GREENING MOSQUITO COIL MANUFACTURING PREMISE USING CLEANER PRODUCTION STRATEGY

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GREENING MOSQUITO COIL MANUFACTURING PREMISE USING CLEANER PRODUCTION STRATEGY

ABSTRACT

Mosquito coil is an insect repellent used to kill or repel mosquitos. The mosquito coils are pesticides made from active ingredient, pyrethroid. Manufacturing of mosquito coils emits carbon dioxide to the environment that contribute to global warming. Thus, cleaner production strategy was implemented to green the chosen premise by reducing the emission of carbon dioxide. The cleaner production strategy is a preventive implementation for environmental protection by minimizing waste and emission and concurrently maximizing the product output. The factors used to calculate the carbon footprint includes the use of raw materials, fuels, electricity, and waste generated. A mosquito premise was selected to conduct the analysis. Based on the findings, the total carbon dioxide emitted from this premise is 61.9 tons of CO_2 per month which is equivalent to 743 tons of CO_2 per year for this premise. The production of mosquito coils per month required 564×10^3 kWh of electricity, 9,412 liters of diesel and a total of 1,540 kgs of the waste generation, inclusive of both solid waste and liquid waste. The release of carbon dioxide from the production of 1kg of mosquito coil was calculated and the outcome is particularly 0.565 kWh/ kg of mosquito coil from electricity consumption, 0.223 L/ kg of mosquito coil from diesel consumption, 0.015 kg/ kg of mosquito coil from solid waste generation and 0.0028 kg/ kg of mosquito coil from liquid waste generation. A total of twenty-eight (28) cleaner production options were identified and analysed to green the premise and eleven (11) cleaner production options amongst it were recommended based on priority measures to be implemented in the premise. This implementation can reduce carbon dioxide emission up to 46.8% which is equivalent to 29 tons of CO_2 per month and 348 tonne of CO_2 per year. This is equivalent of planting

11 thousand of trees per year. Total investment of RM 1,018,500 is needed to implement the recommended cleaner production options with a payback period of 4.8 years. Overall, it is recommended to manufacture a mosquito coil with less smoke as burning of mosquito coils releases carbon monoxide which is hazardous to environment. Mosquito coils that are more environmental-friendly can be manufactured by minimizing the use of raw materials and consumption of fuel and electricity in burning and processing the coils respectively. For future in-depth study, mosquito coils can be printed on a fibre roll paper instead of stamping the coils. This could be an effective way to green the premise.

Keywords: Mosquito Coil, Global Warming, Carbon Dioxide Emission, Greenhouse Gases (GHGs), Cleaner Production

PENGHIJAUAN PREMIS PEMBUATAN LINGKARAN UBAT NYAMUK MENGUNAKAN STRATEGI PENGELUARAN BERSIH

ABSTRAK

Lingkaran ubat nyamuk adalah dupa penghalau serangga untuk menghalau dan membunuh nyamuk. Lingkaran ubat nyamuk ini merupakan racun perosak dibuat daripada bahan aktif, pyrethroid. Pembuatan lingkaran ubat nyamuk menyumbang kepada peningkatan kepekatan gas rumah hijau (GRH) dan akhirnya menyebabkan pemanasan global. Oleh itu, kaedah pengeluaran bersih dilaksanakan untuk menghijaukan premis yang terpilih dengan mengurangkan pelepasan karbon dioksida. Strategi pengeluaran bersih merupakan pelaksanan pencegahan bagi alam sekitar dengan meminimumkan sisa buangan dan pelepasan dan serentak dengan memaksimumkan pengeluaran produk. Faktor yang digunakan untuk mengira jejak karbon termasuk penggunaan bahan mentah, bahan bakar, elektrik dan sisa yang dihasilkan. Sebuah premis lingkaran ubat nyamuk dipilih untuk membuat analisis. Berdasarkan penemuan, jumalah karbon dioksida yang dikeluarkan dari premis ini ialah 61.9 tan CO_2 sebulan iaitu persamaan 743 tan CO_2 setahun untuk premis ini. Pengeluaran ubat nyamuk setiap bulan memerlukan 564×10^3 kWh elektrik, 9,412s liter diesel dan 1,540 kg sisa penjanaan yang merangkumi sisa pepejal dan sisa cecair. Pembebasan karbon dioksida dari 1 kg ubat nyamuk dikira dan hasilnya ialah 0.565 kWh/ kg lingkaran nyamuk dari pengunaan eletrik, 0.223 L/ kg lingkaran nyamuk dari pengunaan diesel, 0.015 kg/ kg lingkaran nyamuk dari penghasilan sisa penjanaan dan 0.0028 kg/ kg lingkaran nyamuk dari penghasilan sisa cair. Sejumlah dua puluh lapan (28) pilihan pengeluaran bersih telah dikenal pasti dan dianalisis untuk menghijaukan premis dan sebelas (11) pilihan pengeluaran bersih dianjurkan berdasarkan langkah-langkah keutamaan untuk dilaksanakan di premis. Pelaksanaan ini dapat mengurangkan pelepasan karbon dioksida hingga 46.8% iaitu persamaan dengan 29 tan CO_2 sebualan dan 348 tan CO_2 setahun. Ini

adalah persamaan dengan penanaman 11 ribu pokok. Pelaburan sebanyak RM 1,018,500 diperlukan untuk melaksanaan pilihan pengeluaran bersih yang disarankan dengan tempoh 4.8 tahun pembayaran balik. Secara keseluruhan, disarankan untuk membuat ubat nyamuk yang kurang asap kerana pembakaran ubat nyamuk melepaskan karbon monoksida yang berbahaya kepada alam sekitar. Ubat nyamuk yang lebih mesra alam dapat dihasilkan dengan meminimumkan penggunaan bahan mentah, penggunaan bahan bakar untuk membakar lingkaran, dan penggunaan elektrik untuk memproses lingkaran. Untuk kajian mendalam masa depan, lingkaran ubat nyamuk boleh dicetak di atas kertas gulungan serat dan bukannya mencantum lingkaran. Ini boleh menjadi cara yang berkesan untuk menhijaukan premis.

Kata kunci: Lingkaran Ubat Nyamuk, Pemanasan Global, Pelepasan Karbon Dioksida, Gas Rumah Hijau (GRH), Pengeluaran Bersih

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LIST OF SYMBOLS AND ABBREVIATIONS

CO_2	:	Carbon Dioxide
CP	:	Cleaner Production
GHSs	:	Greenhouse Gases
LULUCF	:	Land Use, Land Use Change and Forestry
UNFCC	:	United Nations Framework Convention on Climate Change
CH_4	:	Methane
N_2O	:	Nitrous Oxide
CO	:	Carbon Monoxide
IPCC	:	Intergovernmental Panel on Climate Change
SMIs	:	Small and Medium Industries
ROI	:	Return of Investment
ERP	:	Enterprise Resource Planning
FIFO	:	First in First Out
PPE	:	Personal Protective Equipment
DOSH	:	Department of Occupational Safety and Health

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CHAPTER 1: INTRODUCTION

1.1 Background

2019 was the year in which the entire world was hit by Corona Virus 2019. In midst of this pandemic, there are also increase of Dengue and Malaria cases reported in most endemic countries. The minimization of the spread of Dengue and Malaria is possible as most of the countries manufacture mosquito coils and aerosols to kill or repel mosquitoes. Mosquitoes are harmful as they are the vector for many pathogens that are impactful for human health. (Ravi Sharma, et al., 2016). Global report in the year of 2010 stated that 2.2 million of dengue cases were reported and this figure increased to 3.2 million cases in 2015 (Majid, et al., 2019). In Malaysia, about 642 dengue cases were reported with total of 9 deaths cases and the cumulative number of reported cases is 13,496 in the year of 2021. This figure is lower compared to last year where the cumulative number of reported cases was 52,271 (Dengue Situation Update, 2021).

There are many tools used to kill and repel mosquitoes which includes vaporizers, mats, ambient chambers and mosquito coils that can be used to kill or repel mosquito. However, the main tool discussed throughout this research is mosquito coil. Mosquito coils originated from Japan and was first manufactured by Elichiro Ueyama at the end of 19th Century (Deshpande, 2016). Till now the demand for mosquito coil increases yearly. Pyrethroid is the main active ingredient used to manufacture mosquito coils. The main function of pyrethroid is to inhibit odorant receptors by disrupting the behavior of insects. Natural pyrethroid is an insecticidal component of pyrethrum which is a natural pant oil. The natural pant oil is derived from *Chrysanthemums* which has the same genus as ordinary daisy (Moore & Debboun, 2016). Pyrethrum is very effective in killing the mosquitoes, but its toxicity can harm people.

In 2020, the value of $4.1 billion of global mosquito repellent was achieved in market level and by 2027, $6.0 billion estimated to achieved in market level. Figure 1.1 below shows the market analysis for different products of mosquito repellent. (Allied Market Research, 2020). Market of mosquito coil among other mosquito repellents is as highlighted in red.

