KDU IRC INTERNATIONAL RESEARCH CONFERENCE 2021
ID 334

Study of Estimating Greenhouse Gas Emission from Healthcare Solid Waste Management

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Abstract— This research focused on the modern-day healthcare waste management and the emission of greenhouse gases from the waste, considering the environmental pollution and the increase of medical problems and the waste due to those increments. This work comprises of the methods and calculations according to the Intergovernmental Panel on Climate Change (IPCC) guidelines and the Institute for Global Environmental Strategies (IGES) Greenhouse Gas emission spreadsheet model. The amounts of waste generated within the facility were studied and information regarding the management was gathered. From the generation, till the disposal of the waste, the required data was gathered. The cycle of generation of the total waste from healthcare facilities from the generation up to the landfill disposal site is discussed. From the processes studied, the emission estimation is found in kilograms of carbon dioxide equivalent per tonne of healthcare waste (kg CO_2e/tonne of waste). Through the data collected, and calculations with the IGES software and IPCC guidelines, it was found that in reaching net emission to zero, healthcare waste management processes in the selected medical facilities should move to more fuel savings, proper recycling, and composting practices.

Keywords: ***solid waste, healthcare, greenhouse gas, emissions***

I. INTRODUCTION

According to recent studies the waste generations and the waste disposal problems are on a rise with the increasing populations (Bundunee & Athapattu, 2015a). In waste considerations, the environmental components are sensitive assessment areas. According to the United Nations and the World Health Organization, waste can be considered as a leading Greenhouse Gas emitting sector in the world (Bereiter et al., 2015). Methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) are the main gases which are responsible for the Greenhouse effect. In calculation of the Greenhouse gases, International Panel on Climate Change (IPCC) which is an intergovernmental body of UN implemented guidelines. And with calculated emission factors, the emission from every material and every process can be estimated. In overall waste categorization, the healthcare sector is a leading waste generation area. The increasing of diseases and population undoubtedly increase the waste that is generated in these medical facilities. These wastes are simply categorized by the World Health Organization (WHO) as healthcare non-hazardous (general) waste and healthcare hazardous (clinical) waste. Further is divided into several categories for the ease of waste identification and segregation (World Health Organization, 2007).

II. LITERATURE REVIEW

According to the World Health Organization (WHO) it was estimated around 85% of wastes generated at medical facilities are general waste (Emmanuel et al., 2001). Healthcare waste management in developing countries such as Sri Lanka must be done accordingly because if handled incorrectly it could leave medical staff and the general population in danger (Khan et al., 2019). The solid waste within the healthcare facilities and the emission of greenhouse gases from the processes of those wastes from generation to transporting to the disposal site were studied and analysed. By identifying and gathering data of waste amounts and calculations through the software according to guidelines, the final analysing was completed.

A. Estimation guidelines

In estimating the emission of greenhouse gas from wastes, the IPCC guidelines of 2006 integrated software are being developed in many organizations related to the WHO and UN and can be used.

Waste categorization and Segregation

The World Health Organization (WHO) has categorized healthcare waste into several categories. This depends on the local medical authorities' categorization regarding local situations, wastes, disease types, weather, etc.

- Infectious waste – the waste that contain blood and other bodily fluids, infectious agents from laboratories, and waste from infected patients. (e.g., samples, infected animals, swabs, bandages etc.)

Figure 9. Uncovered storage of segregated healthcare waste

- Sharps – Syringes, needles, disposable scalpels etc.
- Chemical waste – disinfectants, sterilant and heavy metal contained medical devices etc.
- Pharmaceutical waste – waste that are expired, unused drugs or vaccines
- Genotoxic waste – waste that contain vomit, urine from patients that are treated with cytotoxic drugs
- Radioactive waste – such as waste that contain a certain amount of radioactivity diagnostic materials
- General waste

In Colombo - Sri Lanka, a study has been conducted regarding the management of healthcare wastes considering 18 out of 26 government hospitals (Bundunee & Athapattu, 2015b). Studies of landfilling showed an amount of 3.84 metric tonnes of healthcare waste per day is generated.

