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Abbreviated Life Cycle Analysis of Medical Supplies

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Background
In 2015, 24 plastic production facilities in the United States produced 17.5 million metric tons of CO_2 equivalent (CO_2e-), which is the same as what 3.8 million cars produced that year (Hamilton 2019). The incineration (controlled burning) of this plastic in 2015 emitted approximately 5.9 million metric tons of CO_2 equivalent (CO_2e-) (Hamilton 2019). CO_2e- is a measure for comparing greenhouse gases to carbon dioxide, by multiplying the amount produced by their global warming potential (Brander 2012). Greenhouse gases trap heat in the atmosphere and warm the planet over time, some are naturally occurring, and some are synthetic. The naturally occurring gases are carbon dioxide, methane, nitrous oxide, and water vapor, and fluorinated gases are synthetic (Denchak 2019). The global warming created can have many disastrous effects on human health.

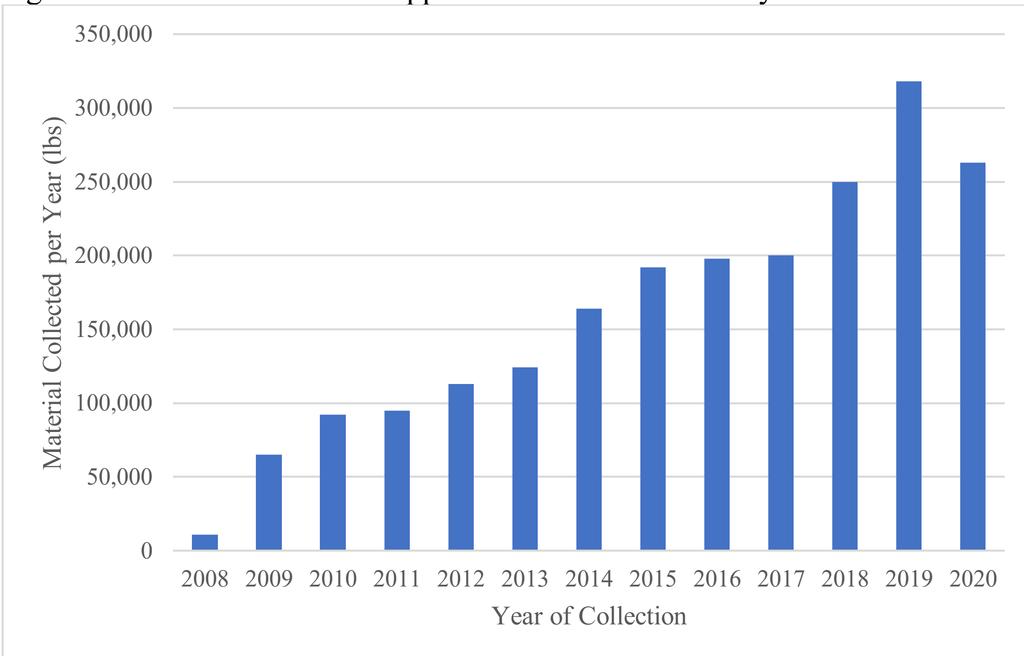
Healthcare waste contributes to 10% of greenhouse gas production in the United States (Hsu, et al. 2020). In the medical field, billions of pounds of medical supplies are discarded yearly. Although some of these items are used and cannot be used again, many are unused or even expired. Many of these items are made up of mostly plastic.

A life cycle analysis is an evaluation method defined by the U.S. Environmental Protection Agency (EPA) as “a method used to evaluate the environmental impact of a product through its life cycle encompassing extraction and processing of the raw materials, manufacturing, distribution, use, recycling, and final disposal” (Hill 2013). This method can be used to calculate and compare emissions saved or produced throughout the entire life of the product, in addition to other impacts such as energy consumption, land use, or cost.