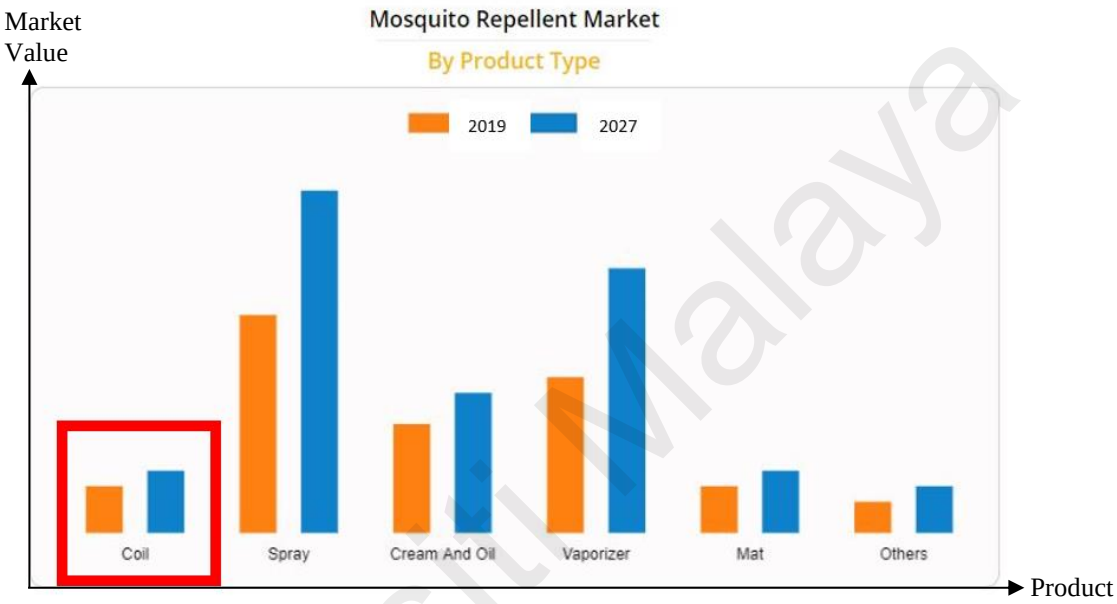

Figure 1.1: Market Analysis for Different Products of Mosquito Repellent (Allied Market Research, 2020)

The increase in the breed of mosquitoes is caused by the continues increase of global temperature of earth and it is expected to further increase in future. Rise of global temperature leads to the increase of greenhouse gases in atmosphere. The hotness in weather enabled the mosquito to be more active as it was the optimum temperature for them to breed more. Thus, the rise of global temperature benefits the mosquito's population. The increase in mosquito population will directly increase the manufacturing of mosquito coils and new designed products to kill or repel the mosquitoes and contributes to the growth of mosquito repellent market. (Allied Market Research, 2020).

Mosquito coils are manufactured in many countries including Malaysia. In the process of making mosquito coils, inputs such as natural resources, energy and raw materials are required. During this process, CO_2 is emitted to the environment and waste is generated. The CO_2 emission to the atmosphere causes global warming and climate change. The generated waste from industries are hazardous to environment. Unfortunately, there is no stern enforcement or authorizations to impose or implement a restriction in limiting the emission of carbon dioxide to the environment and to minimize waste generation from the manufacturing industries to its surrounding. Continuous unlimited emission of carbon dioxide to the atmosphere causes global warming and ultimately climate change. In order to curb this issue, green initiatives and strategies need to be identified and implemented as it can reduce the emission of carbon dioxide and waste generation. To attain a sustainable economic development, greening the industry would be the right path. This includes regulating a policy, efficient use of resource, targeted output and enhancing production process in industry (United Nations Industrial Development Organization, 2010).

Based on the selected mosquito coil manufacturing premise, the process involved are mixing of prepared chemical and powder premix into a kneading machine, stamping of mosquito coil shaped material, drying and packaging process. Along this process, burning test will be conducted to ensure the mosquito coils are completely burned.

1.2 Problem Statement

Mosquito coil manufacturing premise consume electricity, diesel, powders, chemicals and packaging materials that emits CO_2 to the atmosphere and generate waste during the operational process.

The main reason of sustainable development can be seen in the fast developing of human advancement and exhaustion of natural resources. The value of market size of global mosquito repellent shows a positive trend of development all over the world. This is due to the rise in incidence of mosquito-borne disease (Mosquito Repellent Market, 2018). Thus, each premise should formulate themselves with a green initiative as an action of self-sustainability. Many industries are putting in the effort to develop products which are better environmental-friendly to compete in the world market. These efforts can green the premise by reducing the emission of CO_2 eventually. Therefore, CP strategies can be implemented in industries to green the premise and to improve production process efficiently. Therefore, the research questions being addressed are as follows:

I. What are the CO_2 generating activities in mosquito coils manufacturing premise?
II. What is the monthly and annual generation of CO_2 emission?
III. What is the CO_2 emission per kg of product of mosquito coil?
IV. What are the Cleaner Production options that are applicable for the premise?
V. What is the rate of Return of Investment to implement the CP options?
VI. What is the estimated reduction of carbon footprint form the mosquito coil industries in Malaysia?

1.3 Aim and Objectives

This study is aimed in greening the mosquito coil premise by reducing the carbon dioxide emission to the atmosphere. To achieve the aim, the following objectives are targeted in this study:

I. Perform an audit of cleaner production in the premise of mosquito coil manufacturing
II. Generate options of cleaner production in the mosquito coil manufacturing premise.
III. Evaluate and sort the appropriate cleaner production options to be implemented.

1.4 Scope of Study

This research was conducted in a mosquito coil manufacturing premise based in Sungai Siput, Perak. The manufacturing process of chemical and powder mixing, stamping, drying of coils and final packaging will be analyzed and interpreted. The environmental impacts from the manufacturing of mosquito coils will be reviewed.

Options of Cleaner Production will be proposed and initiated in the plant based on data collected on electricity consumption, fuel consumption, material consumption and waste generated. Implementation of Cleaner Production can green the premise by reducing emission of carbon dioxide.

1.5 Dissertation Outline

Five chapters were outlined in this research project as shown:

Chapter 1: Introduction of the research project, growth and strategies used in mosquito coil manufacturing premise were discussed. The problem statement, objectives, scope of research study were also presented in this chapter.

Chapter 2: Global warming and carbon footprint were discussed in literature review. The overview of mosquito coil manufacturing process was included. Related environmental issues, greening strategies, cleaner production, implementation of cleaner production and CP case studies from other industries were discussed in this chapter. Overall literature review was summarised.

Chapter 3: Cleaner production audit methodology was introduced, cleaner production options which are suitable were developed and evaluated. The methodology was used to sort the CP options. Profile of premise including safety precautions were explained. Data collection was included in this chapter.

Chapter 4: Collected data were analysed and evaluated. CP audit result and calculation on carbon footprint were included in Chapter 4. Environmental issues and strategies to green the premise were presented. Implementation of suggested CP options based on certain measures and opportunities available for Malaysia were discussed in this chapter.

Chapter 5: Conclusion of the research is presented in this chapter. Recommendation for future studies are also provided in the chapter.

CHAPTER 2: LITERATURE REVIEW

2.1 Climate Change and Global Warming

The issue of climate change is recent matter of the moment in the arena of social media and environment. Global warming is an international environmental issue where many stakeholders give attention and importance to it. (Nik & Dewan, 2015). When there is a change in the atmosphere and oceans, the weather pattern's location will be changed. This change has impact on the earth's hydrological cycle and greenhouse gases (GHGs). The major component that causes rise in GHGs and contributed of global warming is literally carbon dioxide (CO_2). The increase in the concentration of carbon dioxide causes the temperature of global air to increase in recent years. The concentration of carbon dioxide in Earth's atmosphere ahead of Industrial Revolution is 280 ppm and it is steadily increasing since then. This exceeded concentration level of carbon dioxide has increased to 400 ppm in the year 2015 (Takashi, et al., 2019).

In the global view, most of the places have conducted forecasting analysis and reported on extreme warming with global temperature increase from 1.8 to 4.0 ℃. In Malaysia, the effect of climate change and global warming to be analyze carefully. The increase of GHGs is mainly contributed by emission from industrial processes. In the year of 2011, the contribution of energy sector is 76% of the total emission, 12% from waste disposal, 6% from industrial processes and 5% from agricultural sector. This segregation of CO_2 emission is shown in Figure 2.1. Therefore, sector of energy is the key of greenhouse gas emitter. Industrial processes are from manufacturing industries. For the waste disposal, the major contributors of GHGs are solid waste disposal sites and treatment of wastewater from palm oil mills particularly methane (Daniel, 2018).

