CARBON FOOTPRINT REDUCTION FOR CLINICAL WASTE MANAGEMENT USING CLEANER PRODUCTION STRATEGIES AT A SELECTED HOSPITAL

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ABSTRACT

Due to energy and material consumptions and waste produced, hospital operations generate high level of carbon footprint. In this study a detail analysis was done on carbon footprint generation from clinical waste and was assessed using cleaner production audit. University Malaya Medical Center (UMMC) was chosen as a case study for this purpose. It is estimated that the generation rate for clinical wastes is 0.99 kg per occupied bed per day, which translate into about 32 tons of CO_2 per month. This is estimated based on actual total average clinical waste generated from various departments in 2016. Subsequently 17 major cleaner productions were generated and total reduction in carbon footprint and cost was also estimated. The implementation of these options can potentially reduce about 11% carbon footprints or at 0.88 kgCO_2/bed/day (or reduction about 42 tons of CO_2 per year). This reduction can also potentially reduce cost of operation by 11% (or RM 29,000 saving per month). This study proves that CP can be a strategy to reduce carbon footprint in hospitals and can be adapted by other hospital in Malaysia.

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ABSTRAK

Oleh kerana penggunaan tenaga dan bahan dan sisa yang dihasilkan, operasi hospital menjana tahap karbon yang tinggi. Dalam kajian ini, analisis terperinci telah dilakukan pada penghasilan jejak karbon dari sisa klinikal yang dinilai menggunakan audit pengeluaran yang lebih bersih. Pusat Perubatan Universiti Malaya (UMMC) dipilih sebagai kajian kes untuk tujuan ini. Dianggarkan bahawa kadar penjanaan buangan klinikal adalah 0.99 kg setiap katil yang diduduki setiap hari, yang diterjemahkan kepada kira-kira 32 tan CO_2 sebulan. Ini dianggarkan berdasarkan jumlah sebenar purata sisa klinikal yang dijana daripada pelbagai jabatan pada tahun 2016. Seterusnya 17 pengeluaran bersih utama dihasilkan dan pengurangan jumlah jejak karbon dan kos juga dianggarkan. Pelaksanaan pilihan ini berpotensi untuk mengurangkan kira-kira 11% jejak karbon karbon atau pada 0.88 kgCO_2 / katil / hari (atau pengurangan kira-kira 42 tan CO_2 setahun). Pengurangan ini juga berpotensi mengurangkan kos operasi sebanyak 11% (atau RM 29,000 penjimatan sebulan). Kajian ini membuktikan bahawa CP boleh menjadi strategi untuk mengurangkan jejak karbon di hospital dan boleh digunakan di hospital lain di Malaysia.

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LIST OF SYMBOLS AND ABBREVIATIONS

ALOS	:	Average Length of Stay
CP	:	Cleaner Production
CFP	:	Carbon Footprint
CO_2	:	Carbon Dioxide
DOE	:	Department of Environment
EU	:	European Union
EMS	:	Environmental Management System
ERP	:	Emergency Response Plan
GHG	:	Greenhouse Gas
HIV	:	Human Immunodeficiency Virus
IPCC	:	Intergovernmental Panel on Climate Change
ICU	:	Intensive Care Unit
ISO	:	International Standard Organizations
NIOSH	:	National Institute of Occupational Safety and Health
OSHA	:	Occupational Safety and Health Act
OHSAS	:	Occupational Health and Safety Assessment Series
SOP	:	Standard Operating Procedure
SDS	:	Safety Data Sheets
SDI	:	Sustainable Development Indicators
UMMC	:	University Malaya Medical Centre
UNEP	:	United Nation Environment Program
PPE	:	Personal Protective Equipment
WHO	:	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background

Rapid growth and development in economic activity across the world results in increasing in human activities gives a large impact on the natural environment which lead to irreversible damage to the global environment. In 2007, the Intergovernmental Panel on Climate Change found that the global warming was very likely due to emission of anthropogenic greenhouse gas (GHG). While there are a variety of GHG that impact climate change, CO_2 which also referred to as simply carbon, as in *carbon footprint* is the most important of the human-caused GHGs. WHO reported that the main issue in greenhouse gases is the carbon dioxide emissions which contributed up to 40% of the global emissions.

Clinical waste is one of the sources that produce carbon footprint emission. Clinical waste is different from any other waste produced in the hospitals. Clinical waste consists of various of waste including human blood or tissue, sharp waste such as the usable syringe, urine and stool sample, and other infectious materials which may pose potential health and risks towards environmental. According to Shinee *et al*, approximately, 15 – 25% of clinical wastes are considered infectious. The problem in managing the clinical waste is similar in most hospital and healthcare institutional from the segregation of the waste until the disposal even though there's different in their current practices. Improper management of clinical waste can endanger the human survivals and also impact the natural resources.

In this work, a study was conducted to evaluate the feasibility of using Cleaner Production (CP) strategy in reducing the emission of carbon dioxide (CO_2) in a clinical waste management. The United Nations Environment Program established in 1991 stated that the CP definition is "the continuous application of an integrated preventive

environmental strategy to processes, products, and services in order to increase overall efficiency, and reduce risks to humans and the environment"(U. N. I. D. Organization). Cleaner Production can be used in any industry including in waste management, to products themselves and to provide various services in society. It is a broad term that embraces terms such as pollution prevention, eco-efficiency, and green productivity. In essence, Cleaner Production application can be used to protect the worker as well as the environment while improving industrial efficiency, profitability, and competitiveness. Meanwhile, CP strategy is developing to reduce the emission of CO_2 while also taking into consideration all other aspects in increasing the eco-efficiency and risks reduction toward humans and the environment. Due to this objective, a CP audit will be conducted and the data obtained will be analyzed to evaluate the CO_2 emission in order to implement the cleaner production strategies in managing the clinical waste.

1.2 Research Problem

Health sector including hospital contribute a significant number of greenhouse gases from the generation of clinical waste. The emission of carbon footprint can be generated direct and indirect, for example direct emission due to consumption of fuel and diesel while indirect emission generated from water, electricity and waste. Climate change due to the emissions of carbon can lead to serious consequences towards humans and the environment. The emission of the carbon leads to the raising of global temperatures due to the trapping of solar energy in the atmosphere. Implementation of cleaner production strategies is a one way to reduce the emission of carbon footprint emission.

1. What is the issue related in the clinical waste management in the selected hospital?
2. What is the amount of generated carbon footprint due to the clinical waste production?

3. What are the Cleaner Production options that can be implemented to reduce carbon footprint in the selected hospital?

1.3 Aim of the study

The aim of this study is to evaluate if cleaner production strategies can be used in reducing Carbon Footprint (CFP) in a clinical waste management in UMMC.

1.4 Objectives of the study

The objectives include:-

i. To conduct a Cleaner Production (CP) audit with respect to clinical waste in University Malaya Medical Centre (UMMC).
ii. To estimate Carbon Footprint (CFP) generation per kg of clinical waste generated.
iii. To identify and evaluate Cleaner Production (CP) options to reduce Carbon Footprint (CFP) for managing clinical waste.

1.5 Scope of the study

The research was conducted in Outsourcing Section in the University of Malaya Medical Centre (UMMC) who is responsible for the waste management including clinical waste and municipal waste. The scope of the study was focused on the activities related with the clinical waste management.

1.6 Thesis Outline

This project consists of 5 chapters as follows:

Chapter 1 - Introduction about the background research of the project regarding the management of clinical waste in the hospital. Beneficial of implementation of cleaner production strategies in order to reduce the carbon footprint emission from the clinical waste generated has been reviewed. This chapter also discusses the problem statement, research objectives, and scope of research.

Chapter 2 – Literature review based on the past and current finding of the clinical waste management in Malaysia and other countries has been discussed. The information regarding carbon footprint, cleaner production strategy and also the implementation of cleaner production was also discussed.

Chapter 3- In this chapter, the materials and methodology were explained. The method that will be using is a site visit, interview, and data collection. An audit has been conducted and the data from segregations of the clinical waste until the disposal was collected. The formula to calculate carbon footprint was also stated in this chapter.

Chapter 4 – The data obtained was analyzed and been discussed. The result from the key issue in the clinical waste management in UMMC has been discussed. The total carbon footprint per kg of clinical waste generated was calculated and the CP options have been evaluated. Pollution prevention and safety and health suggestion were also stated in this chapter.

Chapter 5- Conclusion of the finding reflected the objectives have been obtained and recommendation for future work was summarized.

CHAPTER 2: LITERATURE REVIEW

2.1 Global warming and climate change

According to the Intergovernmental Panel on Climate Change (IPCC), due to the warming of the climate change has cause several effects towards global including warming the atmosphere and oceans, diminished the amount of snow and ice, rising the sea levels and also increased the greenhouse gases concentration (Stocker, 2014). Due to these circumstances, Malaysia has taken a step and effort to address the climate change and continually assessing the mitigation source and potential in every key sector. Malaysia has come out with a National Policy on Climate Change, approved by the Cabinet in 2009 providing the structure and guidance towards various sectors including government agencies, communities, industry and other stakeholders focusing on the challenges and barrier upon climate change issue. The aim is to ensure climate-resilient development in order to fulfill national aspirations toward sustainable development (Malaysia, 2009). The objective of the National Policy on Climate is to prevail in the management of the resources and increased the environmental conservation. Development of a proper work plan including national policies, plan, and program is important towards the implementation to achieve the economic stabilization and quality of life improvement. Meanwhile, during the Tenth Malaysia Plan (2011-2015), the government emphasized in focusing toward sustainable growth and proposing a mitigation plan and strategies to reduce the greenhouse gases emission. Malaysia had already achieved a 33% reduction of GHG by the end of year 2013 (Ekonomi, 2010). The government commitment towards sustainable development continues to pursue the green growth goal under the Eleventh Malaysia Plan (2016-2020) further focusing on pursuing green growth for sustainability and resilience (*Malaysia Biennial Update Report To The UNFCCC*, 2015). Four main focus areas have been highlighted including strengthening the enabling environment for green

growth, adopting the sustainable consumption and production concept, natural resources conserving and strengthening resilience against climate change and natural disasters. Implementation of these actions will further reduce the Malaysia's carbon footprint (Unit, 2015).

