutions

Countless solutions exist for making healthcare more sustainable. Recommendations can focus on anything from laboratory practices and recycling programs to designing hospitals with an energy-conscious approach. Sustainability in healthcare is complex and dynamic and requires a multidisciplinary team to be successful. In the age of COVID-19, an effective method of making a profound difference in the amount of plastic waste produced by hospitals is to focus on reprocessing PPE. This approach can also help alleviate strain on supply chains to provide PPE at an increased demand. In order to effectively sterilize PPE, the structure of SARS-CoV-2 and related coronaviruses must be inactivated. To do this, either the RNA genome, the protein capsid, or the outer envelope of the virus has to be altered. Inactivation can be done via heat, ultraviolet light, or biocides. The CDC estimates the US alone will require 89 million medical masks each month to respond to COVID-19 (Rowan & Laffey, 2021). This data has sparked global interest in the reuse of PPE in an effort to help supply chains and protect the environment from single-use products.

Many studies are being conducted to find the best method of PPE reprocessing. Because most PPE is plastic-based and heat sensitive, existing healthcare technologies are not suitable for the reprocessing of PPE. One potential solution is the use of low temperature hydrogen peroxide vapor (VH_2O_2). The FDA has authorized emergency use of the vapor for the reprocessing of N95 masks in areas where there is critical shortage (Caniato et al. 2015). There are many VH_2O_2 sterilization systems on the market that show promise in effectively treating masks in a hospital environment for reuse by medical staff. Treatment by VH_2O_2 has proven effective in reprocessing N95 masks without reducing filtration performance for 50 treatment cycles using 30% hydrogen peroxide. However, in some cases, strap degradation occurred after 20 treatment cycles (Rowan & Laffey, 2021). This is an environmentally preferably option because there are no toxic byproducts produced; hydrogen peroxide breaks down into water vapor and oxygen (Rutala & Weber, 2015). Other comparable methods of sterilization include reprocessing with ozone, nitrogen dioxide, or supercritical carbon dioxide. However, each of these poses its own set of problems. Ozone, when concentrated at 10-20 ppm and exposed to PPE for 10 minutes, can effectively kill viruses but is also dangerous to humans, animals, and plants (Rowan & Laffey, 2021). Reprocessing by ethylene oxide is not recommended because it is carcinogenic and teratogenic even at low concentrations. Other chemical disinfectants, such as bleach, have potential to end up in the soil and waterways and damage ecosystems. For these reasons, hydrogen peroxide vapor is the most promising and effective chemical reprocessing method and could potentially keep millions of masks out of the environment.

Another possible solution is to treat PPE with ultraviolet (UV) light. UV light works by damaging the RNA or DNA of a virus, effectively inactivating it. The water industry has been using 254 nanometer (nm) UV light to treat water for hundreds of years. Ultraviolet germicidal irradiation offers promising results for the treatment of PPE without compromising fit or function of masks when reused. However, most commercial UV lamps do not have the power necessary to sterilize equipment completely, and are subject to a "shadowing effect" produced by the multiple layers of filtering respirators. This means a virus trapped in crevices or mesh may not be irradiated (Rowan & Laffey, 2021). More research needs to be done in order to optimize UV germicidal irradiation for PPE reprocessing before this method can be implemented. For hospitals struggling with PPE supply, cost, or access to other methods like vaporized hydrogen peroxide, UV germicidal irradiation is a helpful and relatively effective solution. The risks to the environment from this method are minimal and centered on the energy required to power UV lamps for an extended period of time. Ultimately, reducing the plastic waste produced by hospitals in any way is an important step in preserving our environment. Without improvement to the current waste generation and management of COVID-19, an estimated 12 billion metric tons of plastic litter will end up in landfills and the environment by 2050. Greenhouse gas emissions from the plastic lifecycle will contribute to 15% of the total global carbon budget. Indiscriminate use and disposal of single-use plastics such as face masks and gloves will lead to further accumulation of plastic in ecosystems globally (Prata et al., 2020).

Once a mask has been reprocessed as many times as possible without compromising function, it is important hospitals have a responsible method of disposal. Methods should aim to maximize collection and recycling while avoiding mismanagement that may result in contamination. The government is responsible for interventions such as increasing the number of disposal facilities and coordinating recycling, but hospitals are responsible for remaining aware of and following all current policies regarding PPE management. It is essential to have reliable storage and transportation of waste to avoid environmental contamination. Waste management is difficult and resource-intensive, so hospitals should look for environmentally-preferable purchasing (EPP) options. Especially during the COVID-19 pandemic, it may be necessary for hospitals to create task forces dedicated to the proper handling and disposal of plastic waste, including PPE (Silva et al., 2020).