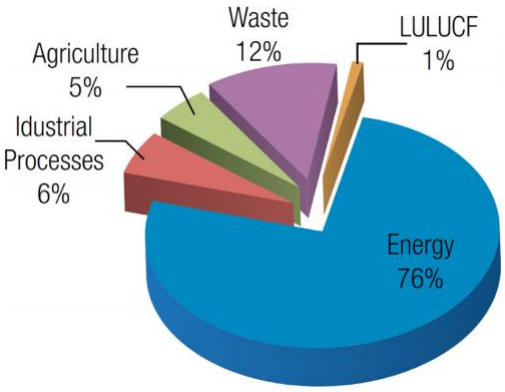

Figure 2.1: Main Emission of CO_2 in Malaysia. (Daniel, 2018).

LULUCF indicates the land use, land-use change and forestry. In this LULUCF, commercial harvesting, forest, draining and development of peatlands causes emission of GHGs. The main cause of global warming is from industrial pollution. As a consequence of the concerns, the companies are facing many challenges in order to prove their awareness about the environmental pollution and their responsibilities towards environmental issues (Nik & Dewan, 2015). Recently, concentration of carbon dioxide based on average ambient has tremendous increase and latest status CO_2 concentration in atmosphere is around 410 ppm. This increase impacted the energy of atmosphere in creating high increase of temperature.

The fast expending of both industrial development and human population growth give rise to the production of waste simultaneously. Malaysia was ranked in third in the region for global warming issue. This was highlighted in the figures of the year 2014 where the emission of CO_2 per capita is 8.00 metric tons. This is the highest value after Brunei and Singapore. Based on the world average, this value is nearly twofold of the world's average. Thus, to achieve sustainable development in future, it is mandatory for Malaysia to reduce emission of CO_2 in the atmosphere. In the year of 2015, Malaysia has

committed to reduce 35% of emission's intensity before 2020 from its baseline in the year 2005 (Helena, 2019).

2.2 Emission of Carbon Dioxide and Carbon Footprint

The carbon footprint is extracted from the idea of "ecological footprint" at the initial stage and later it was indicated as the total greenhouse gases (GHGs) emission in atmosphere from the act of human activities. In terms of GHGs emission, calculation of carbon footprint act as an assessment tool in reducing to cope with GHG emissions. GHG emission is regularly expressed in kg or tons of carbon dioxide (CO_2). Right after the carbon footprint has been calculated, the area of high emission of carbon dioxide can be identified and improvement can be made to eliminate or reduce the emission. Therefore, indicator of sustainable development is obviously carbon footprint (Andrea, et al., 2013). It was reported that, there is a 40-fold increase of CO_2 emission despite the increase of human population is only 3-fold (Surenthira, et al., 2017). Figure 2.2 shows the major carbon dioxide emission by sector.

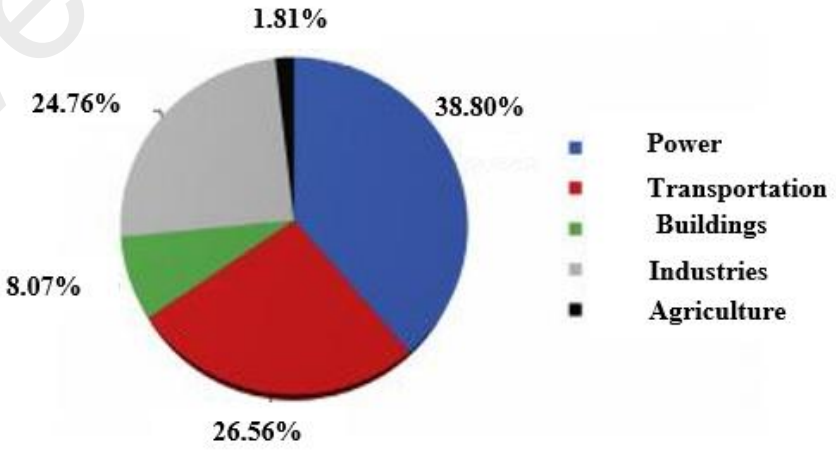

Figure 2.2: Carbon Dioxide Emission by Sector (Surenthira, et al., 2017)

There are few elements to reduce carbon footprint (material and energy):

1) Waste generation reduction
2) Usage of raw material reduction
3) Usage of fuel, electricity and water reduction
4) Improve the productivity and safety

Based on Figure 2.2, the major sectors contributed to emission of carbon dioxide in Malaysia are the generation of electricity, industries, residential area and transportation. It was indicated that, in the of year 2020, 286 million tons of carbon dioxide will be released to the atmosphere if mitigation measures are not taken by our country to reduce the emission. This was predicted back in the year of 2000, whereby in the year of 2020, 68.86% of carbon dioxide emission will be recorded. The largest emitting sector discovered is electricity generation with a total emission of 43.40% (Nor Sharliza, et al., 2010)

Malaysia including many other countries are putting great effort to reduce emission of CO_2 along with mechanisms of intergovernmental and mitigation of national. The United Nations Framework Convention on Climate Change (UNFCC) is an international environmental agreement that focus in reducing the greenhouse gasses (GHGs) in the atmosphere. There are six greenhouse gasses that can cause global warming but CO_2 emission is in the highest list due to human activities. The increase in the concentration of CO_2 contributed utmost 70% of the enhanced greenhouse effect, about 24% of methane (CH_4) and 6% of nitrous oxide (N_2O) (Safaai, et al., 2010).

In the ASEAN region, the emission of GHGs will relatively be two-folded by the year of 2040. Based on the statistical, the energy related emission of CO_2 has rose steadily over the period of 1971 to 2016. It is expected that the supply of energy would increase to 60% between the year of 2016 to 2050 as there are strong increase in oil, gas and coal. Other studies focused on the ASEAN countries particularly to compare the growth of emission between developed countries especially United States, Europe along with large the large population countries mainly China and India. The focal point of analysis from countries in ASEA is on energy related GHG emissions which referred to the alternatives for fuel and renewable energies, conversion of energy and efficiency along with security of energy (Suwin, et al., 2019).

Increase in the amount of CO_2 emission in the world, will cause the water evaporation rate to be high which lead to the increase in temperature of the earth surface. Statistic in the year of 2014, stated that Malaysia was in the 30th place in the world among the countries that have large quantity of carbon emissions. Based on the 20007 Fourth Assessment Report (AR4) from Intergovernmental Panel on Climate Change (IPCC) of the United Nations indicated that utmost of the declared global warming happened due to increase in the concentration of greenhouse gases results from human activities (Donald, et al., 2015). In 2019, emission of CO_2 for Malaysia was 248.8 million tons which is 7.67 tons of CO_2 per capita.

2.3 Mosquito Coil Manufacturing Process

This mosquito coils manufacturing premise have been operating for the past 40 years. The premise operates for one shift with 70 operators. The end products of mosquito coils will be delivered to local customer and exported to the overseas. The simplified process flow of mosquito coils manufacturing process is shown in Figure 2.3.