Table 1. Government healthcare waste generation in the year 2000

	Total health care waste (kg/day)	***Hazardous waste (kg/day)***	
		At 10% of total healthcare waste	*At 25% of total healthcare waste*
Lower estimate	76 623	7 662	19 155
Upper estimate	170 789	17 078	42 697

As per Table 1, a study done for the year 2000 regarding government hospital waste the hazardous waste estimation per year can be percentages of 10% or 25% or in-between (Haniffa, 2004).

B. Waste Management

'Red bag waste' is the general classification done in European countries where the hazardous waste is bagged in red colored bags. While is Sri Lanka it is yellow taped bags or boxes.

In Sri Lanka, separate color-coded system is being followed as per the WHO protocols and the local authorities. The color-coded labels or bins of the color is to be seen in each facility, wards, laboratories, cafeterias, and offices.

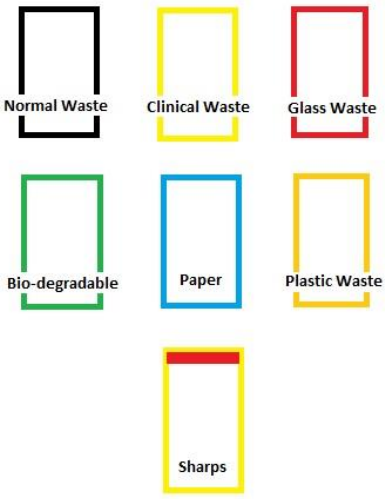

Figure 10 - Color-coded system at Local medical facilities

The yellow bags are sent to incinerator units where they contain both infectious and pathological waste. The yellow boxes which contain sharps waste is also sent to the incinerator units.

The hazardous waste (clinical waste) must be treated or incinerated before being sent to landfill sites while the general waste is generally sent to landfill sites.

C. Emissions

Sources of greenhouse gas emission are from burning of fossil fuels and mix waste landfilling. The emission of greenhouse gases can be classified as direct and indirect (Khan et al., 2019).

- Direct emissions – emissions from the respective locations and the entity owned sources.
- Indirect emissions - use of electricity and other functions and the emission from those sources.

The emissions, savings and net emissions must be considered when conducting an estimation regarding greenhouse gas emissions.

III. METHODOLOGY

A. Scenario description

Step 01 included site visits to the selected medical facilities, studying the waste management practices, having interviews with staff, and my personal observations. Waste generation data was gathered in step 01.

Step 02 included data regarding after the waste were generated and data when the waste was transported up to the landfill or treatment sites.

Step 03 included the data analyzing part using an estimation software which was developed by Institute for Global Environmental Strategies according to the World Health Organization's IPCC guidelines.

B. Facility Selection

The selected medical facilities have modern technology and has highest amounts of patient populations.

- The National Hospital of Sri Lanka (NHSL)
- The Colombo South Teaching Hospital
- The University Hospital of Kotelawala Defence University (UHKDU)
- The Navy General Hospital