2.2 Carbon Footprint

Natural sources depletion and environmental impact create an impact towards the communities. The Intergovernmental Panel on Climate Change (IPCC) insisted that the generation of the greenhouse effect has to encounter big problem towards climate change. A study by Munoz in 2012 indicated that strategies to reduce the impact of carbon footprint are challenging although the consequences and significance of health care's carbon footprint are undeniable. Global warming and environmentalism continue to be broad issues national and internationally due to their complexities and implications become better understood. Health care system is of the ironic contributor to the degradation of the environment. Hospitals in the United States itself generate more than 2 million tons of waste annually through their services in clinical laboratories, wards, and others (Muñoz, 2012). Main critical issues in poor handling and management system in clinical waste can highly increase the exposure of the workers and the public towards the diseases, infection, and illness and also can contribute pollution towards the environment. In 2011, World Health Organization (WHO) emphasized the important of managing the medical waste from the point of segregation, appropriate treatment, and safety disposal. Today, European Union (EU) list of Sustainable Development Indicators (SDI) state that efficient and adequate use of resources and sustainable waste management systems are one of the main priorities topic focusing on waste minimization. The 7th Environment Action Program has been launched with a focus on reduction of waste generation policy, maximization of recycling and re-uses, incineration limitation to non-recyclable material, phasing out landfilling to non-

recyclable and non-recoverable waste and also to ensure full implementation and commitment of the waste policy from every sector (Căilean & Teodosiu, 2016). Moreover, the issues regarding CO_2 have been discussed over the year and Malaysian government has taken initiative in sustainability promotion in the way to protect the environment. Malaysia committed to reducing about 40% of CO_2 intensity by 2020, compared to the level in 2005 during United Nation's Climate Change Summit in 2009 (Rahim & Raman, 2017). The commitment between all stakeholders is important to achieve the sustainable development.

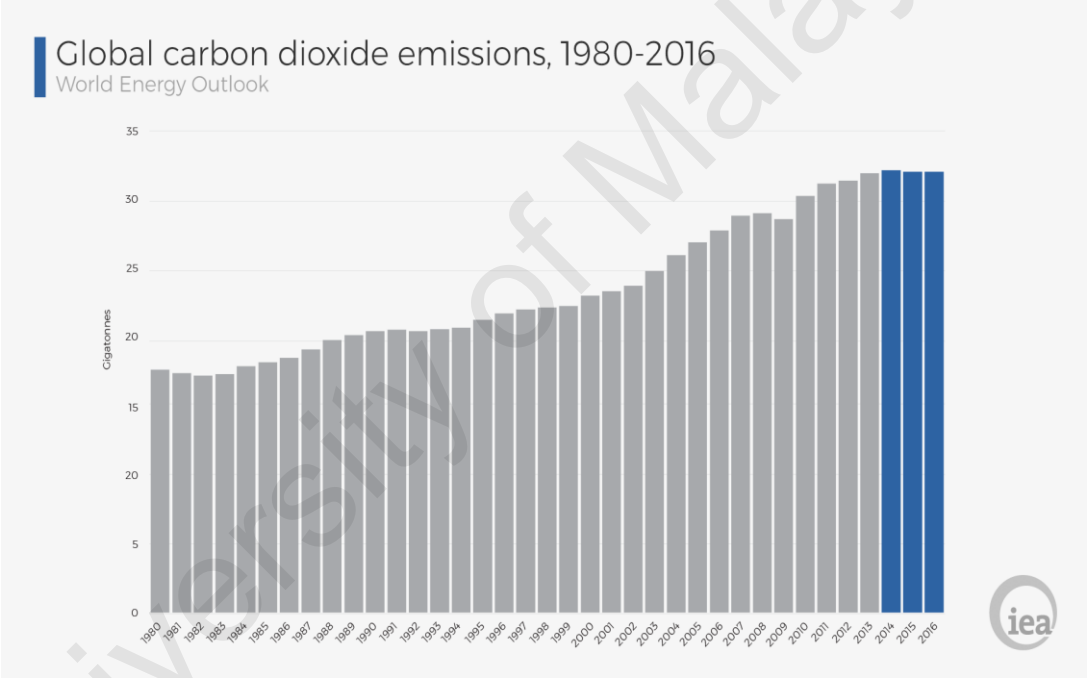


Figure 2.1: Global Carbon Dioxide Emissions (Agency, 2017)

The figure 2.1 shows the carbon dioxide emissions from 1980 to 2016 as reported by International Energy Agency. It is reported that from year 2014 to 2016, the global energy-related carbon dioxide emissions were flat for a third straight year even the global economy increase in 3.1%. This is a signal that a step has been taken towards sustainable development including improvements in energy efficiency and renewable power generation.

2.3 Clinical Waste

Generation of clinical waste is one source of greenhouse gas emission. CO_2 is one of major contributor to greenhouse gas. In Malaysia, under the Environmental Quality (Scheduled Wastes) Regulations, 2005 clinical waste is classified as scheduled waste which includes:-

i. SW403 - Discarded drugs containing psychotropic substances or containing substances that are harmful, toxic, carcinogenic, mutagenic or teratogenic;
ii. SW404 - Pathogenic and clinical wastes and quarantined 9 materials;
iii. SW421 - A scheduled wastes mixture;
iv. SW422 - A scheduled and non-scheduled wastes mixture.

According to the regulation, the following waste criteria have been included recently as scheduled wastes including;

- Waste from the pharmaceutical preparation and product and also discarded drugs which contain substances that are harmful, toxic, carcinogenic, mutagenic and also teratogenic
- Waste that are contains one or more hazardous substances or products which is explosive, flammable, oxidizing, corrosive, and irritant

Minister of Health in further define the clinical waste definition in the guidelines including;

- Any production of waste consists of partly or wholly of animal or human tissues, blood including other body fluid and excretions, pharmaceutical products, syringes and other sharp wastes, swabs or dressings, and

- Any production of waste from medical, dental, nursing, veterinary, teaching or research, treatment, and blood transfusion collection, being waste which can bring infection to a person who has a contact with it.

The table 2.1 below shows the clinical waste classification used for the practice in the healthcare sector as mentioned in the guidelines;

Table 2.1: Major classification of clinical waste and recommended management guidance in Malaysia

Description	Recommended waste management guidance
1. Blood an body fluid waste i. Soiled surgical dressings, e.g. cotton wool, gloves, swabs. All contaminated waste from treatment area. Plasters, bandages which have come into contact with blood or wounds, cloths and wiping materials used to clear up body fluids and spills of blood ii. Material other than reusable linen, from cases of infectious diseases (e.g. human biopsy materials, blood, urine, stools)	Special requirement on the management from the viewpoint of infection prevention. These categories of waste must always be incinerated completely in an appropriate incinerator.

Description	Recommended waste management guidance
iii. Pathological waste including all human tissues (whether infected or not), organs, limbs, body parts, placenta and human fetuses, animal carcasses and tissues from laboratories and all related swabs and dressings.	
2. Waste posing the risk of injury (sharps) All objects and materials which are closely linked with healthcare activities and pose a potential risk of injury and/ infection, e.g. needles, scalpel blades, blades and saw, any other instruments that could cause a cut or puncture.	Collected and managed separately from other waste. The collection container; must be punctured resistant and leak tight. This category of waste has to be disposed/ destroyed completely as to prevent potential risk of injury / infection
3. Infectious wastes Clinical waste arising from laboratories (e.g. pathology, hematology, blood transfusion, microbiology, histology) and post mortem rooms, other than waste included in category 1 waste**.**	Special requirement on the management from the view point of infection prevention. This category of waste must always be incinerated completely in an appropriate incinerator.

Description	Recommended waste management guidance
4. Pharmaceutical and Cytotoxic Pharmaceutical Wastes i. Pharmaceuticals which have become unusable for the following reasons: - • expiry date exceeded; • expiry date exceeded after the packaging has been opened or the ready-to-use preparation prepared by the user; or • use is not possible for other reasons (e.g. call-back campaign) ii. Wastes arising in the use, manufacture and preparation of, and in the oncological treatment of patients with, pharmaceuticals with a cytotoxic effect (mutagenic, carcinogenic and teratogenic properties).	Class I - pharmaceuticals such as chamomile tea, cough syrup, and the like which pose no hazard during collection, intermediate storage and waste management: managed jointly with municipal wastes. Class II - pharmaceuticals which pose a potential hazard when used improperly by unauthorized persons: managed in an appropriate waste disposal facility. Class III - Heavy metal- containing unidentifiable pharmaceuticals: managed in an appropriate waste disposal facility. Intermediate storage of these wastes takes place under controlled and locked conditions. For reasons of occupational safety, cytotoxic pharmaceutical wastes must be collected separately from pharmaceutical waste and disposed off in a hazardous waste incineration plant.

Descriptions	Recommended waste management guidance
5. Other infectious wastes All healthcare wastes known or clinically assessed by a medical practitioner or veterinary/ surgeon to have the potential of transmitting infectious agents to humans or animals. Used disposable bed-pan inners, urine containers, incontinence pads and stoma bags.	Disposed off in a hazardous waste incineration plant licensed by the Department of Environment (DOE).

(Source: Guidelines on the handling and management of clinical wastes in Malaysia)

It is the responsibility of the concession company to supply all the equipment needed such as yellow plastic and bin and also sharp bin (Department of Environment, 2009). All clinical wastes should be deposited in yellow plastic beg provided by the concession company. In 2014, according to the Malaysia Environmental Quality Report by DOE, about 25,523.32 metric tons of clinical waste was incinerated at licensed off-site facilities (Department of Environment, 2014). This show an increment of waste generated compare to 2013 which 21,975.32 metric tons of clinical wastes were incinerated at licensed off-site facilities (Department of Environment, 2013). The increment goes rapidly for this 5 years period from the year 2010 where only 16,781.08 metric tons of clinical waste were incinerated (Department of Environment, 2010). The generation rate for clinical waste is estimated varies from 0.3 to 0.8 kg per occupied bed

per day. An immediate action needs to be taken to overcome this issue to prevent a greater pollution towards our environment. Figure 2.2 shows the clinical waste generation in Malaysia from 2010 until 2014.