Other hospital waste, such as sharps, account for large percentages of plastic waste. It is unrealistic to seek reuse or recycling of sharps materials because of the nature of their use in hospitals, but it is possible to target sharps containers for sustainable intervention. Each year, US hospitals use 35 million disposable sharps containers. Even a single large hospital converting to reusable sharps containers could divert 31 tons of plastic from landfills in a year. Reusable sharps containers are certified for 500 uses and can last decades. Sharps containers are available in sizes up to 12 liters and should be filled to the line in order to limit waste associated with transport and emptying of containers (Grimmond & Reiner, 2012). Many hospitals still use disposable sharps containers because they are lighter, cheaper at initial purchase, and sometimes easier to access. If reusable sharps containers are promoted and more readily supplied, hospitals would be more likely to utilize them, which would drastically cut down on unnecessary plastic waste and transportation costs.

Pharmaceutical waste is one of the most dangerous types of healthcare waste because it can get into waterways or soil and damage ecosystems. It is generated through various hospital activities and can include expired drugs, discarded personal medications, waste materials such as syringes or IV bags containing excess drugs, open containers of unused drugs, contaminated garments, and otherwise discarded drugs. This waste can be classified as hazardous, non-hazardous, or chemo waste. It is essential that pharmaceutical waste is sorted correctly to ensure it receives the proper treatment before disposal. The most effective way to reduce harmful pharmaceutical waste is to reduce our use of pharmaceuticals. Billions of dollars of unused medication are thrown away globally every year (Ying & Breen, 2012). It is possible to implement a return policy, where unused medication is returned to manufacturers for reprocessing. Hospitals could develop pharmaceutical drop sites where community members can drop off unwanted or expired medication for proper handling and disposal, rather than throwing their medication into regular landfills or sewer systems. Legislation regarding pharmaceutical supply chain management and disposal is scarce in any country, but strict regulations could go a long way in regulating quantifiable discharge limits. Doctors should be encouraged to rely on alternatives to pharmaceuticals to initially treat disease, and only turn to medication if absolutely necessary. Hospitals should limit the presence of drug representatives in their facilities in an effort to limit pressures from pharmaceutical companies (Wohler et al., 2020). Public health initiatives should prioritize preventative strategies such as diet and exercise, as well as provide the resources necessary to make lifestyle changes possible, in an effort to prevent illness that may require medication. As our population ages and chronic disease takes over, it will be important to keep everyone as healthy as possible for as long as possible in order to limit the drugs released into our environment.

Considering that such a large percentage of the impact hospitals have on the environment stems from the energy used to maintain every day operations, designing hospitals to be more energy-efficient could drastically reduce the healthcare industry's contribution to greenhouse gas emissions. Much of the problem stems from the fact that 91% of healthcare facilities in the

United States still use natural gas. This reliance on natural gas indicates a need for updated infrastructure of healthcare facilities and HVAC systems (Bawaneh et al. 2019). The American Society of Healthcare Engineering (ASHE) proposes architectural development of buildings capable of protecting the immediate health of building occupants, the health of the surrounding community, and the health of the larger global community. This "Triple Bottom Line for Health" outlines the industry approach to sustainable building while also taking into consideration the technical needs of the hospital (de Fatima Castro et al., 2013). By accounting for the specific needs of each hospital, architects and builders can prioritize space design to maximize environmental performance. Green architecture is a growing field that should be utilized by every healthcare facility early in development. Potential ways to design buildings for energy efficiency include utilizing lighting modifications, supplemental load reduction for HVAC systems, rightsizing air distribution systems, and beneficial electrification. Many hospitals even have potential to incorporate solar or wind energy to reduce reliance on fossil fuel combustion (Practice Greenhealth, 2021a).

Another aspect to consider regarding energy use in hospitals is that much of the energy utilized is dedicated to running medical equipment. For example, the MRI scanner is a major source of energy consumption. Energy consumed by the MRI scanner can be broken up into idle, standby, and active energy. Idle energy is consumed when the MRI is unoccupied but remains on, such as during weekends and nights. Standby energy is the energy used during the time the patient enters the room until they depart and consists of the power required to maintain the magnetic field, cool down the magnet, and power the computing console. Active energy is the energy consumed to excite nuclei and generate images during active use of the machine (Esmaeili et al. 2018). By far, the most energy (at least 20 kWh) is used in idle and standby periods. Many healthcare facilities leave machinery such as an MRI running so it remains ready for emergency imaging. In general, it can take 30-60 minutes for the magnetic field to stabilize after being off, so they need to be left on during daily operations (Esmaeili et al. 2018). However, in an effort to conserve energy, they should be turned off after hours. If a hospital or area has more than one MRI available, only one should be left on while others are turned off. Similar procedures can be applied to all the machinery in a hospital.