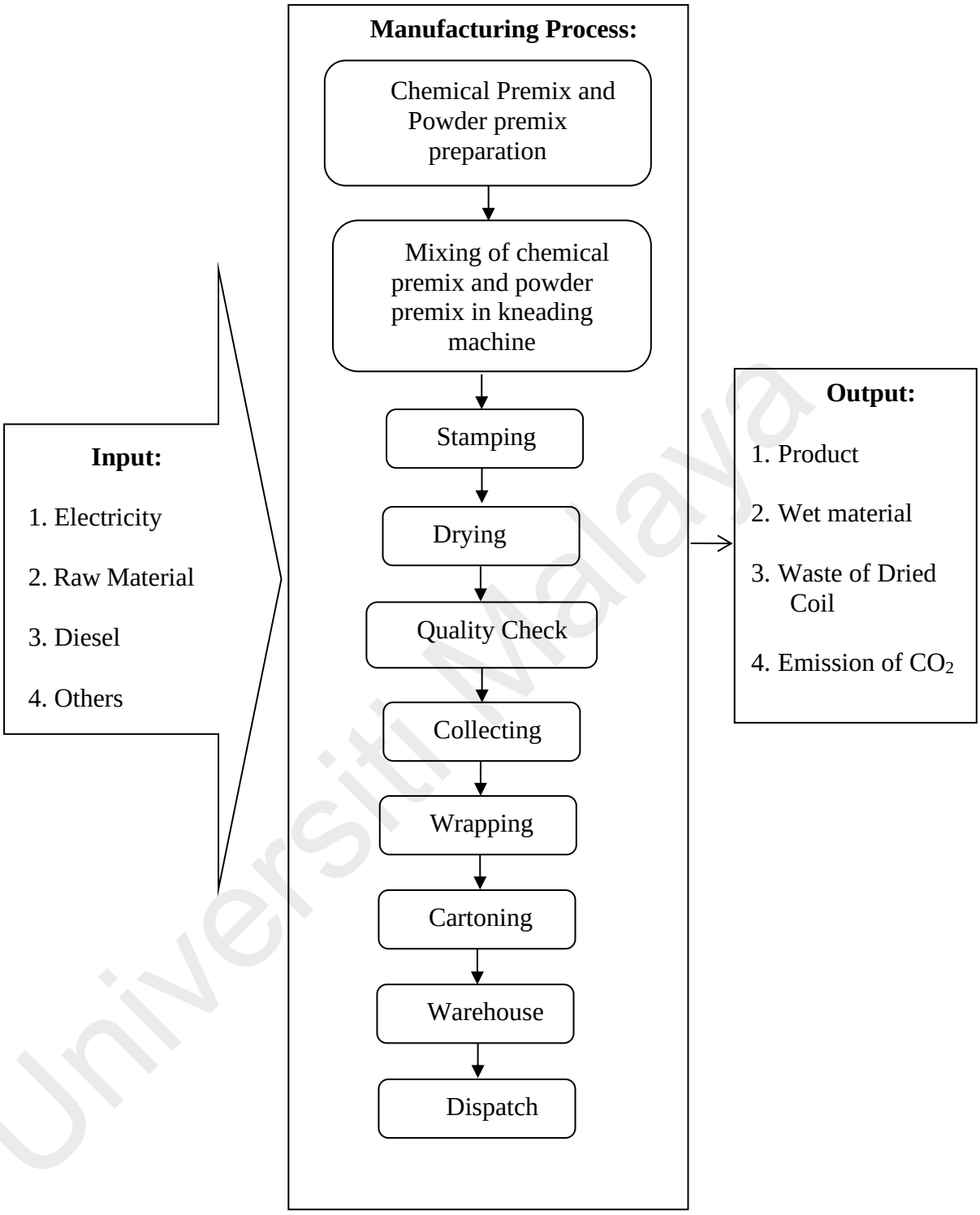

Figure 2.3: The Flow-Process of Manufacturing of Mosquito Coil

The raw materials needed to manufacture mosquito coils are chemicals, powders and packaging materials along with consumption of electricity to stamp the wet mosquito coils and consumption of diesel to dry the mosquito coils. The dried mosquito coils, the wet materials during stamping process, the waste of dried mosquito coils after process of packing and emission of carbon during burning test are those outputs generated from the product. There are sum of 10 processes involved in the manufacture of mosquito coils.

At initial stage, both chemical premix and powder premix will be prepared accordingly. Once the premix is done, they will be mixed together in a kneading. These mixed materials will be released as sheet material from the extruding machine and the mosquito coil-shaped material will be stamped. The mosquito coil-shaped mold spring shape is as shown in Figure 2.4.

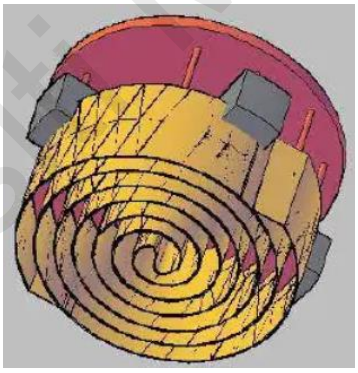

Figure 2.4: Mold spring shape of mosquito coil (Sharma, et al., 2016)

The stamped mosquito coils will be arranged on a tray and will be pulled to chamber room to dry the mosquito coils. Half a day needed to let the mosquito coils to dry. Upon drying, quality checking will be conducted by burning the coils and the hardness of coil. If the mosquito coils are within limited specifications, then the coils will be collected from stacks and packed according. Once complete packing, the coils will be sent to warehouse for storing and delivered out based to order received.

2.4 Environmental Issues in Mosquito Coil Manufacturing Premise

The function of mosquito coil is to repel and it has high demand among customers. However, several environmental issues encountered during manufacturing process of mosquito coils which are pollution of air, pollution of water and greenhouse effect. Pyrethrin used in this process is harmful to the environment. Natural pyrethrin from extract of pyrethrum and synthetic pyrethroids such as allethrin and d-trans allethrin are active ingredients used in the formulations. Besides, brilliant blue is used as a coloring agent and preservative is added to enhance the performance of mosquito coils. After the mixing, the left-over materials containing the active ingredient that adhere to the wall of the machine will be washed off and drained which will eventually pollute the water and aquatic life.

Moreover, burning tests are also conducted to confirm on the quality of coils. Smoke generated from mosquito coil burning, escapes to the atmosphere and releases carbon monoxide (CO). Mosquito coil act as insecticides evaporator in which through slow and steady combustion, the smoke will prevent the mosquitoes form entering the indoors. However, incomplete combustion can generate by-products. This incomplete combustion process is corresponding to emission from variety combustion of biomass such as burning of wood, smoking of tobacco. The fine particles, carbon monoxide and numerous volatile organic compounds are emitted to the atmosphere (Lin, et al., 2010). Therefore, in mosquito coils manufacturing process, quantity of carbon emitted to the atmosphere is considered high and it can form an invisible layer around the earth.

Wet mosquito coils are dried by burning of diesel. Upon burning diesel, the chamber room will heat up to dry the mosquito coils. Consumption of diesel in a manufacturing industry, commits the manufacturer to face challenge in meeting the

quality of strict emission of smoke, hydrocarbon which is unburned, emission of carbon monoxide and oxides of nitrogen. Speeding up the excess air will ensure the diesel is complete combusted. However, insufficient supply of oxygen during the combustion process will avoid complete conversion of carbon and hydrogen. This can lead to particulates of carbon dioxide resulting in increased exhaust emissions (Baskar & Senthilkumar, 2016).

2.5 Greening Strategies in the Premise

Green strategy is the finest method to reduce emission of carbon dioxide in the premise. A premise will be more efficient and effective if the green practice and green innovation are implemented. In Malaysia, most of the organization emphasized on quality initiatives of green technology to be applied not only in premises but also in their businesses. The environmental performance can be improved through the management practice of green supply chain and green balanced scorecard strategy. There are 3 types of green strategies as discussed below:

i. Green Practices

It is a practice to reduce negative impacts of operations on environment. Green practices can be implemented in premise through green purchase, cooperation with customer in consideration of green, eco-design and investment recovery. Green practice help premise to gain extra profit and has an advantage of increased competition. Implementation of green practice in a premise gives benefit in cost reduction, efficacy, improvement of customer feedback period, minimization the consumption of energy, waste generation and usage of hazardous materials.

ii. Green Innovation

Green Innovation of a premise comprises saving of energy, pollution prevention, recycling waste and designing green product and process. The green innovation in a premise can be achieved with the cooperation of environmental commitment, environmental benchmark and strength of research and development. Besides that, through this innovation, the premise can benefit from cost saving, good product quality and increased in efficiency and productivity. At the same time, it enhances performance and reduce environmental burdens.

iii. Green Performance

The focal point is to improve environmental management system. The combination of both green practice and green innovation in a premise enhance greenery performance by implementing relevant strategies, initiatives and opportunity created by the premise. The environmental performance enhances the air emission to be reduced, minimize the discharge of solid and liquid waste from the consumption of hazardous materials (Juriah, et al., 2013).

A good manufacturer with sustainability mind will always consider about concurrent thought of environmental and social effect. Initiation of new practices led to the development of new products, investing in new technologies and tracing new markets. It can be considered as a main mechanism in developing competitive advantages. Innovative environmental practices need to be implemented in order to initiate and launch new greenery products. Competitive advantage among industries can be improved and new market opportunity can be attained. Implementation of green strategies, can reduce industry's total cost and pressure from government. It also concomitantly increases the

industries revenues and incorporeal values which involves the reputation and manufactured brands that can be trusted which contributes to firm's competitive advantages. (Maryam, et al., 2015).

CO_2 emission can be reduced indirectly by energy saving and energy efficiency. Thus, Malaysia government has outlined policies and legislations to enhance energy efficiency and to promote renewable energy in manufacturing industries. Table 2.1 below shows the policies and legislation that was established by Malaysian government to reduce emission of CO_2 (Lee, et al., 2013)

Table 2.1: Malaysia's Policy, Act and Regulations

Policy/Act/Regulations	Aim and Objectives
National Energy Policy	- Providing adequate, effectiveness of costing, safe and multiple sources of energy supplies - Promoting efficient utilization and consumption of energy and includes protection of environment in the production and energy usage.
Five-Fuel Policy 2002	- Reduce dependency on oil as an energy source by enhancing the fuel mixing with oil, gas, hydro-electric and coal and renewable energy.
Efficient Management of Electrical Energy Regulation 2008	- Implementing systematic electrical energy management.
National Green Technology Policy 2009	- Initiating activities of green technology to the route of sustainable development in energy consumption, environmental, economy, and society.
Malaysia National Renewable Energy Policy and Action Plan 2010	- utilizing original renewable energy sources as a contribution to the route of national electricity supply security and sustainable development of socio-economy
Renewable Energy Act 2011	- Establishing and implementing special system to generate renewable energy

Establishing important Malaysian's policies, act and regulation assists in creating awareness and responsibility between the manufacturers, public and investors towards protection of environment. The manufacturers need to take steps in optimizing and the consumption of natural resources and waste generated form their manufacturing sites. A person in-charge should be assigned to monitor and audit the monthly production, consumption and generation as a preliminary step to green the premise.