Community Partner
Partners for World Health (PWH) is a non-profit organization in Portland, ME. Started in 2009 by the president Elizabeth McLellan, PWH and its hundreds of volunteers work to collect medical equipment and supplies from local hospitals, nursing homes, individuals, and other organizations. Supplies could be no longer used, opened but not used, not opened or used, or expired. Expired for some hospitals could be up two or three years past the actual date. These supplies would normally be collected and sent off to landfills. Instead PWH collects them and then works to organize, sterilize, and repackage items to ship them off to partner hospitals in developing countries. Large shipping containers are packed by hand with specific items the hospital may be looking for, and then any other items that will fit. This diverts the supplies from going to our landfills and creating more greenhouse gases, while also reducing the amount of new supplies that need to be produced. If PWH did not do what it does, many of those supplies would be produced twice, once for the United States and again for our partner hospitals. Instead, PWH can divert the supplies from landfills and incinerators, and consequently reduce CO_2e- emissions. This reduces the U.S. overall carbon footprint, and ultimately keeps a cycle of production from occurring.

Figure 1 below shows the pounds of supplies collected per year by Partners for World Health over the duration of time the organization has existed. In total at least 2,085,000 pounds of supplies have been collected and accounted for over 13 years. There was a decrease in 2020 which can be explained by the COVID-19 pandemic, but that number has already greatly increased in 2021.

Figure 1. Pounds of Medical Supplies Collected Per Year by Partners for World Health.