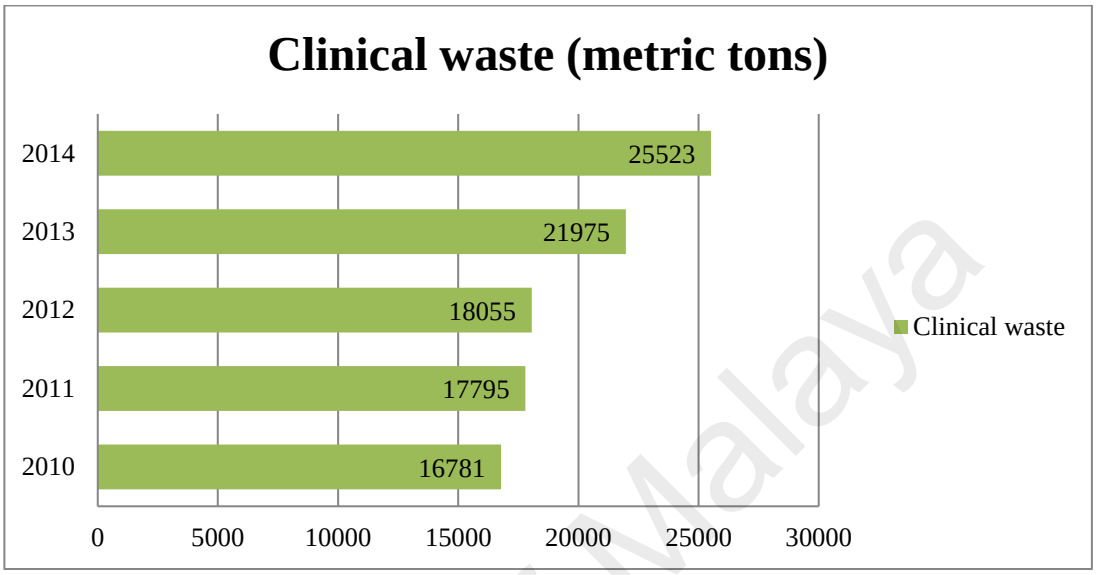


Figure 2.2: Clinical waste generation in Malaysia from 2010 until 2014 (Metric tons/year)(Department of Environment, 2014)

From the trend, it shows the increment of clinical waste disposal from 2010 until 2014. This increment can lead a pollution towards the environment and harmful to the human health if improper handling and management of clinical waste. The emission of greenhouse gases including CO_2 can give a negative impact towards climate changes.

2.4 Clinical Waste Management

The sources of clinical waste in the hospital are mainly from the wards, operating theatre, laboratory waste, pharmacy, clinics and other hospital facilities (Bendjoudi et al., 2009). Several factors contribute to the generation of the clinical waste including general condition of the hospital area, the ratio of the disposable item and also a number of the patient including inpatients and outpatients (Alagöz & Kocasoy, 2008). The number of the patients has a significant effect on the generation of the waste

compared to the other factors (Patwary et al., 2009). One of the challenges that humanity currently faced is managing clinical waste management that proves to be far more complex and demanding for medical services that it used to be years ago. The total kilograms of clinical waste produced by hospital per day is divided with the total number of occupied beds in the hospital is a common metric used for quantifying the amount of clinical waste generated at the hospital. The kg/bed/day is a metric used to attempt the generation of waste in the hospital and act as a basis for a comparison for the production of hospital waste. Studies finding that the number of occupied bed in hospitals is related to the amount of clinical waste generated (Windfeld & Brooks, 2015). Table 2.2 shows the comparison of waste generation rates reported in different countries. From finding, it stated that low waste generation rates in developing countries compared to other countries such as Europe and America (Hamoda, El-Tomi, & Bahman, 2005; Mohee, 2005)

Table 2.2: Comparison of waste generation rates at hospital in other countries

Country	Generation rate (kg/patient/day)
Canada	4.1
France	3.3
Iran	2.7
Saudi Arabia	1.1
Spain	4.4
United Kingdom	3.3
USA	4.4

World Health Organization (WHO) classified clinical waste as “waste that is generated in the diagnosis, treatment or immunization of human beings or animals.” Clinical waste disposal is a broad issue of considerable scale. In the United States alone as the world's top medical waste producing nation, it creates over 3.5 million tons of medical waste per year with an average disposal cost of $790 per tons (Lee et al., 2004). Due to their potentially dangerous and polluting towards the environment, clinical waste

management and disposal is a matter of continuing public and professional concern. Errors in waste management continue to occur at every point of the disposal chain. A proper care and handling of the clinical waste is important to minimize the risk of the infection. However, the implications of blood-borne virus infection and environmental impact mandate great care in the handling, packaging, storage, and processing of wastes (J. I. Blenkharn, 2011). The source, quality, and quantity of the waste generation play an important role in deciding the effective and comprehensive clinical waste management practice (Coker et al., 2009). Another issue regarding the disposal of clinical waste is to ensure the personnel do not come into contact with the disposing of infectious items whether accidentally or on purpose. Studies focusing in the United Kingdom found that majority of the hospitals doesn't have adequate safety system to prevent these contact with the hazardous medical waste and also the standard operating procedure which frequently neglected by the staff and personnel (J. Blenkharn, 2006). Another study in India has reported an issue with clinical waste management where the government confronting with the disease outbreaks due to the reselling items such as sharps to the black market for reuse purposes. It reported that almost 10% the health facilities in India sold the used syringes to the waste–picker (Solberg, 2009). It is important that every personnel should be noted that the infectious clinical waste cannot be reused, regardless of the use of a sterilization process (Zhao et al., 2009). An increment in the production of waste in healthcare facilities in developing countries has become a major concern due to inappropriate treatment and disposal practices (Diaz et al., 2005). An effort and awareness for better understanding on the waste management have influenced many countries to develop national and local strategies for better management of their waste (Al-Zahrani et al., 2000). Every stakeholder plays important roles to ensure the effectiveness of clinical waste management in every institution.

2.5 Clinical Waste Management Practice in Malaysia

In Malaysia, clinical waste generation has increased significantly over the last few decades. The crucial management system in handling clinical waste during 1980's and due to the emergence of Human Immunodeficiency Virus (HIV) has lead the collaboration between Ministry of Health and Department of Environment to review the policies and guidelines for prevention and control of infectious disease and handling of clinical waste. A study conducted in 2009 shows that the average rates of the total clinical waste generation in government hospitals in Selangor were estimated to be 1.355 kg/bed/day (Razali, 2011). From the finding, it shows that the major issues arise in clinical waste management is due to non-segregated waste, awareness as well as attitudes among the hospital's staff and the patients as well. The current practices need to be revised and improved in order reduce the hazards and risks to the ecosystem and the community.

Another study was conducted which focus on the clinical waste management in the district hospital of Tumpat, Batu Pahat and Taiping cover the critical aspects in the process of clinical waste from the generation of clinical waste until the final disposal (Omar et al., 2012). Poor clinical waste management will result in problems towards safety, health, and environment (M. Ali & Kuroiwa, 2009). Generally, the most common issue in clinical waste management was due to improper waste segregation from the source and mixture of general waste into clinical waste which results in additional cost to the hospital. From the study, it stated that although the clinical waste management is following the standard and regulations, a continuous proper clinical waste management was difficult to practice due to several weaknesses and deficiencies from the management (Omar et al., 2012). In many countries including developed countries, World Health Organization (WHO) emphasized that the main issues in clinical waste management was due to poor management and disposal handling which

will pose a threat towards human life, safety and healthy working environment (Ananth et al., 2010). Proper management practice in handling the clinical waste was important in order to prevent any incident and accident among the personnel and all staff members.

2.6 Cleaner Production Audit

Cleaner production audit was a tool used in developing cleaner production plan for economical, technical and environment feasibility. According to Cleaner Production Audit Guidelines, CP audit is a "management tool comprising a systematic, documented, periodic and objective review of a company's processes, products and operations, designed to identify and provide information about opportunities to reduce environmental hazard, by reducing the use of hazardous substances in the product life cycle". The important of an audit was to assess the function of the existing production systems, to identify and implement suitable management action that needs to be taken and also to attain the integrated objectives towards environmental protection (Environment, 2007). A waste audit was one of an essential step in promoting cleaner production. Development of this management tool is to interact with the prevention and reduction of waste in the environmental management philosophy. UNEP (Baldasano, 1991) emphasized that a waste audit was a comprehensive tool to encourage understanding regarding material flows and also in focusing on the areas of waste reduction which can lead to a cost saving. China is one example of a country which highly active promoting cleaner production. The basic step in the CP audit that has been practiced is an inquisitional procedure, selection of the scheme, feasibility analysis, program implementation and sustainable cleaner production. Cleaner production audit can cut down the cost, material, and energy consumption in the industries sector. As for country, audit tools can be used as a benchmark for energy conservation and reduction of greenhouse gases emission (Wei Li, 2015). In Malaysia, Department of Environment

(DOE) has come out with a Cleaner Production Audit Guidelines as an effort to provide an opportunity to the industries in order to increase the effectiveness of resource utilization, encourage the waste minimization, recycling and reuse to comply with the environmental regulation (Environment, 2007).