2.6 Cleaner Production Strategy

In the year of 1989, cleaner production was defined as an integrated strategy's permanent application. It is an approach to increase the efficiency of the products, to minimize the left over and reduce the risks for end products, production processes and services. Cleaner production strategy involves conservations of raw materials and energy, removal of hazardous raw materials and reduction of waste generated. It is an improved environmental strategy which allows premise to produce more output with less usage of energy and raw materials with lesser generation of waste and emissions.

The contribution from both the government and industries helps to alter the way of industries interact with the environment. Reducing environmental impact is the main goal for industries as a result of development of technology and activities from industry. It could not be denied that, the main contribution of environmental protection failure and reducing of natural resources is obviously from human activities. Corruption in air, water and soil are among the biggest environmental challenges faced by today's world. It is better to prevent pollution rather than controlling it. Therefore, implementing cleaner production can fits and commits to the pollution prevention. (Nilsson, et al., 2007).

However, to remain competitive in the global economic paradigm, industries face many challenges. Therefore, practice of cleaner production strategy enables a well-organized industry which enhance the manufacturer to attain better performance in manufacturing sustainability. The efficiency of production operations can be improved through cleaner production and to increase competitiveness which automatically improves economy (Hasrulnizzam, et al., 2014). Application of CP in process of production minimize the use raw materials that are hazardous to environment, eliminate raw materials that are toxic to environment and minimize the release of toxic emissions to the atmosphere. Concerning about the products, the aim is to minimize impacts through the life cycle of the product, starting from extraction of raw material to the disposal of used products (Nilsson, et al., 2007). Malaysia now has enforced the industries to handle and minimize the waste generation from their operation. Thus, implementation of CP practice in industries helps the manufacturer to obey government's rules and regulations. Figure 2.5 shows the cleaner production summary.

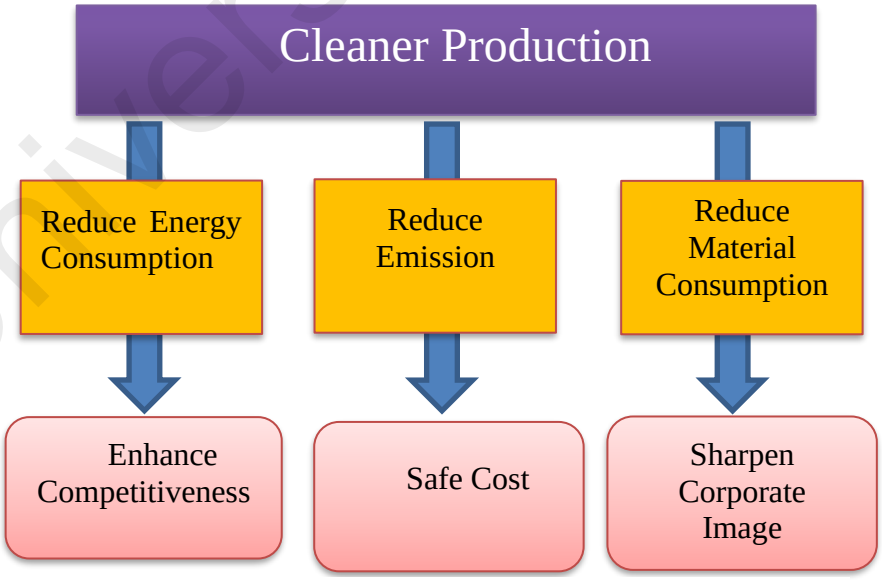

Figure 2.5: Cleaner Production (CP Partnership, 2010)

2.7 Methodology on Implementation of Cleaner Production

Cleaner production is a strategic resource mainly use to minimize emission. Besides, it is also applied to minimize the effluents and waste through continuous improvement in production process and products. Therefore, cleaner production can be seen from top level to the end-of-pipe technologies for environmental and economic reasons (Syntia, et al., 2018). A total of five general principles needed to implement CP in mosquito coil manufacturing premise which includes:

1. Substitution of Greener Materials

Raw materials which are less hazardous and has longer lifetime can be substituted. For instance, the active ingredient used to manufacture mosquito coils are hazardous to environment and humans. It can be substituted with a greener material.

2. Adaptation of New Technologies

New technology adaptation can reduce consumption of resource and minimize generation of waste by improving efficiency of operation. This option needs high investment of cost but the payback period can be enchanted. For instance, to improve efficiency, outdated equipment or machinery can be upgraded and modified based on current specification. In addition, the process of burning test of mosquito coils can be improved to reduce the release of smoke to the environment.

3. New Product Design

Chance of product design can contribute to the life cycle of the product by reducing the use of hazardous materials and easy waste disposal. Besides, this new design product will reduce the consumption of energy and increase the production efficiency. For instance, a

mosquito coil can be redesign for a more environment friendly product which uses less energy and resource in production.

4. Good Housekeeping Practices

Efficiency of production output can be increased through good housekeeping. Equipment and machines that are used to manufacture mosquito coils should be cleaned after completion of production to ensure a smooth production process the next day. Workers should be trained well to keep their work place clean and safe.

5. Inhouse Recycling Method

Materials can be recycled to reduce accumulation in disposal area. For instance, the rejected mosquito coil during manufacturing process can be recycled by crushing them into powders and add those crushed powders during powder premix process.

Cleaner production action can be performed in mosquito coil premise by comprehending its manufacturing process. First is to define the process unit followed by understanding the mosquito coil manufacturing process by knowing its chemical and physical activities. A working flow should be generated with input and output streams. Besides, material stream has to be focused and study the existing cross media effects (Nilsson, et al, 2007).

Thus, Cleaner production audit will be conducted and greening strategies will be implemented in mosquito coil premise. CP will be implemented based on analysis and data collected from CP audit, interview session with workers, and overall observation. The data collected will be analyze and CP options will be proposed. Before implementing, the proposed CP options will be evaluated based on its feasibility and return of investment

(ROI). CP options for implementation will be ranked according to the feasibility and ROI as CP practices enables the controlling process and reduces the operational cost. Overall, it can be said that, CP helps to achieve sustainable development in manufacturing industries (Hasrulnizzam, et al., 2014).

2.8 Case Studies on Implementation of Cleaner Production

Green initiatives have been developed in manufacturing premise to reduce impact of environment and to save money. At the same time, this development helped to change the business development's direction to a sustainable process and product. Studies have been conducted on green initiatives implemented by manufacturer from variety nature of business by implementing cleaner production practice.

2.8.1 CO_2 conversion from energy/material and plastics

This study discussed about the transformation and application of plastic and carbon dioxide conversion into beneficial chemicals or fuels in a high temperature of metallurgical process. This study involved the high carbon footprint reactions and production process of iron and steel. The benefit of this process is the decreasing effects of greenhouse gases, a more efficient and clean energy resources. It does not depend much on non-renewables, practices on well managed plastic waste and implementing sustainable pollution. Compared with fossil carbon sources, 30% of CO_2 emission was reduced by using waste plastic in iron and steel industry. Reformation of carbon dioxide with the CH_4 produced fuel gases and reduced gases like hydrogen. This process uses high temperature. In this process, to process iron and steel, carbon monoxide was used. Plastics reduces 99% of CO_2 released in a process of high carbon footprint. This includes the production of magnesia when the magnesite is thermally decomposed. This reaction

converted to energy and produced combustible gases such as hydrogen (Devasahayam, 2019).

This case study discussed on the practice of sustainable manufacturing by manufacturing firm. This firm manufactures electrical and electronic component and have been operating for the past 22 years. This firm is certified with ISO 9001which is Quality management System standard and ISO 14001 which is Environmental Management System standard. The annual sales turnover for this firm is more than RM 50 million. By implementing many types of sustainable manufacturing practices, this firm managed to issue sustainability in its operations. This sustainable practice includes the concept of prevention, eco-efficiency, environmental strategy and full life cycle.

Besides that, 3R approach which is Reduce, Reuse and Recycle was adopted in order to conduct its operational and business activities. The design of the process specifically in manufacturing operations, focuses to reduce energy and material resources consumption. Not only that, the firm optimize the process to reduce waste and emissions and at the same time the firm finds alternative materials to substitute its non-environmental-friendly materials. Some of the products and even components of the product are being recycled and reused back in process. The process helps the firm to reduce the waste from their manufacturing process and start to consume environmental-friendly materials and processes.