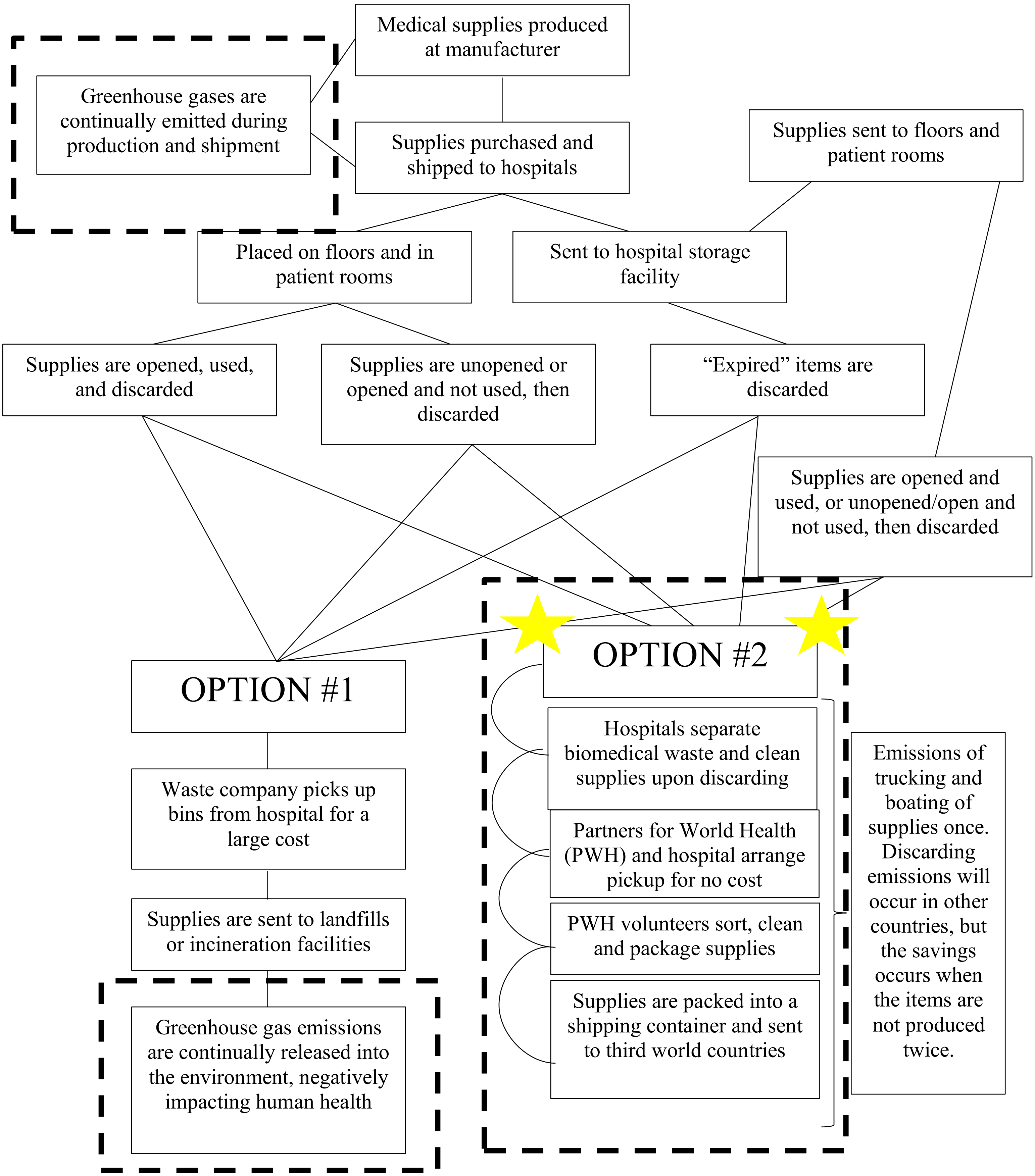
Purpose

The purpose of this capstone is to evaluate the life cycle of plastic in medical supplies for the healthcare system that has been diverted by Partners for World Health (PWH). There have been years of research on the lifecycle of plastic and other products, but not medical supplies specifically. Researchers have looked at how to reduce the waste of supplies in specific areas of hospitals, but this capstone is the first study to my knowledge that estimates the total plastic in medical supplies diverted by a specific organization. For this project, plastic in medical supplies will be analyzed, while other materials will be left for future review. With this information, I will be able to provide the community partner, PWH, with statements they can use to promote their environmental and health impact.

By analyzing the weight of supplies collected, and the amount of plastic collected, I will be able to calculate emissions diverted from producing and incinerating the plastic, and find out the environmental and health impacts that PWH is making.

Figure 2 shows the conceptual model of the life cycle analysis of the medical supply chain and the emissions. There are two options for these supplies: 1. the normal life cycle where supplies are sent to a landfill or incineration facility; or 2. recycling of the medical supplies by PWH. There are emissions during production and shipment of supplies, and in option #1, there are emissions during movement to landfills or incineration facilities as well as the actual emissions produced at these facilities. Option #2 includes the recycling of the supplies where emissions are only produced during the shipping of supplies to other countries. What it doesn't show is how other countries discard their supplies after use, but the true savings of emissions comes from not producing the supplies twice at the manufacturing facility. The scope of the project will include certain steps of the model in Figure 2. See the dotted-lined boxes in Figure 2 for the scope of the project.

Figure 2: Conceptual Model of Medical Supply Chain



Methods

I used the following procedure to determine the amount of CO_2e- emissions avoided from reuse of plastics in medical supplies obtained by PWH. First, I weighed the pallet of medical supplies that were donated from Vygon and recorded the total weight. Then I separated each single-use item by material type into four separate bins labeled: plastic, rubber, paper and other. I weighed each category of material type and calculated the percentage of material versus the entire weight of the pallet. Next, based on the manifest total weight, I calculated percent of durable medical equipment versus medical supplies. Then, I calculated total plastic percentage of medical supplies by breaking down the medical supplies category of the manifests. Using the pounds per year collected from PWH, I calculated the year and total percentage of plastic in medical supplies. Using the equations and global warming potentials given by the U.S. EPA, I calculated greenhouse gas emissions in CO_2e- for CO_2, CH_4, and N_2O. The formula I used to calculate combustion CO_2 emissions in kg of CO_2e- is: (Mass (lbs)/2000)*2850kg CO_2/short ton*1 CO_2e-/CO_2. To calculation combustion CH_4 emissions in kg of CO_2e-: (Mass of plastic (lbs)/2000) *1.216kg CH_4/short ton*25 CO_2e-/ CH_4. To calculate combustion N_2O emissions in kg of CO_2e-: (Mass of plastic (lbs)/2000) *0.16kg N_2O/short ton*298 CO_2e-/ N_2O (EPA 2021b). To calculate the emissions for regular plastic production as well as renewable plastic production, I used the numbers and equations provided by Posen et al. (2017), after dividing the yearly mass of plastic in pounds by 2205 to get mass in metric tons. Posen et al. (2017) calculated that 1.89MT of CO_2e- is produced per MT of plastic produced conventionally, and for renewable energy plastic production Posen et al. (2017) calculated that 0.90MT of CO_2e- is emitted per MT of plastic produced.