In addition to managing our waste, the United States healthcare system needs to work to generate less waste in the first place. A good target for intervention to reduce waste is the laboratory setting. A clinical laboratory uses more energy and water per unit area than any other office building. Scientists should be encouraged to share resources and reduce the production of solid waste. If labs can incorporate on-site recycling of their organic solvents, it would eliminate the waste and costs incurred by transport to an off-site facility (Molero et al., 2021). Physicians should be conscious of efforts to rationalize test orders and reduce test redundancy. This will help reduce the number of tubes used, as well as reduce materials used for collecting specimens. It is not uncommon for tests to be over-, under-, or mis-ordered. The implementation of a best practice alert in electronic medical records (EMRs) has shown success in limiting the ability of clinicians to order repetitive lab tests. The Veterans Affairs System adopted an electronic laboratory utilization management system and saw an 11.18% decrease in test volume in a single year (Bejjanki et al., 2018). EMRs not only reduce paper waste produced by hospitals, but can serve as a safeguard against laboratory waste. Another good target for waste reduction is the operating room. Most surgical units use disposable, custom gowns and drape packs with prepackaged utensils. By utilizing a nondisposable pack produced by FDA-regulated facilities that contains a table cover, towels, gowns, Mayo stand cover, and basins, it is possible to reduce medical waste by 5 pounds per procedure. After a surgery, the materials are shipped off-site for reprocessing, rather than for disposal. This can yield up to a 70% reduction in waste from operating rooms that reaches a landfill or incinerator (Conrardy et al., 2010). Intensive care units (ICU) are also prime targets for waste reduction because of the complex and extensive chronic care required by patients in these units. Physicians caring for critically ill patients typically err on the side of over preparation, so supplies are often pre-prepped but never used. Unused medical waste consists of medical equipment, either opened or unopened, that is brought into a patient room but not used, and is then disposed. Some studies suggest that simply refraining from overstocking patient rooms with supplies will help keep physicians and nurses from generating as much unused medical waste (Ghersin et al., 2020).

Perhaps the most effective intervention available centers on preventative medicine. Sustainable medicine begins with prevention. Preventative medicine is cheaper and healthier for the planet, especially if we can effectively prevent chronic disease. It requires drastically fewer resources to promote healthy lifestyle than it does to treat a chronic disease like diabetes or cardiovascular disease. The United States is already a world leader in tertiary care, such as innovative surgeries and emergency medicine, as well as in secondary care, which includes medical screenings for disease such as breast cancer (Moses et al., 2013). However, it falls behind in primary care interventions, which focus on actively preventing the development of disease. The National Prevention Strategy identifies seven priority areas of primary care to focus on. These include tobacco-free living, preventing drug abuse and excessive alcohol use, healthy eating, active living, injury- and violence- free living, reproductive and sexual health, and mental and emotional well-being. Interventions focused on these areas would be able to address many of the underlying issues that result in chronic disease (Benjamin, 2011). By addressing chronic disease before it happens, it is possible to drastically limit the amount of waste produced associated with chronic treatment. Currently, more than 50% of the United States population has a chronic disease, and almost 90% of healthcare costs are attributed to chronic disease care. Healthcare waste is directly related to the number of beds in service as well as how long those beds are in service (Holman, 2020). This means that chronic disease management produces exponentially more waste than acute disease. Healthcare systems should prioritize preventative medicine in an effort to preserve the health of our patients and therefore reduce waste to preserve the health of our environment. Some of the priority areas identified in the National Prevention Strategy, such as healthy eating and mental and emotional well-being, directly rely on a healthy environment to be accomplished. Keeping waste from medical care out of the environment is an essential step in preserving the health of our ecosystems and communities. If we can limit the waste we produce in the first place, it will be far easier and more realistic to manage the waste we do produce. The medical field has a fundamental responsibility to foster a healthcare system that meets the needs of our current patients. Green healthcare will require collaboration with government, local communities, and personnel from every stage in the healthcare cycle.

Conclusion

Our climate is measurably changing, and climate change is the most significant health threat of the twenty-first century. Effects on human health can be direct, such as heatwaves and severe weather, or indirect, such as the emergence of infectious and respiratory diseases. There is room for innovation in every step of healthcare. Hospital buildings can be designed to maximize energy efficiency and incorporate solar power, and staff can be trained to utilize medical equipment without wasting energy. An effort as simple as not overstocking patient rooms can drastically decrease the amount of waste generated in units such as the ICU. Looking for environmentally preferable purchasing options can completely turn around the surgical floor and cut unnecessary waste. The pharmaceutical industry should develop strong working relationships with healthcare facilities in order to establish pharmaceutical return lines and limit drug waste. Electronic medical records can be designed to limit repetitive or unnecessary tests, therefore limiting laboratory waste and costs. Simply switching from a disposable to a reusable container for sharps storage can save billions of tons of plastic waste across the United States.

In terms of managing the waste still produced, priority should be placed on recycling what we can, and properly sorting what we cannot. Especially in light of the soaring PPE requirements of COVID-19, hospitals should invest in reprocessing technology such as vaporized hydrogen peroxide. Once materials have been used to their full potential, they can then be sanitized and disposed. Utilizing methods such as VH_2O_2, which degrades harmlessly, can keep chemical disinfectants out of the environment and water supply. Finally, the United States needs to prioritize preventative care. Focusing on preventing disease before it occurs is healthier for our communities and the environment. Treating chronic disease is expensive and extremely resource intensive. By providing the resources and education communities need to live healthy lifestyles, virtually every aspect of healthcare would see marked improvement. We can learn from other countries to implement proven best practices and keep our communities healthy without ever needing to visit a hospital.

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