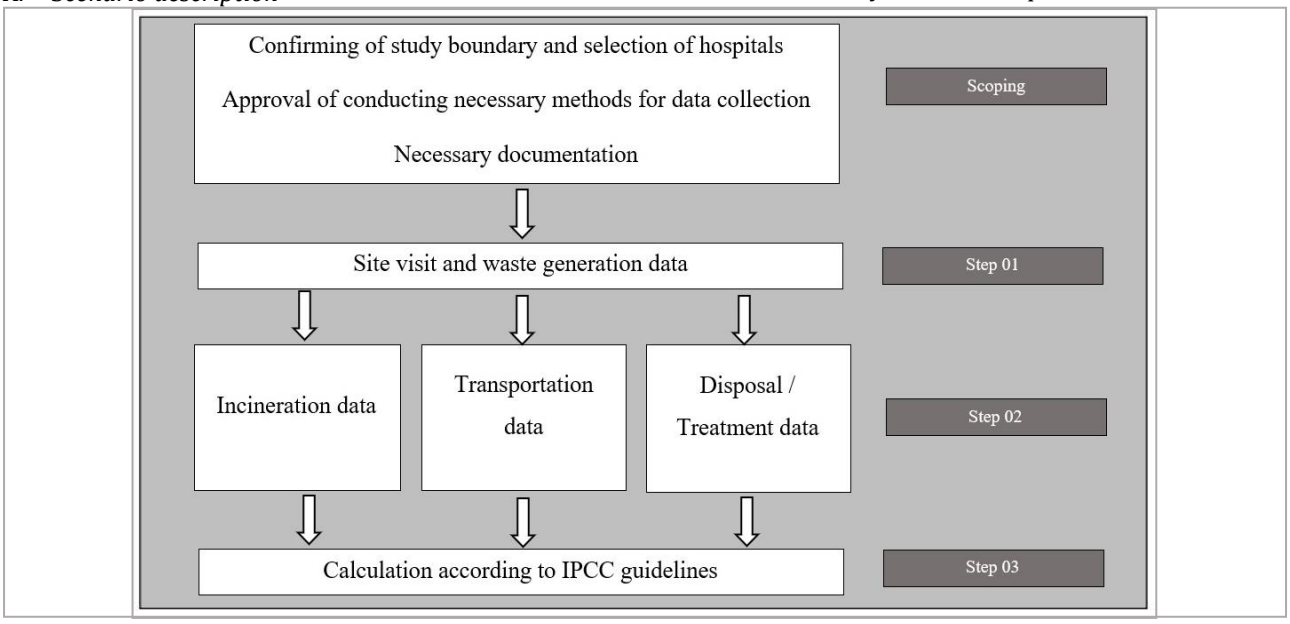

Figure 11. Scenario description

Figure 3 shows the overall study that was conducted in three steps. Figure 5 shows the study boundary of the research. A separate documentation were used for step 01 and step 02 studies only considering solid waste of the healthcare facilities.

Figure 4 shows the most common waste segregation categories that can be seen at medical facilities. The selected medical facilities are situated in the Colombo area and its outskirts. All the selected medical facilities are government-based hospitals, while 2 are military administered. The

National Hospital of Sri Lanka (NHSL) being the country's central medical facility, and the Colombo South Teaching Hospital which specializes in emergency situations use a semi-government treatment unit for incineration of hazardous waste. Other two facilities have on-site incineration units.

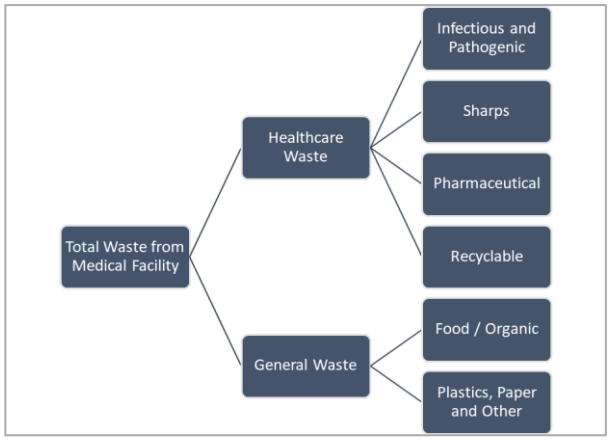

Figure 12. Local facility waste segregation

C. Data Collection

The data regarding step 01 and 02 were collected with site visits. Site visits were conducted two to four visits per each medical facility. Each visit consisted of data collection from record books, interviews with expertise personnel, working staff, and personal observation.

Main locations within the facility for data collections were the infection control units, the on-site Public Health Inspector (PHI), local ward record books and the temporary waste storage record books.

The collected data were fed to the software which finally outputs the estimation amounts of greenhouse gas per ton of waste.

D. Estimation Software

The estimation software follows the tier 3 calculations for greenhouse gas emission for wastes, which demonstrates that global emission factors are used rather than country specific data. Since Sri Lanka's emission factors were not calculated the tier 3 approach is the most suitable in estimating greenhouse gas emissions. Figure 4 demonstrates the study boundary of data collection. The software is developed at Institute for Global Environmental Strategies (IGES). The IPCC guidelines of the year 2006 were followed in the software and is specifically developed for South Asian countries (Menikpura, 2013).