Table 1: Combustion Emission Factors and CO_2 equivalents (Source: EPA 2021b)

Greenhouse Gas	**Combustion Emission Factor**	**CO_2 Equivalents**
Carbon Dioxide	2850kg CO_2 per short ton	1
Methane	1.216kg CH_4 per short ton	25
Nitrous Oxide	0.16kg N_2O per short ton	298

Results

Tables 2 through 7 below indicate the calculation results, following the process described in the methods. There are multiple major findings in the results below. Table 5 indicates that most of the material that was not calculated, such as metal or more plastic, comes from the durable medical equipment. 23.8% of all medical supplies donated were plastic products, but additional plastic comes from the durable medical equipment. Table 7 shows the calculations for combustion emissions saved for plastic in medical supplies alone, by not sending this amount of plastic to the facility and shows that PWH has saved at least 707MT CO_2e- from carbon emissions, 7MT CO_2e- from methane emissions, and 12MT CO_2e- from nitrous oxide emissions. Table 8 then shows the savings from producing items twice just for plastic, in total for regular energy production are equivalent to 425MT CO_2e- saved from being emitted by production. If it was assumed that all plastic production facilities were based on renewable energy systems, then 202.54MT CO_2e- was saved from being emitted at plastic production facilities in the United States.

Table 2: Material Collected and Weight (estimate from boxes sampled, and total)

Item on Pallet	**# Of Boxes per Item on Pallet**	**Plastic Weight per Box(lbs)**	**Rubber Weight per Box (lbs)**	**Paper Weight per Box (lbs)**	**Other Weight per Box (lbs)**	**Total Plastic Weight (lbs)**	**Total Rubber Weight (lbs)**	**Total Paper Weight (lbs)**	**Total Other Weight (lbs)**
Central Line Dressing Change Kit	26	2.8	0.8	0.8	0.4	72.8	20.8	20.8	10.4
Central Line Maintenance Kit	7	2	0.9	0.9	0.5	14.0	6.3	6.3	3.5
IV Start Kit	48	1.2	1.2	0.8	0.3	57.6	57.6	38.4	14.4

Table 3: Total Weight and Weight Percentage Supplies in Pallet

	Plastic	**Rubber**	**Paper**	**Other**
Total Weight from Pallets (lbs)	144.4	84.7	65.5	28.3
Total Weight of Pallet (lbs)	322.9			
Percentage Weight of Pallet (%)	44.72%	26.23%	20.28%	8.76%

Table 4: Manifest Totals

Container #	**Total Weight of Container (lbs)**	**Weight of Medical Supplies (lbs)**	**Weight of Durable Medical Equipment (lbs)**	**Percentage Supplies (%)**
1	20904	1093	9811	53.0%
2	21077	9719	11358	46.0%
3	22727	10470	12257	46.1%
4	21684	13887	7797	64.0%
5	23562	15750	7812	33.2%
6	3024	1648	1376	46.0%
7	22108	9729	12379	44.0%
8	21888	10238	11650	46.8%
9	22456	8141	14315	36.3%
10	22791	15541	7250	68.0%
11	23225	22816	409	98.2%
Total	225446	119032	96414	52.8%