Another interesting change the firm did was by adopting paperless concept. Online system or electronic mail delivery is used to update information related to management rather than use paper or hardcopies. The use of chemical substances was reduced in production in accordance of environmental protection. To implement this, the

firm requested the suppliers of chemicals to build an appropriate system to control chemical substances contained in process materials (Alias, Hami & Shafie, 2019).

2.8.2 Implementation of Clean Technology in Crude Palm Oil Industry

The case study is based on the industry of crude palm oil which is a fast-growing sector compared with other industries. However, the pollution level generated from this industry has been escalating. Palm oil production is being used for food and non-food application. Two types of processes involved in milling of palm oil which are dry processing mills and wet processing mills. These processes create many pollution problems such as consumption of large amount of water, high organic loaded wastewater generation, high amount of solid waste generation and air pollution. Palm oil mill effluents (POME) contributes to the pollution of water surface in the area where the palm is grown and processed. POME happens during rainy season and the high spillage from the wastewater treatment plant causes pollution of heavy rain to nearby waterway. Not only that, methane and carbon dioxide are produced in anaerobic ponds which will be released into the atmosphere.

To overcome all these problems, the industry has considered cleaner production approaches. The impact of waste can be reduced by minimizing the amount of waste that need to be treated and disposed. Environmental impacts from crude palm oil mills can be reduced by implementing pollution prevention measures. Implementation of cleaner production in minimizing the waste stream at the source initiates the industry to encounter appropriate reuse of the waste streams which remains during production. In modelling the industrial system, the environmental control is an attempt after modelling natural ecosystem. Optimizing resource consumption and minimize waste discharge to the environment are the goals of this industry (Chavalparit & Orathai, 2006).

2.9 Summary of Literature Review

Current status of climate change and global warming issues in Malaysia and all over the world were discussed in this literature review. Carbon footprint and emission of CO_2 from industrial activities have been discussed. The manufacturing process of mosquito coils, materials and resource consumptions, and waste generated from the premise were also discussed in this chapter. The environmental issues that arise from manufacturing of mosquito coils were discussed. Emission of CO_2 from the premise causes global warming. Thus, greening strategies to reduce the emission were discussed together with the establishment by Malaysian government. Green strategy is divided into 3 which are green practices, green innovation and green performance. Cleaner production strategies in greening the premise by minimizing the environmental impacts were discussed. Implementation of CP options which includes input substitution, good housekeeping, internal recycling, technological optimisation and optimization of products were discussed. Case study on implementation of CP strategy in different industries were discussed. Green initiative enhancement by manufacturer to green the premise and to reduce emission of CO_2 were discussed in the case study. Thus, material consumption and waste generation from the premise need to be analysed to implement CP strategy with the aim of greening the premise and at the same time to increase process efficiency concurrently.

CHAPTER 3: METHODOLOGY

3.1 General Research Methodology

The overview of the research is shown in Figure 3.1. The research begins with literature findings followed by selection of premise, finding information about the premise and Cleaner Production Audit. This audit was conducted at the manufacturing site. The findings of the audit were analyzed and tabulated. On site CP audit was performed according to observation on site, interview with workers and collected data from person in charge.

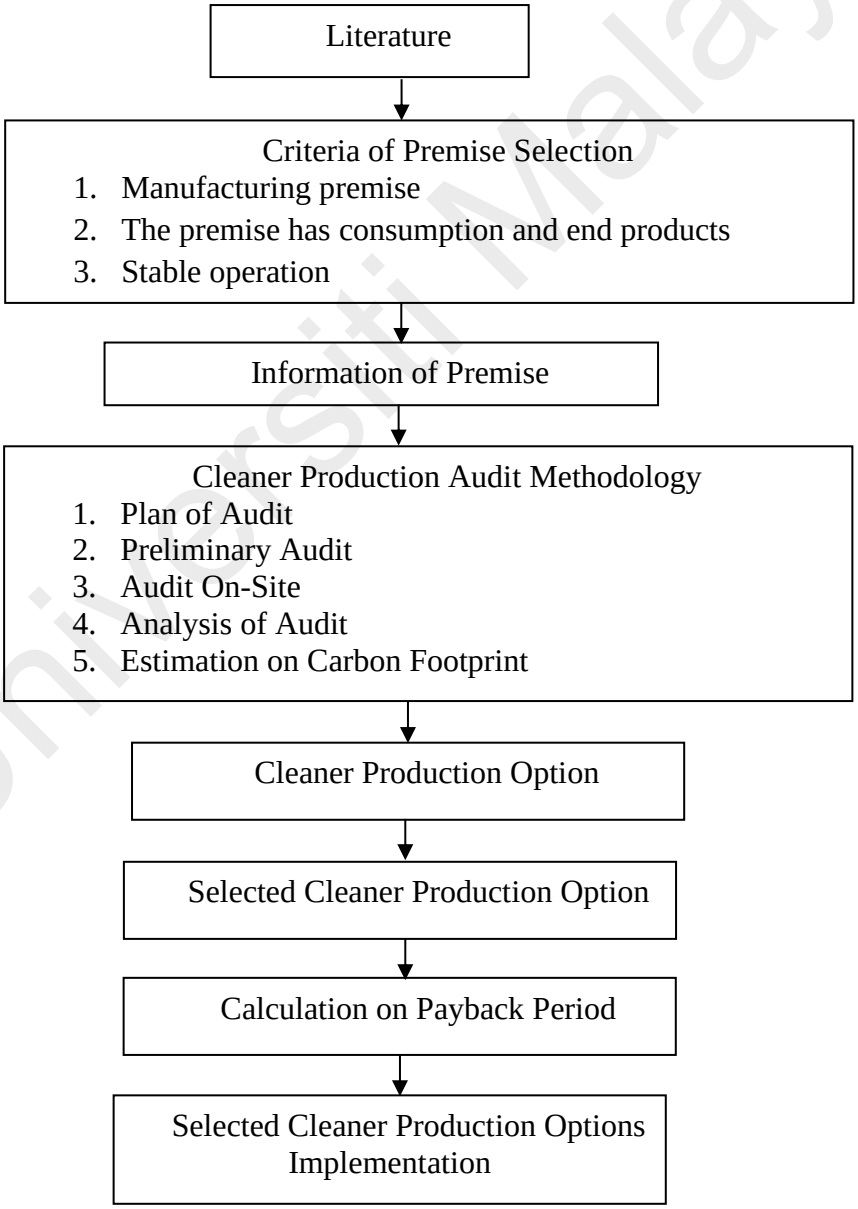

Figure 3.1: Research Project Methodology

3.2 Premise Selection

This research was conducted in a mosquito coil manufacturing premise. The selection of premise is based on stable operation with proper documentation and a system to record and monitor their manufacturing operations, daily processes and waste generated from the manufacturing process. Permission was granted on 10th of November 2020 by the management of this premise to collect the data regarding the premise's manufacturing process and to interview the workers during their operating hours.

3.3 Details of Premise

This premise stationed at Sungai Siput, Perak which is a mosquito coils manufacturing premise. The plant operates for 8 hours per day and a total of 70 employees working in that premise excluding staffs. This premise manufactures approximately 1,040 batches of mosquito coils which is equivalent to 83,200 kgs per month.

3.4 Cleaner Production Audit Methodology

3.4.1 Audit Plan

Cleaner production audit is the foundation to implement cleaner production in the premise. Thus, the starting point of cleaner production is by planning an audit and execute the audit. Planning at the initial stage is very important to ensure a smooth flow and effective audit process. The aim, objective and scope must be clearly defined. To make a CP audit to be successful with all aspects, a CP team was formed. The team members were from different department mainly from production, safe, health and environment maintenance, quality control and quality assurance. Team members were selected based on their experience and well-verse about overall operations. They were able to contribute and assist during the CP audit and the implementation of CP. Table 3.1 shows the prepared CP audit schedule.

Table 3.1: Schedule of CP Audit Plan

No.	Date	Activities
1	10th November 2020	Visit of Preliminary i. To obtain details about the premise (type of manufacturing, number of employees) ii. To recognize the flow of operational process iii. To recognize the category of equipment and machineries available
2	11th February 2021	Audit On-site with a manufacturing process visit and interview session with workers i. To obtain data from processes of production 1. Consumption of materials 2. Production output 3. Consumption of electricity 4. Consumption of fuel 5. Solid waste and liquid waste 6. Management of safety and health ii. To identify the resource used during production input and output
3	31st January 2021	Generation of CP option i. To study environmental needs and to identify the best CP options.

3.4.2 Preliminary Audit

Preliminary audit was organized to obtain particulars on the premise's background, material used to manufacture a product, premise's operating hours, the total number of operators working in the premise, quantity of total final product and required time to produce 1 batch of mosquito coils from mixing until packaging. This audit was conducted by the guidance of the CP team that comprises of members from different department. Table 3.2 shows the process input and process output.