2.7 Cleaner Production Implementation

For general, cleaner production is a preventive and company-specific environmental protection initiative which is intended in waste and emission minimization with the outcome of product output maximization (Y. Ali & Fresner, 2006). Implementation of cleaner production has been developed in many sectors including mining industries (Jia et al., 2014), ceramics industries (Huang et al., 2013) and production plant (Rahim & Raman, 2015). However, the adoption of the CP still lacks in many other industries although it has been rapidly applied (Dieleman, 2007). Promoting the cleaner production is important for the conservation of the environmental performance within human and society (de Vries et al., 2012). The use of International Standard Organizations (ISO)'s ISO 14001 environmental management system (EMS), a standard that encourages the global sector to apply environmental efforts (Rahim & Raman, 2017) and gives a positive impact and influence all stakeholders towards environmental performance (de Vries et al., 2012). However, due to the lack of environmentally friendly culture and behavior is an obstacle towards an effort in promoting cleaner production in organizations (Vieira & Amaral, 2016). According to reports of United Nations, the CP options include the following categories (UNEP, 2002):

1- Good housekeeping or good operating practices.

2- Material and raw material changes.

3- Technological modifications.

4- Product modifications.

5- On-site reuse and recycling

Several options that can be used by the health facilities in order to reduce waste generated and emissions through composting, recycling, better purchasing and waste transport minimization for local treatment and disposal. Rather than incinerated, the small portion of clinical waste that is potentially infectious might have a high proportion of plastics and can be landfilled after disinfection. High quantities of greenhouse gases will be produced during the burning process and will pollute the environments with the toxic pollutants including furans and dioxins (W. H. Organization, 2004). Adoption of integrated framework and multi-tool strategy including environmental management systems and other socio-economic incentives can be practiced in order to implement cleaner production. Government acts as an important stakeholder to create policies and strategies towards clear objectives and technological tools to ensure their realization and environmental training and education for the purpose of a long-term result. Furthermore, cleaner production will thus be a part of conventional economic and social practice by paying more attention to ecological industries and sustainable consumption.

2.8 Case study 1

A study conducted in Libya focused on the management of hospital waste reported that the hospital produces 28% of hazardous waste which includes clinical waste and infectious waste. The waste generated was weighed and the average quantity was determined. The average waste generation rate was 1.3 kg/patient/day. Out of 14 hospitals, only 2 hospitals (14%) have implemented waste management policy where the sharp waste was collected in close plastic containers and plastic bags before transported to the respective incinerators. From the finding, about 85% of their personnel were not properly trained regarding the waste management and unaware of the potential hazard that might present from the hazardous waste. The study also revealed that no proper documentation available in the hospital regarding the waste management (Sawalem et al., 2009). In general, it is important for all the personnel to take precautions in the clinical waste management including handling, collecting, separating, storing and disposing of the waste. Proper protection, training, and guidance are important to increase awareness among the staff involving whether directly or indirectly in the management of clinical waste.

2.9 Case study 2

Cleaner production in hospitals project has been developed in New Zealand health sector (Ltd, 1997). A study has been conducted in Hutt Valley Health hospital with approximately 1,400 staff and 320 bed hospitals using the CP approach in order to identify the options and opportunities for the hospital in the adoption of environmentally work practices. Every aspect has been audited including laboratories, pharmacy, wards, and others to ensure all the resources and production of waste been identified. A CP option has been identified and implementation of feasible options has been carried out involving the economic, environmental and technical evaluations of the opportunities. The result stated that the generation of the general waste is 190 tons/year

while special waste contributes to 66.5 tons/ year and recycled waste is 14 tons/year. The benefit from the waste monitoring was where the impact on the implementation options on the waste stream such as recycling can be monitored. A CP option has been recommended in clinical waste management as such the use of reusable sharp containers. Implementation of CP strategies helps in reducing the costs associated with consumption of resource and waste disposal as well as improving the environmental performance and also the public image of the hospital.

2.10 Case study 3

A CP audit has been conducted in Jordan public hospital with the aim to get an overview regarding the environmental performance of the health facilities and also to identify the areas which are suitable to implement CP strategies. The hospital consists of 400 beds with 1000 employees. For the year 2009, the medical waste generated was reported about 3300 kg and the water consumption was 4200 m^3. A CP audit has been conducted in the hospital and the CP options have been identified for the hospital which will bring environmental benefits, economic establishment and increase the safety for the staff as well as the patients. Several CP options have been adopted including the installation of water saving equipment which reduces the fresh water consumption and reducing in the generation of wastewater. Some benefits of CP implementation in the hospital are reducing in a number of raw material purchasing and also energy consumption. Other than that, number of waste and emission at the source also was reduced with improvement in eco-efficiency. Furthermore, awareness about the CP also increases among the staff in the hospital thus improving the environmental conditions and economic performance.

2.11 Summary of literature review

For the summary, it is crucial and important that all public and stakeholders understand their role and responsibilities in order to ensure the implementation of cleaner production strategies to reduce the impact of carbon emission from clinical waste production. Hospitals generate 0.3-0.8 kg/bed/day of hazardous waste which translates into high CO_2 generation. An action is needed to reduce the carbon footprint emission by implementing cleaner production strategies. Emission of carbon towards the environment is a global issue which will lead to the climate change and other environmental issues. So, a study is required to evaluate CP strategies that can be used to reduce the carbon footprint from the clinical waste in hospitals.

CHAPTER 3: METHODOLOGY

3.1 Material

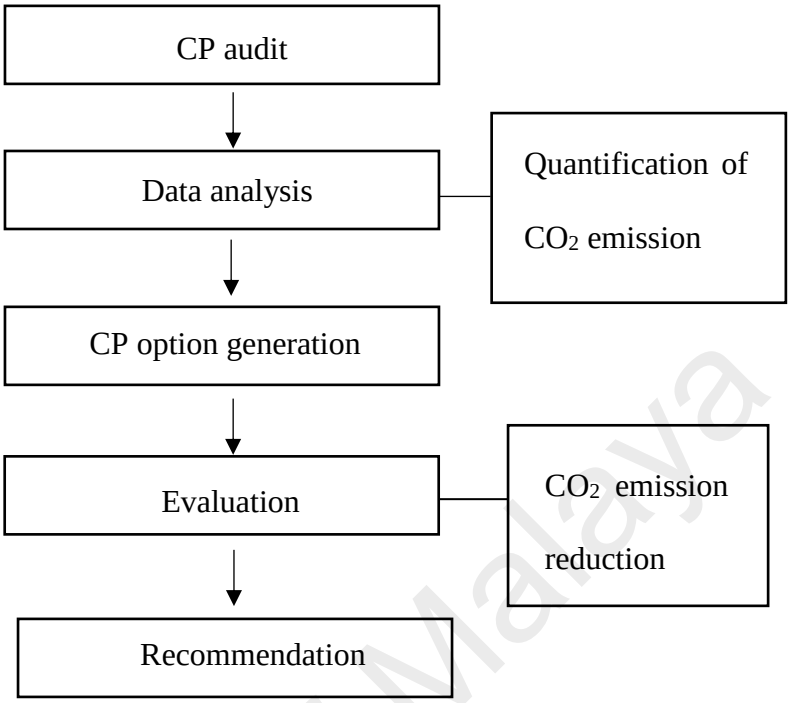
This study used an audit approach to explore the potential for sustainability in clinical waste management by measuring and estimating the Carbon Footprint (CFP) generation per kg of clinical waste generated and assessing the potential Cleaner Production (CP) options in the management of clinical waste.

3.2 Methods

This study focused on the University Malaya Medical Centre (UMMC) and the data on clinical waste generated from various departments for the year 2016 was obtained. A cleaner production audit was conducted to obtain a clear and comprehensive overview of the clinical waste management in order to achieve the objective of the audit including safety issues, resource efficiency, and waste minimization. Observation on the overall process in managing clinical waste has been done from the segregation to disposal steps. The CO_2 emissions generated was quantified and related CP strategies were evaluated. In this study, main methodologies were highlighted:

- Site visit to the department in charge of clinical waste management in UMMC
- Conduction of initial CP audit and interview to identify the current situation in management of clinical waste
- Carbon Footprint calculation
- Generation of CP options using standard CP options generation methodology

3.3 Overall methodology workflow



3.4 Site Visit

This study was conducted in the Facility Unit in UMMC which is divided into three section including Operation Section, Administration Section, and Outsourcing Section. The Outsourcing Section is responsible for the waste management including clinical waste and municipal waste. The NZS Bersatu Sdn. Bhd. is a concession company who has been hired to handle the clinical waste management.

3.5 Cleaner Production audit

It is important to conduct a CP audit in order to implement CP measures. An audit is a part of an on-going program which designed to gain a maximum resource optimization and performance process. A CP audit checklist has been provided during the observation and the data was collected in this study. Besides that, an interview has been performed with the management and person in charge to obtain the following information:

1. Current practice in clinical waste management
2. Number of bed in UMMC
3. Number of inpatients in UMMC
4. Clinical waste generation for the year 2016
5. Composition of waste
6. Information regarding disposal of waste

A problem associated with the clinical waste management also has been identified. A CP audit was conducted in the department with the guidance from the audit checklist. The following data has been obtained including:

1. Waste production
2. Water consumption
3. Safety & health management status

All the data obtained from the interview and CP audit process was accompanied by the organization's staff.

3.6 Carbon Footprint calculation

Carbon footprint (CFP) is the measurement used to estimate the impact of human's activities towards climate change. The calculation for CFP is not just depending on the emission of CO_2 but also the emission of other GHGs. The following are the basic formula to calculate CFP release to the atmosphere. The formula used for this study according to IPCC methodology is ("IPCC Guidelines for National Greenhouse Gas Inventories," 2006) :

Total CO_2 emission (kg CO_2) = Σ (Entity data x Entity Emission Factor)

Table 3.1: Carbon Emission Factor

Resources and waste	Emission	Unit	Reference
Electricity	0.67	kg CO_2/kWh	(Rahim & Raman,2017)
Waste Water	1	kg CO_2/m^3	(Rahim & Raman,2017)
Water	0.8	kg CO_2/m^3	(Cornejo et al,2017)
Solid Waste	3.7	kg CO_2/kg	(Murphy & McKeogh,2004)
Clinical Waste	0.57	kg CO_2/kg	(DEFRA, 2010)

The data was collected including total clinical waste per kg generated by the departments in the hospital per months and per year and amount of CO_2 produced has been calculated.