E. Emission from sectors

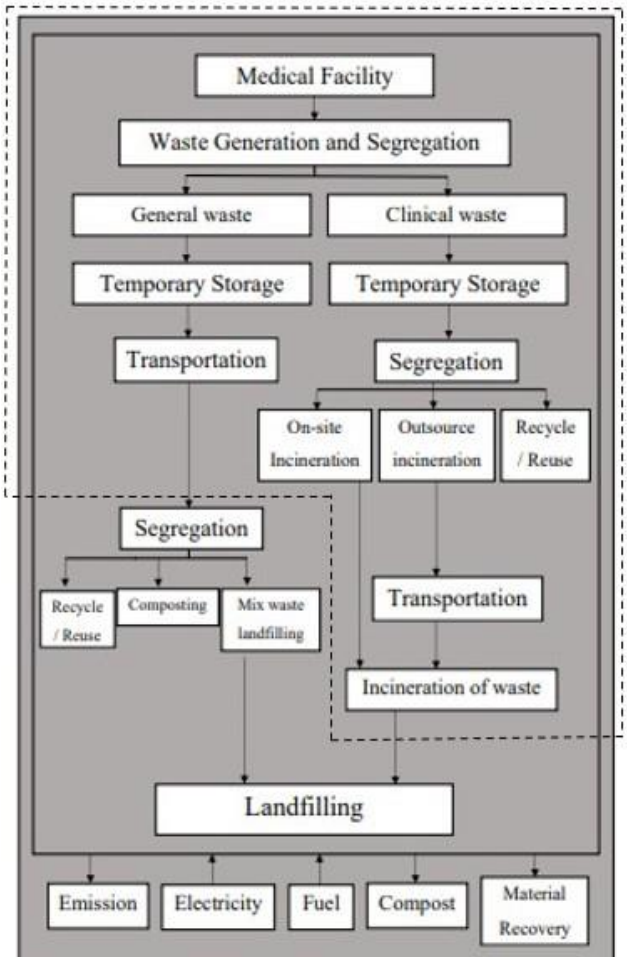

Figure 13. Study boundary (Cradle to gate analysis)

The wastes generated were put to processes from the management of the wastes where the emission of greenhouse gases occur due to those processes. The equations for each of the processes are integrated within the software.

The studied processes of these healthcare wastes are transportation, incineration, composting, and recycling.

1. Transportation – In Sri Lanka transportation is done with either waste-trucks or tractors. Either Petrol or diesel is used. Depending on the route, fuel consumption and routine of the emissions depend.

2. Incineration - The main objective of incineration is to reduce the volume of waste. However, when it comes to hazardous healthcare waste, it is necessary to

Table 2 - Monthly waste generation in kilograms (Step 01)

Hospital Name	Pathological & Infectious waste	Sharps waste	Radioactive waste	Recyclable waste	General waste	Total waste generated
National Hospital of Sri Lanka	46205.6	7469.36	1	637	147000	**201312.96**
Colombo South Teaching Hospital	15586	899.2	0	183	36000	**52668.2**
University Hospital of KDU	3600	268	0	54	19200	**23122**
Navy General Hospital	740	96	0	21	3900	**4757**

incinerate the waste within 24 hours after generation. Incineration is the highest greenhouse gas emitting process as the fuel consumption and electricity consumption is high. Incineration directly eliminates the emission of methane (CH_4) and replaces it with carbon dioxide (CO_2) which is considerably lower impacting than methane.

3. Composting - There is an emitting of greenhouse gas in composting, but it is replacing a higher emission possibility by landfilling the wastes. The food waste and the garden waste is used in composting. In most steps there is a possibility of using machinery for composting but the non-machinery involving processes are recommended. Even though healthcare waste contains organic waste in hazardous waste, they are not used for composting considering health factors and other situations.

4. Recycling - Recycling is a massive GHG avoidance as the material recovery helps a lot to avoid material dumping at landfill sites. In healthcare waste only selected materials are being used for recycling. That too is to be sent to the closest treatment unit, which is on-site, and then used back. The theory in greenhouse gas regarding recycling as follows. Through recycling materials the emissions due to producing new material is avoided/ reduced.