Table 3.2: Process Flow Chart for Mosquito Coil's Input and Output

Process	Input	Output
Raw material receiving from warehouse and Quality check	1. Raw material 2. Use of forklift	Used container, sacks Wastage of raw material
Preparation of chemical and powder premix	1. Raw material 2. Use of electricity	Solid waste and liquid waste
Mixing of chemical premix and powder premix, Mixing of colour	1. Raw material 2. Use of electricity	Contaminated solid and liquid waste
Stamping	1. Chemical and powder premix 2. Use of electricity	Contaminated solid wet waste
Drying (Chamber room)	1. Fuel for burning 2. Use of electricity	Dried coils waste
Quality control checking	1. Use of electricity	Release of carbon monoxide during burning test Contaminated solid waste
Packaging	1. Packaging materials	Wastage of packaging materials
Warehouse	1. Use of forklift 2. Electricity	Emission of carbon dioxide

3.4.3 On-Site Audit

CP audit was carried out at the mosquito coil manufacturing premise on 11th February 2021. The audit was carried out in few actions which includes:

- Introductory Meeting with selected CP team members
- Review of documents on the process workflow, inventory records and management of raw material records
- Detailed Site Inspection

- Interview with Production Manager, Safety, Health and Environmental Executive, Production Supervisor and Maintenance and Quality control Executive.
- Review Evidence obtained from Audit
- A Conclusory Meeting

The focus of this on-site audit is to know the process flow and to identify the details of the material used in production, electricity and fuel consumption and type of waste generated form the manufacturing process. An Audit was used to ease the audit process which is attached in Appendix A was used to throughout this audit.

3.4.4 Audit Analysis

All documents and data were reviewed and positive aspects and expectations were explained to the personnel of the facility. Feedbacks were highlighted to each department's person in charge for further improvement purposes on proper procedures at respective department. Table 3.3 shows the method to estimate on activity of production to be use for audit analysis.

Table 3.3: Method to Estimate Production Activities

Aspect		Estimation Method
Production	Consumption of raw materials	Quantity of raw material needed to produce 1 mosquito coil
	Consumption of electricity	Quantity on consumption of electricity (based on premise's utility bill)
	Consumption of diesel	Quantity of diesel needed to produce 1 mosquito coils
Waste	Contaminated solid waste	Solid waste generated from production process

Table 3.3: Method to Estimate Production Activities

	Contaminated liquid waste	Generated liquid waste from production process
Others	Cost of Operation	Cost of operational production
	Production hours per batch	Time needed to mix one batch of mosquito coils
	Issue of safety during production	Safety, Health and Environmental risks encountered during: - preparation of chemical and powder premix - mixing of premix in the kneading machine - Packing process

3.4.5 Carbon Footprint Estimation

Energy from industry is the main cause concerned in generating GHG. Thus, carbon footprint calculation was used to calculate the total amount of emitted greenhouse gases from the life cycle of product. This calculation used as an estimation tool in managing and reducing the emission of carbon dioxide. Intergovernmental Panel on Climate Change (IPCC) reported that GHG is increased from activities of all nations and this has noteworthy negative impact on climate change. Thus, it can be proved that, of all the greenhouse gases, carbon dioxide has the largest contribution (Radu, Scrieciu & Caracota, 2013).

Malaysia's emission factors were used to calculate the entity emission factor. This calculation together involves the emission factors form IPCC guidelines of National Greenhouse Gas Inventories. The total emission of CO_2 can be calculated by addition of individual CO_2 of the entity emission factor (Rahim & Raman, 2017).

CO_2 emission (kg CO_2) in total = $\sum$ (Unit of Data × Unit of Emission Factor) -------(1)

Table 3.4: Emission Factor of Carbon

Source and Waste	Emission Factor	Unit	Reference
Electricity	0.67	kg CO_2/ kWh	(Rahim & Raman, 2017)
Fuel-Diesel	2.69	kg CO_2/ litre	(Rahim & Raman, 2017)
Waste from Solid	3.7	kg CO_2/ kg	(IPCC, 2006)
Waste from Liquid	1.0	kg CO_2/ kg	(Rahim & Raman, 2017)

3.5 Cleaner Production Options Generation

Based on the complete data collection and result analyzation, cleaner production options will be proposed to be implemented in this premise for further improvement and development. Cleaner production leads to the maximum feasible reduction of all pollutants generated at the production site in a premise. It also leads to gain profit through improvement in productivity and environmental performance. CP options can be categorized as listed below:

i) Material Substitution

Material substitution is mostly implemented to initiate CP options. In this premise, the common materials used are, active ingredient, dye, raw powders, perfume and packaging materials. Thus, material substitution can be done by analyzing the characteristics of each material used in the premise. Through this way, we can help to identify which material gives negative impact to the environment and that particular material can be replaced to an environmental-friendly material. It is also important to ensure the material substituted must not affect the quality of the product.

ii) Process Control Modify

Process Control can be done by analyzing the equipment instructions and the online process. Commonly, process control modify is performed based on recommendation from supplier or vender or recommendation from experienced staffs. Thus, process control that is done must not affect the overall process and the efficiency of the finished goods. Process of record keeping must be diligent to enable the processes carried put in a more efficient way and at lower rate of waste and emission generation.

iii) Design change/Modification

Design change is referred to modify the existing production machinery or equipment to run the process at higher efficiency and with minimal generation of waste. The parts of machinery need to be changed if they are out of specification or if they are too old. This can contribute to significant improvements in the premise.

iv) Housekeeping

Housekeeping is an appropriate managerial and operational action to prevent any leakage or spills during any operation process. A good housekeeping can also provide a safe working environment that is clean for all workers for a better daily productivity.

v) Technology Change

Technology change can be implemented by changing the old machinery into a new machine which will be more efficient in terms less waste production. Many machineries available in market that has tendency to minimize the consumption of material and energy.

vi) Recycle and Reuse

Recycling and reuse options are ranked in the environmental management hierarchy as the most preferable and cost saving methods. In this premise the leftover materials used during premix can be recycled and be used back in mixing. This implementation can avoid waste management options. However, during recycling and reuse, person in charge must make sure the properties of mixing material to be within required specification.

vii) Training and awareness programs for workers

Workers must be trained on how to implement cleaner production strategy throughout their working period. Employee with lack of knowledge on CP, could be a reason for high waste generation to occur by lowering the productivity.

3.6 Cleaner Production Options Evaluation

Generation of cleaner production options are determined according to the collected data from mosquito coil manufacturing premise. The implementation of generated CP is based on process and suitability. This implementation of CP will prevent environmental strategy towards processes. At the same time, it can increase overall efficiency and reduce damage and risk for humans and environment. Thus, the CP options are classified based on feasibility study of environmental, economic and technical. Environmental feasibility study focuses on waste generation and reduction of pollution while technical feasibility study focuses on practice to implement CP options without disturbing the operational performance. Study on economic feasibility is mainly on the investment cost, the return of investment (ROI), and benefits of annual production. Thus, estimated savings after the implementation of CP should be considered to conduct these feasibility studies, Thus, the selected options are based on minimal investment cost.

Technical evaluation involves the collection of additional information with analysis that were not collected during assessment phase. This evaluation must involve the right person who is knowledgeable of the following aspects:

i) Operation procedures and technical skill requirements

ii) Process control requirements

iii) Maintenance requirements

iv) Space requirement

v) Spare part requirements

vi) Need for new utilities or upgrades

vii) Safety and health

viii) Compatibility with environment

ix) Supplier service levels

In environment evaluation, it is very important to estimate the impact of investment on the environment. The information regarding the impacts of production process on the environmental and energy efficiency of a unit operation should be gathered. A reliable estimation of the waste is needed to implement cleaner production investment. The aspects that need to be taken into consideration are as follows:

i) Scarcity of resources

ii) Volume of waste streams

iii) Toxicity of waste streams

iv) Shifts of waste from one medium to the other and sub-optimization

v) Health and safety issued

vi) Energy consumption

Economic evaluation is to evaluate the effectiveness of cost from cleaner production options. This evaluation provides an economic benefit via reduction in waste generation and resource consumption. The profit of a proposed investment and the standard measures implemented is assessing through return of investment (ROI) in this study. To calculate ROI, the cost of investment and annual saving of the premise will be considered.