3.7 Generation of CP options

After the data had been obtained, it was analyzed to generate options to improve the issues in managing the clinical waste in UMMC including waste optimization, housekeeping, material substitution, technology change, recycling and reuse and training and awareness programmed for the staff. Safety and health risk issue in clinical waste management has also been discussed to get a clear overview and problem associated in the management. Implementation of these can contribute a wider view in generating the CP options in order to achieve the CP objectives.

3.8 Safety Precaution

During the audit process, safety issues regarding clinical waste management have also been analyzed. It is compulsory for all workers to wear personal protective equipment (PPE) before performing their task. A standard operation procedure also has been provided as guidance for all workers. Every worker needs to report to the manager before performing their task to the site allocated and adequate consumables including yellow plastic bags and sharp bin were provided to all workers. Every incident was reported to the manager including spillage and self-injury and been documented.

CHAPTER 4: RESULT & DISCUSSION

4.1 Cleaner Production Audit Summary

From the Cleaner Production (CP) audit, the following information has been collected including:

4.1.1 Site visit in UMMC

The scope of this study is focused on University Malaya Medical Centre, Kuala Lumpur. The institution is a large organization consists of about 53 departments which include clinical, clinical support and non- clinical departments (www.ummc.edu.my). It has approximately 1,439 beds which are distributed by 44 wards throughout the medical center serving a population of 1,782,375 for the district of Petaling.

NZS Bersatu Sdn. Bhd. was a concession company that is given responsibility in managing the clinical waste in UMMC. An interviewed has been conducted to gain the information with the site manager Encik Zahar and the administration executive, Puan Norziah from NZS Bersatu Sdn. Bhd. 14 workers were included for the clinical waste collection task.

Figure 4.1 shows the overall process flow for clinical waste management practice in UMMC.

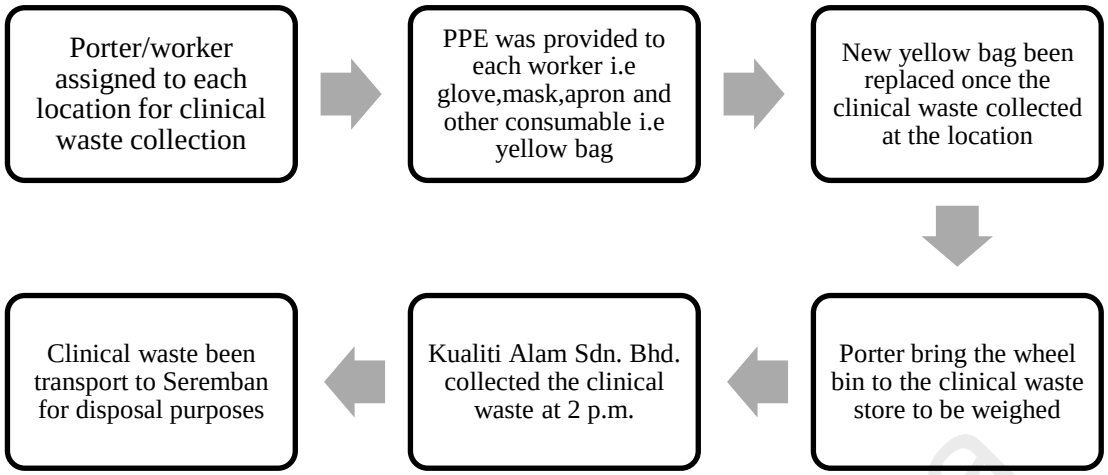


Figure 4.1: The process flow for Clinical Waste management practice in UMMC

The clinical waste was collected in 14 different areas in UMMC from 6 main building; main wing, north wing, south wing, women and children's health complex, dental faculty and medical psychology complex. The clinical waste collection is a daily basis consists of 3 shifts; morning, afternoon and night with the first collection start at 8.00 a.m. in the morning, at 2.00 p.m. for afternoon session and the last collection is at 7.00 p.m. The scope of their work was to ensure a clinical waste been collected at the assigned area, to supply and ensure enough consumable including yellow bag delivered, to ensure the cleanliness of the yellow bin and also disposal of the clinical waste.

Once the clinical waste has been collected, the worker will bring the waste using the wheeled bin to the clinical waste store to be weighed. The wheeled bin used was labelled with SW404 which used to collect the pathogenic and clinical waste. The bin been cleaned up and disinfected immediately following any spillage or accidental discharge. The clinical waste storage areas in UMMC are in the specific building and located at a site so as to minimize the movement of waste in the open from initial storage areas. The disposal procedure was handled by Kualiti Alam Sdn. Bhd., where the clinical waste was sent to Clinical Waste Treatment Centre in Seremban for disposal

process. The designated vehicles collected the waste twice a day at 2.00 p.m. and last collection at 8.00 p.m. Kualiti Alam Sdn. Bhd. was specialized in downstream hazardous waste management involving waste treatment and final disposal. It also has been recognizing for its excellence with various certifications includes MS ISO 9001, MS 1722, ISO 14001, OHSAS 18001 and ISO/IEC 17025. The Centre was equipped with the cutting edge technology in medical waste disposal, Microwave Ecosteryl. This revolutionary innovative medical waste treatment facility offers an eco-friendly process that uses minimal electricity while provides a safe and environmentally friendly solution to bio-medical and clinical-related industry players.

From the observation, safety measures have been taken by the management to ensure the safety of the workers. The workers were provided with personal protective equipment including glove, mask, apron and need to wear a cover shoes. This is to prevent the worker from any injury during handling the clinical waste. The standard operating procedure also has been provided to ensure all the workers to follow the guidelines before performing their task. Every worker has to take their own responsibility to protect themselves from any injury. From the report, the incident had occurred during handling the clinical waste such as finger pricking with the needle which is accidentally dispose in the yellow bags and spillage of wastewater due to leakage of yellow bags. These occur due to improper disposing of sharp waste from the staff where the sharp waste should be disposed in the sharp bin. Any incident occur has been reported to the management and action was taken immediately. The management will bring the affected worker to the clinic and appropriate treatment was given. In the case of spillage, the cleaner cleaned and disinfected the area with the appropriate detergent provided by the hospital. The entire reported incidents were documented for further references. Figure 4.2 shows the complete PPE has been provided to the porter before performing their task.

Figure 4.2: Porter provided with PPE before performing task

Figure 4.3 shows the porter taken out the clean wheel bin to the assigned location.

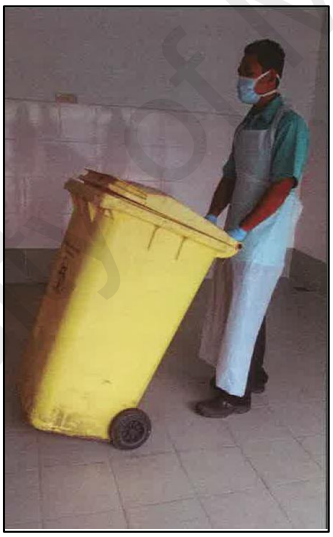


Figure 4.3: Clean wheel bin taken from store to the assigned location

4.1.2 Clinical Waste category

The clinical waste can be categorized into 5 group; group A consists of medical cloth, gloves, bandage ,dressing and biopsy material including blood, urine and stool, group B is a sharp waste including scalpel, slide, blades and syringe, group C consists of waste from pathology laboratory, hematology and blood transfusion, microbiology, histopathology, animal carcasses, and clinical waste from operational theatre.

Meanwhile, for group D, it consists of waste from expired and unused medicine and drugs, and group E waste consist of urine container, used disposable bed pan linen, incontinence pad, and stoma bag. Table 4.1 shows the clinical waste category comprises of the clinical waste groups, source of waste and activity and also the level of the risk for each clinical waste group.

Table 4.1: Clinical Waste Category

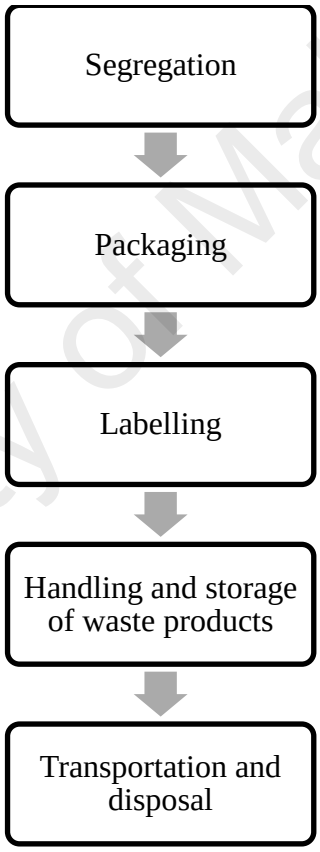
Group	Source of waste/activity	Level of risk
A  	• Medical cloth, gloves, bandage ,dressing and wiping material used to clean the body fluid • Biopsy material including blood, urine and stool	Contamination risk e.g. Waste comprises of non-infectious human body parts, organs and tissues and blood bags. It is warranted to assume that these wastes might be contaminated with pathogens
B 	• Sharp waste including scalpel, slide, blades and syringe	Highly hazardous e.g. Sharp injury during handling sharp waste contaminated with infectious agents, needle prick injury.

Group	Source of waste/activity	Level of risk
C  	• Waste from pathology laboratory, hematology and blood transfusion, microbiology, • histopathology • Animal carcasses • Waste from operational theatre	Highly infectious e.g. Direct contact with culture waste contaminated by causative agents of diseases
D 	• Expired and unused medicine and drugs	Moderate risk e.g. Misused of expired or unused drugs by unauthorized person.
E  	• Used disposable bed pan linen, urine container, incontinence pad and stoma bag	Infectious e.g. Contamination during handling the waste.

All clinical wastes must be disposed using the yellow bag with the biohazard symbol in the plastic bag. All staff are responsible to ensure that the segregation of clinical waste is deposited only in yellow bags and is carried out at the source. Meanwhile sharp waste must be thrown in the sharp bins only. For general waste, black bags will be used for disposal purposes.