IV. RESULTS AND DISCUSSION

Inventory – Step 01 and 02

The inventory analysis of this study which is generated waste within the facility was done through step 01.

Through collected data, it showed the waste generation and amounts were of both the healthcare hazardous and healthcare nonhazardous wastes. The Table II shows the monthly waste generation data.

While the general wastes were the only input for non-hazardous waste all other wastes were of hazardous healthcare waste. The hazardous waste composition has increased over the last decade. To which the representation shows the percentage is 27%.

The general waste composition of different materials was also gathered and each of the facility generates a similar amount of general waste material composition. Even though the percentages were similar the waste amounts were different since, NHSL has high patient attendance and the highest of the waste generating facility. The lowest being the Navy general hospital which has low patient attendance and low bed strengths.

The waste data regarding transportation, incineration, composting, and recycling were

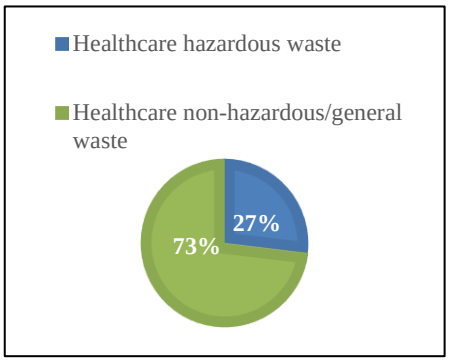

Figure 14 - Resulted healthcare waste composition

gathered through the documentation and book records.

Wastes from NHSL and Colombo South Teaching hospital were shown together as the clinical waste is both transported to relevant locations together.

The NHSL, UHKDU and the Navy General medical facilities have zero generation of wastes of metal and other. The metal wastes from the Colombo South hospital resulted because of small constructions were taken in place.

Table 3. General waste composition (NHSL and Colombo South)

Monthly General waste amounts	NHSL	%	Colombo South	%
Food waste	67500	**45.92**	16500	**45.83**
Garden waste	45000	**30.61**	10800	**30.00**
Plastic, Polythene & PVC	23400	**15.92**	5100	**14.17**
Paper	1500	**1.02**	300	**0.83**
Textile	4800	**3.27**	1800	**5.00**
Leather, rubber, foam	3000	**2.04**	900	**2.50**
Glass	1800	**1.22**	450	**1.25**
Metal	0	**0.00**	120	**0.33**
Other	0	**0.00**	30	**0.08**

Table 4. General waste composition (UHKDU and Navy General)

Monthly General waste amounts	UHKDU	%	Navy General	%
Food waste	10500	**54.69**	1800	**46.15**
Garden waste	4200	**21.88**	1350	**34.62**
Plastic, Polythene & PVC	3300	**17.19**	600	**15.38**
Paper	450	**2.34**	0	**0.00**
Textile	0	**0.00**	0	**0.00**
Leather, rubber, foam	450	**2.34**	60	**1.54**
Glass	300	**1.56**	90	**2.31**