Table 5: Breakdown of Weight by Percentage

Item	**Overall Percentage**
Durable Medical Equipment (DME)	47.2%
Plastic	23.8%
Rubber	13.9%
Paper	10.8%
Other	4.3%

Table 6: Estimated Pounds Collected Yearly by Material Type

Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Total (lbs)	11000	65000	92000	95000	113000	124000	164,000
DME (lbs)	5192	20680	43424	44840	53336	58528	77408
Plastic (lbs)	2618	15470	21896	22610	26894	29512	39032
Rubber (lbs)	1528	9029	12779	13196	15696	17224	22780
Paper (lbs)	1188	7020	9936	10260	12204	6321	17712
Other (lbs)	474	280	3965	4094	4870	5344	7068.4

Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
Total (lbs)	192,000	198,000	200,000	250,000	318,000	263,000	2085000
DME (lbs)	90624	93456	94400	118000	150096	124136	984120
Plastic (lbs)	45696	47124	47600	59500	75684	62594	496230
Rubber (lbs)	26669	27502	27780	34725	4417	36531	289607
Paper (lbs)	20736	21384	21600	27000	34344	28404	225180
Other (lbs)	8275	8534	8620	10775	13706	11335	89864

Table 7: Estimated Total Combustion Emissions Saved Per Year

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
CO_2 Emissions (kg CO_2e-)	37301	22045	31201	32219	38324	42055	55621
CH_4 Emissions (kg CO_2e-)	40	234	333	344	409	449	593
N_2O Emissions (kg CO_2e-)	62	369	522	539	641	704	931

Table 7: Combustion Emissions Saved Per Year (cont'd)

	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**Total (kg CO_2e-)**	**Total (MT CO_2e-)**
CO_2 Emissions (kg CO_2e-)	65117	67152	67830	84788	107850	89196	707127	707
CH_4 Emissions (kg CO_2e-)	695	716	724	904	115	951	7543	7
N_2O Emissions (kg CO_2e-)	1089	1123	1135	1418	1804	1492	11830	12

Table 8: Production Emissions Saved Per Year

Type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Regular **(MT CO_2e-)**	2	13	19	19	23	25	34	39	40	41	51	65	54	425
Renewable Energy (**MT CO_2e-)**	1	6	9	9	11	12	16	19	19	19	24	31	26	203

Table 9: Production Emissions per Metric Ton of Plastic

Type of Plastic Production	**Metric Ton of CO_2e- emitted per MT of Plastic produced**
Regular Energy	1.89
Renewable Energy	0.90

Environmental and Health Impact

Greenhouse gases are the warmers of our planet and human activities are to blame for the increase in the greenhouse gas concentration world-wide. To keep the global temperature from rising 1.5°C from 2020-2030, greenhouse gas emissions must drop by 7.6% from what they were in 2019 (United Nations 2019). Most of these greenhouse gas emissions are caused by human activities, and from 1990-2019, the volume of gases that was emitted because of human activity increased by 2% in the United States and from 1990-2015 this number increased 43% worldwide (IPCC 2013). Carbon dioxide accounts for ¾ of all emissions and increased drastically over the same period (EPA 2021a, b).

To decrease global warming, the United States would need to decrease emissions by 498,408,000MT CO_2e-. At PWH, 726MT CO_2e- was saved from being emitted during combustion, and 425MT CO_2e- was saved from the double production of medical supplies. They can't do it alone, but if the healthcare system worldwide can begin to adapt and recycle supplies to developing countries, we may see a massive decrease in emissions.

Carbon dioxide can last in the atmosphere for thousands of years and some can be absorbed very quickly. Methane lasts for approximately 12.4 years, and nitrous oxide lasts for 121 years. These gases cause an increase in the temperature of the planet and are the main factor in global warming. Although this has a negative effect on the planet, environmentally, it has a negative impact on human life and can cause many health problems (EPA 2021a).