4.1.3 Clinical waste management process

The overall clinical waste management process in UMMC is as follows:



4.1.3.1 Segregation

It is the responsibility of nursing and clinical staff to ensure that segregation of clinical waste is carried out at the source and that all clinical wastes are deposited only in yellow bags and sharps in sharp bins only. The standard color coding for waste disposal should be followed by all healthcare industries;

Black : General waste

Yellow : Clinical wastes for incineration only

Light blue: Wastes for autoclaving or equivalent treatment before ultimate disposal

All clinical wastes that requiring autoclaving, or other equivalent treatment, before disposal, shall be stored in light blue autoclave bags before such treatment but should be placed in yellow plastic bags after treatment. The clinical waste should be disposed in the yellow bag with universal biological hazard symbol as appropriate. Basically, the clinical waste as such the sharp waste will be stored in puncture-proof containers. Figure 4.4 below shows the yellow plastic bag with biohazard symbol that been used for disposal of clinical wastes.

Figure 4.4: Yellow plastic bag for clinical waste disposal

Figure 4.5 below shows the sharp bin used for disposal of sharp waste. All sharp waste must be disposed in the sharp bin provided by the concession company.

Figure 4.5: Sharp bin for sharp waste disposal

From the observation, the staff in the hospital will separate the clinical waste and general waste accordingly. However, there is also an issue where the clinical waste is mixed up with the general waste. For example, the tissue and the disposable drip bottle were thrown in the yellow bin. Disposable drip bottle should be put aside for recycling purposes.

4.1.3.2 Packaging

Clinical waste should be put into appropriate containers as quickly as possible so as to avoid contaminating other materials and to minimize potential human exposure. Containers for holding clinical waste should be covered by secure lids. The containers should be in good condition and free from contamination, damage or any other defects which may impair their safe and secure use. Inspection has been done by the workers to define the condition of the container and change the container if the damage occurs. The sharp waste must be disposed in the sharp bin and the containers are rigid puncture-resistant containers that cannot be reopened. Containers of clinical waste should not be filled above the warning line indicating between 70% and 80% of their maximum volume before sealing. The packaging and sealing should be conducted with care to ensure that no clinical waste adheres to the external surface of the containers. From the observation, the clinical waste plastic bags were sealed by tying the neck securely to prevent spillage. The yellow bins were replaced with a new yellow plastic bag after sealing the clinical waste to be transported to the storage room. From the observation,

there's also an issue regarding disposable of sharp waste. Some of the sharp bin was overfilling with the sharp objects and it may lead to the incident to the porter and people surrounding. The porter will record and report to the management about the issue and notice that has been given to the person in charge in the department involved with the overfilling of sharp bin issues. Training and guidelines on a proper way to dispose of the sharp waste was given to the staff. Figure 4.6 below shows the porter sealing the clinical waste in the neck of the yellow plastic bag and replacing with a new plastic bag into the yellow bin.

Figure 4.6: Porter seal the clinical waste and replace new plastic bag into the yellow bin

4.1.3.3 Labelling

All bags and drum containers must be identified at the point of production and should be indelibly and clearly marked with the biohazard symbol. The waste collector labeled the waste according to the pickup location according to the task given. The information regarding the waste collection including the date when the scheduled wastes are first generated, name, address and telephone number of the waste generator was included in the label. From the observation, every clinical waste collected was recorded in the collection form provided to the assigned porter.

4.1.3.4 Handling and storage of waste products

From the results, it shows that NZS Bersatu Sdn. Bhd. had provided 14 porters for handling and carrying out the collection and storage of clinical waste operation. The operation was scheduled three times per day. The waste collectors were handling the clinical waste at the neck of the plastic bag. It is to prevent any injury and accident from direct contact with the yellow plastic bag. Double yellow bags has been used for clinical wastes from high-risk areas such as infectious disease and isolation nursing units and also for heavy clinical wastes such as waste from labor rooms and human tissues from operating theatres. The wheeled bin is used to transport the waste containers to the main storage area. These vehicles are used only for the transportation of clinical waste. The clinical waste was weighed and the amount of waste was recorded. The bin were thoroughly cleaned and disinfected immediately following any spillage or accidental discharge. Facilities for washing down and disinfection of the central clinical wastes storage area, waste containers, and trolleys used for transporting waste, was provided adjacent to the central storage area. All wastes from cleaning process were discharged to the foul sewer. From the report, there were issues regarding disposal of pharmaceutical control drugs. The control drugs which need to be disposed need to be reported to the pharmacy before can be disposed of. Awareness and proper training to the staff is required so that everyone is taking a responsibility before disposing of any waste including drug and medicine. Figure 4.7 below shows the weighing procedure by the porter to get an actual amount of clinical wastes generated before sent to the temporary storage room.

Figure 4.7: Weighing procedure for clinical waste

4.1.3.5 Transportation and disposal

The transportation and disposal procedure was handled by Kualiti Alam Sdn. Bhd., where the clinical waste was sent to Clinical Waste Treatment Centre in Seremban for disposal process. The clinical wastes were transported twice per day from the central storage area for disposal process. The first collection was at 2.00 p.m. and last collection was at 8.00 p.m. During the process, proper documentation and record of the generation and handling of clinical waste was generated and prepared in order to comply with the Environmental Quality (Scheduled Wastes) Regulations 2005, which require an inventory be kept and a consignment note system to be used for the transport waste from the hospital to an approved facility. The concession company was fulfilling the requirement of the collection in compliance with legal requirements.

4.1.4 Data analysis

From the data analysis, the number of bed in UMMC for the year 2016 was 1076 and it was divided into 11 departments with the average length of stay is 5.69 as shown in table 4.2. To date, UMMC has 1439 beds compare to the year 2016. It consists of additional of 95 beds from UMSC, 88 beds from the emergency unit, 180 beds from admission ward and day-care unit.

Table 4.2: Number of bed in UMMC in 2016

Department	No. of Bed	ALOS (Average Length of Stay)
Obstetric (Mother)	86	2.62
Obstetric (Baby)	0	2.28
Otorhinolaryngology	18	5.81
Ophthalmology	20	2.83
Gynecology	49	3.52
ICU (Intensive Care Unit)	25	5.45
Medicine	392	6.75
Pediatric	148	5.04
Psychology	44	8.27
Orthopedic Surgery	112	9.77
Surgery	182	7.11
Total	**1076**	**5.69**

The Average Length of Stay (ALOS) refers to the average number of the days that patients admitted to the hospital. It is measured by dividing the total number of days stayed by all inpatients during a year by the number of admissions or discharges. The average length of stay (ALOS) usually used as an indicator of efficiency. A study had reported that a shorter number of stay will reduce the cost per discharge and shift care from inpatient into less expensive treatment (Indicators, 2015). In the United States itself, hospital care cost has reached $377.5 billion per year (Weiss & Elixhauser, 2014) and modification in a length of a hospital stay can give a positive impact to the numbers. Furthermore, a longer LOS also increases the likelihood of a hospital-acquired infection (HAI) which also can cause harms towards patients and community. This also can contribute to even longer and costlier stay. Reducing the LOS number helps in improving the safety of the patient as well as in lowering the cost. It is also can release

the capacity of the system which includes hospital beds and staff time so that the hospital enables to serve more patients.

Several ways that can be adopted in a way to reduce the number of patients stay including:

- Organizational and management roles

  The commitment between the hospital and the community including patient and families is important to implement and sustaining LOS improvement efforts. The organization needs to recognize the committee in the hospital in order to reduce the LOS number.

- Resources availability

  Fully utilizes the available source can help in ensuring the patients can be discharged in a safe and timely manner. For example, increasing the staff coverage of shifts in the acute units in order to handle any late discharges can help the patients to go home early without the need to stay for any extra night. The addition of extra resources also allowed any medical requirement to monitor every patient. Addition of clerk and expanding the discharge planning support also can increase the efficiency and save more time in addressing patients discharge needs.

- Proper discharge planning

  A standardized process and workflows are required in managing LOS through the system from admission until discharge of the patients. Development of establishing pathway is required including the inpatient care process, proper discharge plan process and estimated date of discharge as early as possible.

Many other options can be adopted in reducing LOS number in a hospital. However, a full commitment from every staff and management is required to ensure the proposed plan is successful. The continuous learning process is important in order to give an efficient service to the patients.

The table 4.3 below shows the total number of inpatients in UMMC for the year 2016 which is 54473. From the table, it shows that the highest number of patients were admitted was in March with 5014 patients and the lowest number of patient been admitted in July with 4248 patients.

Table 4.3: Number of inpatients in 2016

Month	Number of patient
January	4688
February	4463
March	5014
April	4486
May	4433
June	4503
July	4248
August	4617
September	4462
October	4590
November	4507
December	4462
TOTAL	**54473**

The table 4.4 below shows the amount of clinical waste generated from January to December 2016. From the table, the total amount of clinical waste generated in that year was 684 tons.

Table 4.4: Total clinical waste generated and cost per month

Month	Waste (kg)	Cost (RM)
January	5.8×10^4	0.028 million
February	5.3×10^4	0.025 million
March	6.2×10^4	0.030 million
April	5.8×10^4	0.027 million
May	5.8×10^4	0.028 million
June	5.6×10^4	0.027 million
July	5.4×10^4	0.026 million
August	5.7×10^4	0.027 million
September	5.3×10^4	0.025 million
October	5.5×10^4	0.026 million
November	5.7×10^4	0.027 million
December	5.7×10^4	0.027 million
Total	**68.4×10^4**	**3.287 million**

From the data analysis, it shows that the highest number of clinical waste production was in March 2016 which 62 tons have been generated. The increasing number of the clinical waste collection was due to a large number of patients admitted in March 2016 with 5014 patients. It shows an increment in cost of disposal with RM300, 000 used in March for clinical waste disposal purposes. The total cost has been invested for the whole 2016 was RM3, 287,000 with the cost per kg of waste was RM4.80.