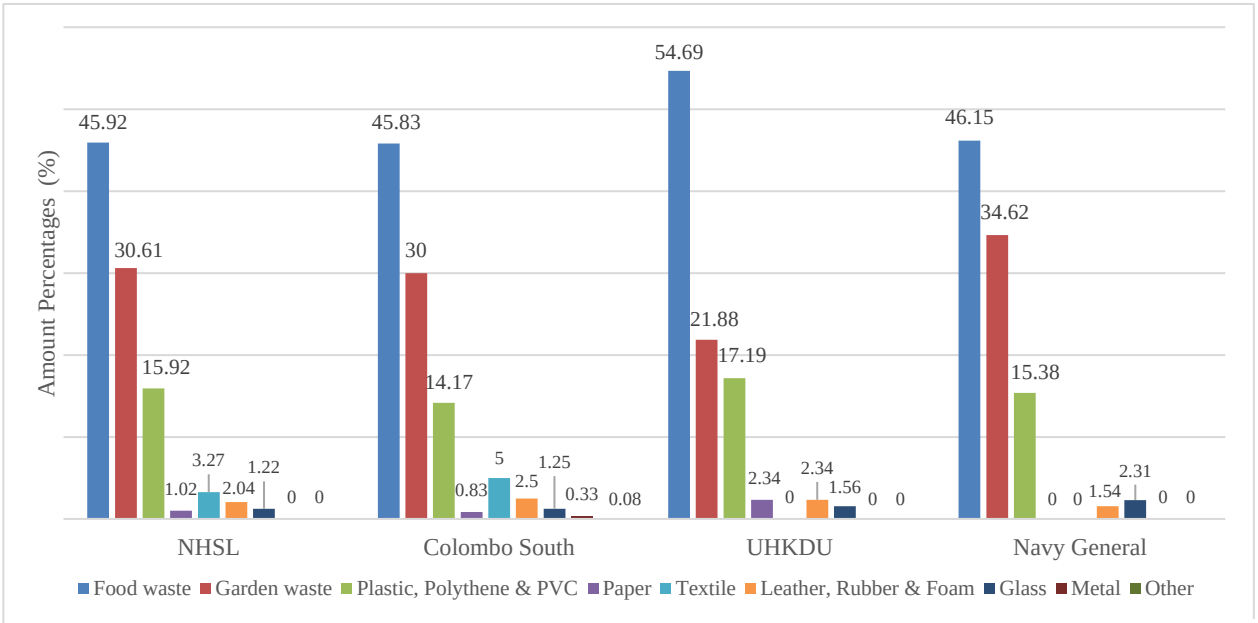

Figure 15. Waste Percentages of Each Facility (Inventory Analysis – Step 01)

Transportation data for the healthcare waste data are shown in Tables 5 and 6 The University hospital of KDU and the Navy General hospitals have onsite incinerator units and because of that the transportation emission of hazardous waste for those two medical facilities are zero.

The waste transported through carts which require no fuels. Colombo South composts 900kg of food waste while Navy General composts the whole of garden waste which is 1100kg per month. Approximately 800 kg of food waste is sent to the piggery.

Table 5. Healthcare hazardous waste transportation data

	Healthcare hazardous waste	**Distance (km)**	**Fuel usage (litres per month)**
National Hospital of Sri Lanka	Sent to treatment facility	One route starting from Colombo South hospital to treatment facility: 22.4	48.69
Colombo South Teaching Hospital			
University Hospital of KDU	On-site incineration	-	-
Navy General Hospital			

The medical facilities in the study are segregating the whole collected wastes into hazardous and non-hazardous wastes.
As per the data collected and observations, UHKDU and the Navy General Hospital have on-site incineration units therefore has no transportation fuel usages regarding hazardous wastes.

Table 6. Non-hazardous waste Transportation data

	Healthcare non-hazardous waste	**Distance (km)**	**Fuel usage (litres per month)**
National Hospital of Sri Lanka	Muthurajawela waste dump	15.1	197
Colombo South Teaching Hospital	Karadiyana waste dump	9.1	119
University Hospital of KDU	Karadiyana waste dump	4.2	63.6
Navy General Hospital	Muthurajawela waste dump	1.8	19

Table 7. Recycling material data (kg)

Monthly Recyclable	**NHSL**	**Colombo South**	**UHKDU**	**Navy General**
Paper/car-dboard	202	48	12	0
Plastics	110	55	8	0
Glasses	325	80	34	21