This overall global change in temperature can have an impact on food for humans. Higher CO_2 levels certainly can increase crop yields allowing plants to achieve optimal growth capacity, but that is counteracted by the effect of droughts and floods that are seen during extreme weather change. During these times, weeds and pests can be increased, there can be issues with runoff from pesticides during floods, making drinking water unsafe, and agricultural producers can lose their livelihood from these events occurring (Brown 2015; NASA 2021).

Extreme heat, poor water and air quality, reduced food and population displacement all occur from an increase in temperature, precipitation extremes, extreme weather evens and a rise in the sea level, caused by global warming (USGCRP. 2016). Heat related deaths are expected to increase by 50% over the next 80 years. There is already and will continue to be an increase in Lyme Disease and vector-borne illnesses due to the change in the ecosystem, and there are many water-related illnesses that will occur because of contaminated fish, more precipitation, and increased runoff from crops (CDC 2015). Extreme weather events will also continue to increase the impact on human health. Projections in climate change predict that there will be a continuous increase in the severity of heat waves, tornadoes, hurricanes, and floods by the end of this century (Fann 2015), leading to more lives lost, not only from the event itself, but also during storm preparation and clean-up (NOAA 2010).

Living in and around an area where plastic production and destruction is prominent can cause major health concerns. These places, such as landfills, incineration and waste facilities, and plastic production factories, release carcinogenic and toxic substances in addition to greenhouse gases. Effects can include respiratory issues, low birth rate, nervous system impairment, cancer, and reproductive and development problems (Center for International Environmental Law 2021).

Limitations

There are a few limitations in this study that can be worked on in the future. The biggest limitation is that due to the lack of measurement tools in the type of material donated to PWH, the numbers calculated are estimates. EcoMaine, a recycling organization in Maine, has lasers that will tell the amount of material type, plastic, metal, glass, rubber and more, that is in any given load brought through their facility. If PWH had this, it would certainly be beneficial to getting precise measurements of material type at the beginning of the study. If this was a study that could be done over the course of one year, or two, and if there was the ability to have more manpower, ideally every pallet that is brought through the door over a course of a month, a quarter, or a full year would be measured and separated out by material type. Because this was not the case, we used one pallet that the organization identified as items that are representative of most of the items they normally get. Another limitation of this study is that not all material collected would have been combusted; it could have gone to a landfill, or it may have been recycled somewhere else. An additional limitation is that the emissions from the ground and shipping transportation were not calculated into this abbreviated life cycle analysis but could be calculated in future studies. Further, the calculation of emissions for plastic production varies based on type of plastic and amount produced and varies among different studies. Since there is not one number that is released through the Environmental Protection Agency, numbers were used from a few different reputable studies. Finally, the study could only assess medical supplies and not durable medical equipment, which would increase greatly the amount of plastic and metal measured. In the future, additional studies would help the numbers be as accurate and complete as possible.

Conclusions

Looking at the results above, it seems the true savings would come from the amount of plastic that isn't being combusted in the United States. But the supplies must still be discarded at some point, even if it is in a different country, so additional savings come the supplies not being produced twice; rather supplies are used to their full capacity, whether it's in the United States or in developing countries.

My capstone has laid some groundwork for future projects at PWH and other non-profits to continue to refine the research and calculations. This methodology can be expanded in the future to include other parts of medical supplies and durable medical equipment, as well as expand to include the entirety of the life cycle analysis of medical supplies. This means that every step of the process would be calculated, not only production and disposal, but also the shipment of the supplies overseas, the emissions from trucking supplies to hospitals, or trucking supplies from PWH to the ports for the shipping containers. My study has contributed to what already exists for literature on the life cycle analysis of medical supplies. Prior work applied the life cycle analysis methodology to the recycling of supplies in the emergency department, or other floors on a hospital (Hsu et al., 2020), whereas this study examined reuse of plastic supplies otherwise destined for disposal.

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