4.1.5 Water consumption

From the observation, the water used to clean the wheeled bin once any spillage or any accidental discharge occurs. During cleaning, the continuously flow of water was used to ensure the cleanliness and total disinfection of the contamination. Table 4.5 below shows the total amount of water consumption .Approximately, 53 m^3 of water was used for cleaning purposes with the cost of RM85.33 per month.

Table 4.5: Water Consumption

Type of usage	Amount m^3/ month	Cost/month(RM)
Wheel bin washing	33	53.13
Cleaning the storage area	12	19.32
Domestic (hand washing, etc.)	8	12.88
Total	**53**	**85.33**

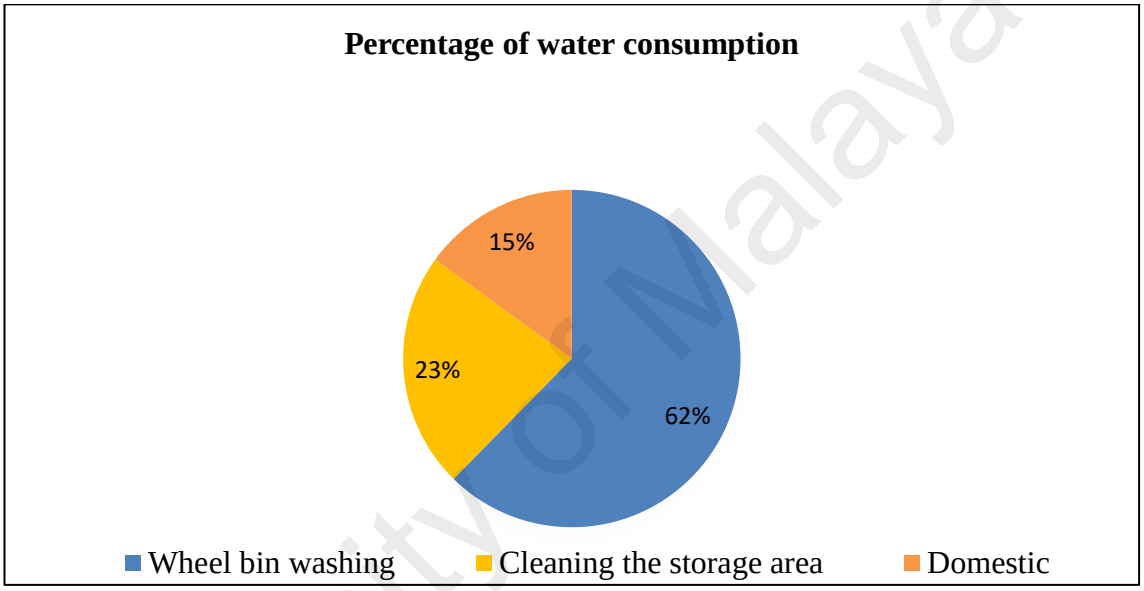


Figure 4.8: Percentage of water consumption per month

Figure 4.8 above shows the total percentage of water consumption per month. The tariff from Syarikat Bekalan Air Selangor was used as a reference to calculate the estimated cost of water consumption which is RM1.61/m^3.

Water consumption cost

= Total water used x Number of hours per month x Cost per cubic meter

4.1.6 Chemical and Disinfectants used for cleaning purposes

For disinfected purposes, the cleaning agent used was concentrated power pine gel. Meanwhile, for hygiene purposes, concentrated hand soap has been used for cleaning purposes. Safety Data Sheet (SDS) for this chemical has been attached in the Appendix.

4.1.7 Safety & Health management status

From the observation, the safety procedures were implemented according to the National Institute of Occupational Safety and Health (NIOSH) requirements. All workers were provided with a personal protective equipment (PPE) prior working session including gloves, mask and safety boot. This PPE is important in order to protect the workers from any accidental injury. Person in charge will ensure that all staff is obliged to this order. Best practice requires workers to wear gloves, and protective clothing to help prevent exposure to bacteria, dust, blood or any spillage or sample taken from the patients. The Standard Operating Procedure (SOP) has also been documented so that every worker can have a clear instruction and understanding prior handling the clinical waste to ensure all safety precautions being in placed to prevent any accidents or incidents. Document related to near-missed accidents were available and documented. Safety Data Sheet (SDS) for any chemical used in cleaning and disinfection are also available for reference. Audit was done during non-peak hour to avoid disturbance of workflow.

4.2 Carbon Footprint calculation

Quantification of carbon emission was done according to a formula developed by Intergovernmental Panel of Climate Change (IPCC). Equation below shows the formula while the list of emission factors is included in Table 3.1.

Total CO_2 emission (kg CO_2) = Σ (Entity data x Entity Emission Factor)

Table 4.6: Total CO_2 emission of clinical waste

Month	Waste (kg)	Carbon emission/month (metric ton CO_2)
January	5.8×10^4	33
February	5.3×10^4	30
March	6.2×10^4	35
April	5.8×10^4	33
May	5.8×10^4	33
June	5.6×10^4	32
July	5.4×10^4	31
August	5.7×10^4	32
September	5.3×10^4	30
October	5.5×10^4	31
November	5.7×10^4	32
December	5.7×10^4	32
Total	**68.4×10^4**	**390**

Table 4.6 shows the total emission of CO_2 due to the generation of clinical waste in 2016 was 390 metric ton. From that, the highest amount of CO_2 was in March with 35 metric ton. This large number of emission was due to the increasing number of patient being admitted to the ward in March which contributes to a high number or clinical waste generation. From the table 4.6 also shows in February and September, only 30 metric ton CO_2 being produced. This large number of CO_2 emission can lead to an environmental problem if no action is taken to reduce the increasing number of greenhouse gases emission.

Figure 4.9 shows the carbon emission of clinical waste in UMMC for year 2016. From the graph, it shows that the emissions of carbon are between the ranges of 30 metric ton to 35 metric ton.

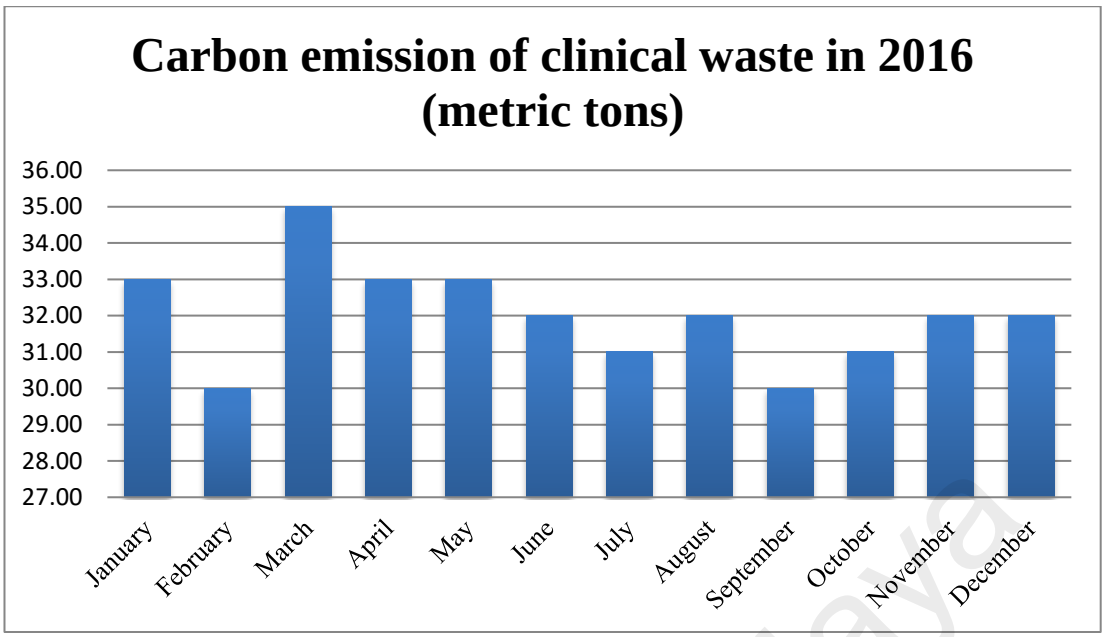


Figure 4.9: Carbon emission of clinical waste in UMMC for year 2016 (metric tons)

Table 4.7: Total CO_2 reduction before and after CP implementation

No.	Component	Before CP	After CP	% of reduction
1	Total CO_2	390 tons	348 tons	11%
2	Total CO_2/patient	0.99 kg/bed/day	0.88 kg/bed/day	11 %

Table 4.7 shows the reduction of total CO_2 before and after CP implementation. For overall, 42 tons of CO_2 was reduced upon implementation of CP for a total clinical waste generation.

4.3 Cleaner Production options generation

From the audit finding and data analysis in the clinical waste management in UMMC, amount of CO_2 emission has been obtained. CP is all about tackling waste at its source rather at the ends. CP application to any activities or processes will lead to waste minimization, increase efficiency and decrease in production cost. Besides that, a

positive impact can be obtained by an organization towards CP implementation. Based on the analysis, the summary of the Cleaner Production (CP) options are suggested in order to mitigate the problem as shown in the Table 4.8 below:

Table 4.8: Summary of carbon footprint reduction using cleaner production options

No.	**Category of CP Options**	**Recommendation**	**kgCO_2 Reduction**
1	Good housekeeping	Proper disposed of clinical waste and general waste according to the respective bin and plastic	600 kgCO_2
2		Personnel hygiene for worker	
3	Management initiatives	Efficient management and record keeping	5045 kgCO_2
4		Establish a general environmental policy provided with the objectives and targets for the environmental improvement	
5		Employee training	
6	Resource efficiency	Substitution of materials and resources for less hazardous and less toxic alternatives	8400 kgCO_2
7		Changing practices in the current SOP and equipment for more efficient alternatives	

No.	Category of CP Options	Recommendation	kg CO_2 Reduction
8	Minimize water usage	Use water valves to prevent water wastages	115 $kgCO_2$
9	Waste optimization	Establish waste minimization program throughout the management	
10		Use reusable and washable medicine beakers rather than disposable beakers	
11		Return unused/expired medicines to pharmaceutical supplier	27000 $kgCO_2$
12		Supply patients with no more medicines than they need	
13		Review any possibilities to return back the sharps waste to the supplier/manufacturer	
14	Material waste collection	Investigate different waste disposal/treatment possibilities	420 $kgCO_2$
15	Safety and health	Review on emergency response plan (ERP) status	
16		Review on safety equipment provided to worker	420 $kgCO_2$
17		Perform a health surveillance to worker	
		Total reduction	**42000 $kgCO_2$**

4.4 Good housekeeping

Good housekeeping process is the first thing to implement in order to integrate with a sustainable development in the management. Personnel hygiene of the worker is important so that every flow of work has been done accordingly to ensure their safety and health. Good housekeeping is one of the CP options which not require any cost for implementation and can be done directly in the management.