Computation and analysis of data through software - Step 03

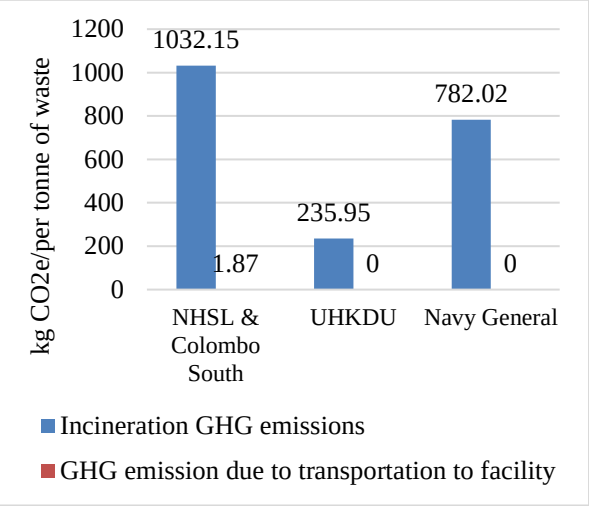

Figure 8. Hazardous waste transportation and incineration emissions

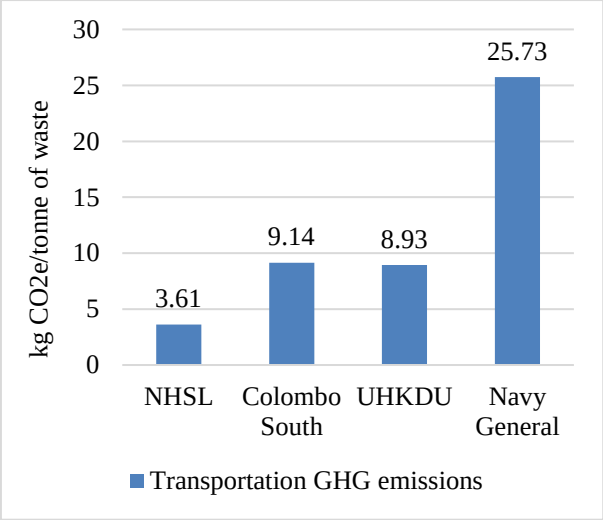

Figure 9. Non-hazardous waste transportation emissions

Emission due to transportation depends on the route the waste truck takes and the monthly fuel consumption. The national Hospital of Sri Lanka's final disposal site is Muthurajawela which is the highest distance in all hospitals. Hence the maximum distance and highest fuel consumption occurs in that process. The emission of greenhouse gases can be reduced if the distance to the landfill is reduced.

The emissions and savings related to composting showed a high value of minus (-) values in the net emissions. A ton of waste degradation will give a value of 177 kg CO_2e. This shows that the process is avoiding greenhouse gas emissions and savings the possible emissions. The avoided savings is defining that the number of emissions that is avoided, by terminating the waste to go and degrade at the landfill and emit methane (CH_4) emissions.

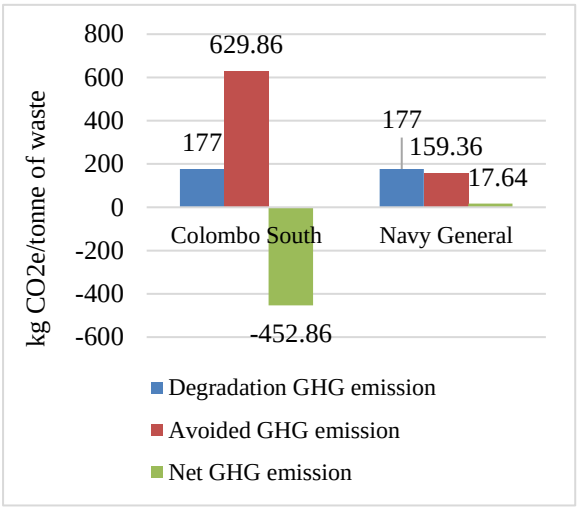

Figure 10. Non-hazardous waste composting emissions

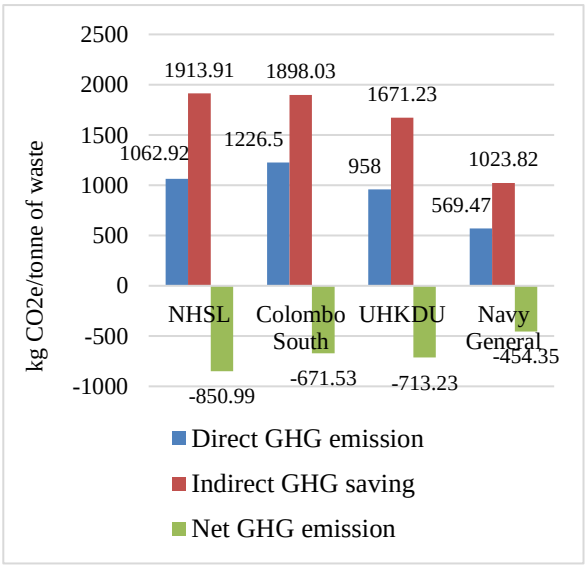

Figure 11. Waste recycling emissions and savings

If considering the composting process alone, the Colombo South Teaching hospital has achieved net zero emissions and saving the possible emissions that is expected at landfills.

Final Estimation

The final estimation with all the wastes and all the emissions studied in the research is as follows in Table VIII. Due to the 4 hospitals in the study, an estimated value of 263.163 kg of CO_2e per tonne of waste will be emitted to atmosphere due to processes in waste management with a waste amount of 281860.16 kg (281.86 tonnes) of average monthly total waste. The net emittance of greenhouse gas carbon dioxide equivalence (kg CO_2e) were 74 176.85 kg CO_2e.

Table 8. Final emissions per month and per tonne of waste

	Direct Emissions	Indirect Savings	Net Emissions
Total monthly	75145.77	-968.92	74176.85
Per tonne of waste	266.60	-3.437	263.163

The direct emission per tonne of healthcare waste studied in the research emits 266.6 kg CO_2e. However, with the emission saving processes such as composting and recycling reduces the total emission by 3.437 kg CO_2e. This gives the final net emission value of 263.163 kg CO_2e per tonne of waste from the studied 4 medical facilities.

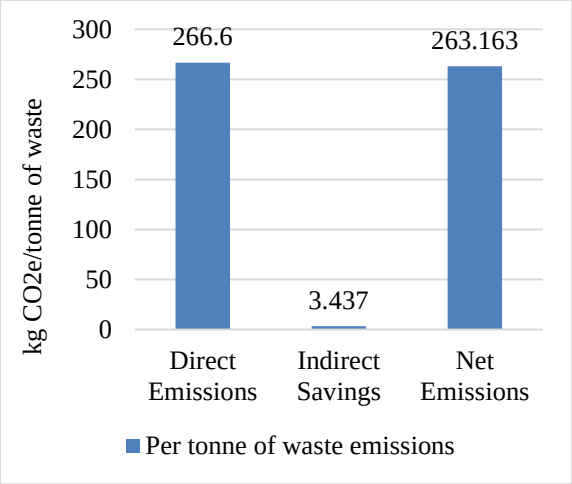

Figure 12 - Per tonne waste emissions

- Total waste data collected = 2810860.16 kg (281.86 tonne)
- Total net emissions per tonne = 263.163 kg of CO_2e per tonne of waste

As for simplification of the research, from the cradle to gate analysis of healthcare waste a single tonne of waste will emit a net amount of 263.163 kilograms of carbon dioxide equilants of greenhouse gases in the entire disposal route.

V. CONCLUSION

The study consists of present-day healthcare waste management and the greenhouse gas emissions from the processes that the waste goes through.

The direct emissions, indirect emissions and emission savings from healthcare wastes were estimated in the study. The study was divided in to 3 different steps and conducted through site visits and data gathering. And the final results of emissions due to a tonne of healthcare waste were estimated.

The minus (-) values show the significant saving is higher than the emission in the whole process. Considering the air quality and pollutant emissions in the study authorities should enforce more emission standards for the healthcare waste managements and its processes. Modern technology could be equipped with the current high fuel consuming and electricity consuming machinery, more focus towards composting and recycling of materials and such actions could avoid and prevent higher emissions of greenhouse gases.

The amounts in results are at the stable situation when considering studies from other countries regarding healthcare waste and greenhouse emissions (Khan et al., 2019) as in Sri Lanka's waste management is more focusing in achieving higher values in energy saving and material recovery.

Through possible steps and actions, a more functional management system could prevent further emissions of greenhouse gases to the atmosphere by healthcare wastes.

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ACKNOWLEDGMENT

The author would like to express gratitude to everyone who supported and for the guidance delivered throughout this study.