4.5 Management initiatives

4.5.1 Efficient management and record keeping

It is a management responsibility to ensure the standard operating procedures is provided and been followed by the worker and people involved in the clinical waste management. Every job description was documented as references and put in the place that was easily accessible.

4.5.2 Development of a general environmental policy

One of the CP options that have been implemented is the development of a general environmental policy where it used to be a communication tool towards the staff progression. It is also acts as a benchmark for institutions in a way progression to the clients, contractors, suppliers and also the community. The management also can integrate the environmental tasks in the job description and create as such an 'Environmental Winner' program for the worker so that can increase their awareness towards the environment. The other options also that implemented as such establishment of an 'Environmental Committee' among the staff in order to manage the activities across the hospital.

4.5.3 Employee training and reward

Award recognition to the worker is one of the management initiatives to develop awareness among worker. The several options were done including the installation of an environmental notice board to provide information to the staff about the environmental issues and motivational support. The management also has included the environmental component for training purposes. Other than that, it is responsibilities of every stakeholder towards the carbon issues and the institutions can hold regular environmental meetings with a staff from various departments in the hospital. Incentives also has been offered to encourage and reward been offer to new and effective environmental ideas from the employees. For example, rewards the staff for the environmental progress in such as recycling which can reduce the cost of the institutions.

4.6 Resource efficiency

Another CP options that has implemented is the substitution of materials and resources for less hazardous and less toxic alternatives. Further investigation can be done for any option that can be used in order to create a safety environment towards the worker and also the public health. Other than that, management and workers also have developed changing practices in the current SOP and equipment for more efficient alternatives. One of the practices that have been done after CP implementation in a clinical waste generation is the drip bottle from the ward was packaging separately and discards as general waste or sold to the recyclable items. It reduced the cost of disposal of clinical waste. Substitution of the disposable bed pan linen and urine containers also help to reduce the cost and increase the return on investment due to the reducing number of clinical waste generated.

4.7 Minimize water usage

Cleaning the wheeled bin is one the process that consumes an amount of water. Average usage of water used in a month is 53 m^3. One of the options in order to minimize the water usage is the usage of water valves to prevent the water wastages and check the water supply system for leaks and turn off unnecessary flow. The water usage reduces to 41m^3 per month after the implementation. About 9.6 kgCO_2/ month were reduced with a total saving of RM19.32 per month. Integration of the CP options for water efficiency can help in control a large amount of water used for cleaning purposes.

4.8 Waste optimization

4.8.1 Establish waste minimization program throughout the management

Generation of a large amount of clinical waste creates an impact towards the environment due to the carbon emissions. By developing a waste minimization plan, a reduction of cost in the clinical waste was obtained. Several options were developed as such by using the reusable medicine beakers (washable) instead of the disposable ones, return the expired medicines to pharmaceutical supplier rather than dispose in the clinical waste bin, adjust the purchasing of the medicine and preparation prior to demand and manage the stock by using the first-in-first-out principle. The management has further revised the purchasing policy and stock management. Supplying patients with sufficient medicine will reduce treatment cost and increase the return on investment. The generation of clinical waste before CP implementation is 57072 kg and reduced to 50872 kg per month with a total saving of RM29760 per month after the implementation. The management also reviewed any possibilities to return back the sharp waste to the supplier/manufacturer but this action will need further investigations and discussion from various stakeholders.

4.9 Materials waste collection

4.9.1 Investigate different waste disposal/treatment possibilities

Another category of CP options that have been implemented is regarding the materials waste collection. The management takes an action to investigate the different waste disposal or treatment possibilities. For example, another treatment possibility is such as implementation of non-incineration technologies including thermal, chemical process, irradiative or biological processes. However, many aspects need to be considered including cost factor which might be higher compared to the current practice. Current practice was the collection of clinical waste by the concession company and offsite incineration of the clinical waste. Further investigation was recommended to propose an onsite incineration of clinical waste and landfilling of non-recyclable of general waste.

4.10 Safety and health

Safety and health in the workplace is the most important factor that should not be compromised. Following proper standard operating procedures (SOPs) is important to avoid any unsafe act and unsafe condition while performing the job task to ensure the efficiency of the operations in the workplace. According to OSHA 1994, “it is the duty of every employer and every self-employed person to ensure, so far as is practicable, the safety, health, and welfare at work of all his employees in the organizations”("Occupational Safety And Health Act 1994 ", 1994).

4.10.1 Review of emergency response plan (ERP) status

Every worker has been given training for emergency response and made aware of the correct procedure for prompt reporting. The workers were provided with necessary equipment and be readily available at all times to ensure all the required measures can be implemented rapidly and safely. A written document regarding the procedure for the

different types of emergencies should be prepared. Any accidents or incidents, including near-misses, inappropriate segregation, spillages, damaged containers, and any sharps injury have been reported to the management. The cause of the accident or incident was investigated by the Waste Management Officer or other responsible officer, who should also take all possible actions to prevent recurrence. The records of the investigation and subsequent remedial measures have been kept for further references.

4.10.2 Review on safety equipment provided to worker

From the observation, a PPE was provided to the entire worker. However, incident still happens for example during handling the sharp waste. Only surgical mask has been provided to the workers and this PPE was not recommended to filter the aerosol resulted from the clinical waste. An N95 mask is recommended as it can filter the particle from been inhaled by the worker and this can help to protect the worker itself from inhaling the infectious agent. It is recommended to provide the worker with the heavy –duty gloves and industrial boots as they involved with the hazardous waste. The thick soles of the boots offer protection in the pickup and storage area, as a precaution from spilled sharps, and where floors are slippery. Needles or other sharp items may have been placed in plastic bags; such items may also pierce thin-walled or weak plastic containers if the segregation is inadequate. If this occurs, it might come into contact with workers legs during handling and accident will happen. It is important to ensure the safety of the workers as well as the public.

4.10.3 Perform health surveillance to worker

Provision for the continuous monitoring of workers health and safety was included in the health care waste management policies to ensure that correct handling, treatment, storage, and disposal procedures are being followed. An essential occupational health and safety measures need to be taken including the establishment of an effective

occupational health program which includes immunization, post-exposure prophylactic treatment, and medical surveillance. Viral hepatitis B infections have been reported among health-care personnel and waste handlers, and immunization against the disease was therefore recommended. Tetanus immunization was also recommended for all personnel handling waste.

4.11 Challenges in implementing CP in hospitals

Implementation CP in hospital is less likely compared to other sectors in the way improving the environmental management and also to share information on the achievement. Environmental issues are relatively new to many hospitals in Malaysia. Some of the reasons are there are no national organization that can facilitate the CP adoption by the hospitals or information sharing between the hospitals. Most of the hospitals are unaware of the overseas CP guidelines and information that is available, and also the case studies that have been reported. Furthermore, hospital staff has limited time addressing environmental management due to a limitation of the hospitals budgets available for investigating environmental management. Health sector is different from other sector or industry because all CP options need to be evaluated for their impact toward hygiene. Hygiene can never be compromised in the pursuit of waste minimization. Cooperation from all level of staff is important to ensure the efficiency of CP implementation. Currently, there are no appropriate standards which exist to control waste management in hospitals. The guidelines on the handling and management of clinical wastes in Malaysia briefly address the segregation of general, special, radioactive and cytotoxic waste but does not consider the reduction, reuse, and recycling of waste. Further research and investigation need to be done in order to implement cleaner production in hospitals.

CHAPTER 5: CONCLUSION & RECOMMENDATION

5.1 Conclusion

Cleaner production audit has been conducted in the selected hospital to review the clinical waste management and identify any possible ways to reduce carbon footprint emission from clinical waste generation using cleaner production strategy. The study focused on the clinical waste generation in UMMC for the year 2016. About 684 tons of clinical waste was generated for the respective year with the total cost of RM3.3 million.

From the study, clinical waste generation contributes approximately 390 tons of carbon emission for the year 2016 .It is estimated that the generation rate for clinical wastes is 0.88 kg per occupied bed per day. By implementing the CP strategies, 74 tons of clinical waste has been reduced which is equivalent to a reduction of 42 tons of CO_2 a year. In term of cost saving, the implementation of suggested cleaner production can benefit the hospital through total saving of RM355k per year.

There were 17 CP options that have been identified and implemented in reducing the carbon footprint for clinical waste management including resource efficiency, waste optimization and also safety and health. Reduction of 11% of CO_2 from total clinical waste generated in the year 2016 was obtained after the CP strategies implementation. Other cleaner production options that also have been implemented were good housekeeping, management initiatives, and optional waste collection method. The implementation of CP has brought benefits to the hospital in reducing the operational cost through reducing spending on resources including raw materials, water consumption and reducing waste disposal cost. Safety and health for staff and patients have also been improved as well as the public image of the health sector nationally and nationally. Safe and secure management of medical and health care waste can be

ensured by the adoption of management practices which are based on clear plans and policies that have been provided for continuous improvement.

5.2 Recommendation for future research

Further research can be recommended to increase the efficiency and productivity including collaboration with other medical center for sustainability adoption and conduct a CP audit for the entire department in the hospital.

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