3.7 Payback Period Calculation

Payback period determines the exact proportion of time needed by a premise to recover its initial investment in CP option implementation and to identify the expected savings. The most preferable CP options in this project are with low payback period as short period of time required with ability of investment cost. Equation 2 shows the formula used to calculation of payback period.

$$\text{Payback period} = \frac{Total\ Investment}{Annual\ Savings} \quad \text{----------(2)}$$

The investment is represented by the cost of the following items:

i) Process Equipment

ii) Material and location of preparation

iii) Utility connection

iv) Construction and installation

v) Engineering and consulting services

vi) Start-up which includes training to operators and maintenance personnel

vii) Subsidies

3.8 Safety Precautions

During the site visit, Safety, Health and Environmental executive will explained on the safety procedures before entering the production floor. Implemented safety rules and practices in this premise must be obeyed. Handbook on premise's safety was distributed prior to enter the premise. Before entering the production site, face mask, safety shoe and ear plug must be worn. The scope of the audit covered the aspects of raw materials, electricity and fuel consumption, solid and liquid waste, output of production and performance of safety and health in the premise. Machine operation, process of production, warehouse storage and material handling were inspected. Before the visit, plan of audit, checklist of audit and area to be inspected were well prepared as the auditors informed their arrival to premise in advance. All the workers must be informed on the audit to ensure they are aware about the visit. The workers must be informed on the interview section before the visit. The site visit is to improvise the process of operation and condition of work place. The interview sessions with workers were carried out in accordance to the time allocated by the supervisor without affecting the efficiency of production. This was to done to ensure that the site visit and interview sessions did not affect the operating hours or work efficiency of the premise. Neither repairing nor maintenance work should be conducted in production area during the site visit. The management or person in charge should completed all those work before the audit.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Introduction

Audit of cleaner production was performed in the mosquito coil manufacturing premise based on the scopes specified in the audit plan. 70 workers working in this premise with 8 hours per day of operation hours and 6 days per week. 40 batches of mosquito coils are produced daily which is equivalent to 3,200 kgs. 30 minutes to produce one batch of mosquito coil. Consumption of material energy and waste generation were recognized and analyzed based on the collected data. The findings of the audit are listed in Audit Form at Appendix A. Initiation of CP options were according to result of analysis and feasibility studies.

4.2 Cleaner Production Audit

4.2.1 Electricity Consumption

The electricity consumption is calculated based on utility bill form Tenaga National Berhad (TNB). The total electricity consumption is calculated as RM 0.4407 per kWh and total consumption for this premise is 564×10^3 kWh per year. This electricity consumption is further divided into two aspects namely consumption of electricity during mosquito coil manufacturing process and consumption of electricity other than mosquito coil manufacturing process such as maintenance, lab and warehouse. Overall consumption of electricity includes lights, machineries, air conditioner and equipment operation. Consumption of electricity per month and per year were systemize in Table 4.1.

Table 4.1: Electricity Consumption for Mosquito Coil Production

Consumption	Energy Resources	Electricity (kWh)
Consumption in mosquito coil manufacturing process	Annual	372×10^3 kWh
	Monthly	31×10^3 kWh
Consumption in non-manufacturing process (maintenance, lab, warehouse)	Annual	192×10^3 kWh
	Monthly	16×10^3 kWh
Cost per unit		RM 0.4407/kWh
Annual Cost		RM 247,176

Table 4.2 shows electricity consumption for each equipment used to manufacture mosquito coils starting from initial step of chemical and powder premix until the final stage of finished goods. Thus, the electricity consumption of each equipment to produce 1 kg of mosquito coil was further extracted and tabulated as below.

Table 4.2: Consumption based on Equipment for 1 kg of Mosquito Coil

Equipment	kWh	Consumption for 1 kg of Mosquito Coils (kWh/kg of Coils)
Chemical Mixing Tank	2×10^3	0.02
Powder Premix Machine	5×10^3	0.06
Kneading Machine	7×10^3	0.08
Stamping Machine	10×10^3	0.12
Collecting Machine	1.5×10^3	0.02
Wrapping Machine	3.5×10^3	0.04
Cartoning Machine	2×10^3	0.02
Total		0.37 kWh/kg of Coils

4.2.2 Consumption of Chemicals, Powders and Packaging Materials

This mosquito coil manufacturing premise uses a small amount of chemical and large quantity of powders to produce mosquito coil. Based on the audit result, 80 kg of chemical and powder premix is used for one batch that produces a total of 3,300 pieces of mosquito coils. Packaging materials includes, wrappers, paper boxes and carton boxes. Table 4.3 shows the consumption of chemicals, powders and packaging materials.

Table 4.3: Consumption of Chemicals, Powders and Packaging Materials

Source	Monthly Consumption (kg)	Annual Consumption (tons)
Chemicals	1,040	12
Powders	72,800	870
Packaging Materials	3,600	430
Total	**77,440**	**1,312**

4.2.3 Fuel Consumption

The premise uses diesel as the fuel for chamber room and for forklift. Chambers are used to heat up the wet coils by burning the diesel. Both storehouse and production use forklift to transfer raw material, chemicals, powders and finished goods. The use of diesel will be quantified based on chamber and diesel consumption. The audit shows that a monthly consumption of 9,412 liters of diesel cost about RM 18,635 per month and RM 223,629 per year.

Diesel consumption for chamber room is calculated as shown below:

Diesel consumption for 4 chamber rooms = 312 liters per day

= 8,112 liters per month (26 days)

Diesel consumption for forklift is calculated as shown below:

50 liter per day × 26 = 1,300 liters per month

Table 4.4 shows the consumption of diesel annually for mosquito coil production and consumption for 1 kg of mosquito coil.

Table 4.4: Consumption of Fuel in Mosquito Coil Production.

Resources	**Diesel**
Annual Consumption	113×10^3 liters
Unit cost	RM 1.98/ liters
Annual cost	RM 223,629
Diesel consumption for 1kg of mosquito coil	0.113 L/kg of mosquito coil

4.2.4 Waste Generation

Any waste that is hazardous is considered as a scheduled waste. It has higher potential to impact the environment and public health. In the first schedule, there were a total of 77 types of scheduled waste that included industrial wastes. The waste generated during manufacturing of mosquito coils were further classified into solid and liquid waste. The quantity of waste generated for both types were calculated and tabulated in Table 4.5 in accordance to the manufacture of per kg of mosquito coils and total manufacture of mosquito coils per year.

Table 4.5: Generation of Solid and Liquid Waste

Category of waste	Generated quantity
Liquid schedule waste	2,880 kg per year
	0.0028 kg/ kg of mosquito coils
Solid schedule waste	15,600 per year
	0.015 kg/kg of mosquito coils

The total liquid schedule waste recorded is 2,880 kg per year that sums a total of 240 kg per month. This liquid scheduled waste includes the waste form kneading machine during chemical mixing and expired raw materials. Based on the observations from the audit, quantity of waste during chemical mixing in kneading machine is higher compared to expired raw materials and spillage. Generated solid scheduled waste in this premise is 1,300 kg per month which is 15,600 kg per year. The solid scheduled waste consists of a container or drum which are contaminated by chemicals, contaminated gloves, gunny bags and packaging materials.

4.2.5 Safety, Health and Environment Issues

The Safety, Health and Environmental issues were too discovered throughout the audit. Several risks were identified and the level of the risks identified were assessed and prioritized. The method of risk evaluation is identified from probability and severity that is shown in Table 4.5. This method was helpful to construct immediate control steps or actions to be taken if in case any incidents happen in the premise.

Table 4.6: Risk Evaluation

		Probability/Chances			
		I	II	III	IV
Severity		Never happens but possible to happen	It might happen before but unsure	It Happened before	It happened frequently before
A	Treatment of First Aid	1	2	4	7
B	Minor injury (Leave 1-3 days)	3	5	8	11
C	Major injury (Leave >3 days)	6	9	12	14
D	Fatality	10	13	15	16

The risk level is identified by multiplying the probability and severity. The criteria for risk level are listed below:

- Low (Risk level 1- 3) – No need to control
- Medium (Risk level 4 -10) – Control steps are needed
- High (Risk level 11 – 16) – Control steps are urgently needed

The probability criteria are as below:

I – Never happens but possible to happen in premise

II – It might happen before in other premises but unsure

III – Happened in premise

IV – It happened frequently in premise before

The criteria of severity are listed below:

A – Treatment for fight aid for light injuries

B - Minor injuries that required 1 to 3 days of leave

C – Major injuries which requires leaves for more than 3 days

D – Death causing injuries

Table 4.7 shows the risk assessment listed in safety, health and environmental observation which was identified in mosquito coil manufacturing premise. This comprises of observations, potential risk from the observations and level of risk identified.

Table 4.7: Observation on Risk Assessment

No	Observation	Potential Risk	Probability	Severity	Risk Level
1	Lack of enforcement on usage of PPE in stamping department	Risk to worker health as the stamping machine sound is loud	5	5	High
2	Non authorised person driving forklift	Cause injury to worker	3	5	High
3	No proper wiring system and wires are on floor	Cause injury to worker	3	3	Medium
4	Incomplete first aid box in production site	Delay in giving first aid treatment	2	1	Low
5	Chemical bottle was found in production site without any label	Workers might consume the chemical	1	5	Medium
6	First Aid box is far from production site	Delay in giving first aid treatment	2	1	Low
7	Improper labelling on container of waste to be disposed	Possibility of workers to dispose hazardous waste into general waste	5	1	Medium

Table 4.7: Observation on Risk Assessment

No	Observation	Potential Risk	Probability	Severity	Risk Level
8	Workers carry heavy cartons in packing department	Ergonomic problem to the worker	3	2	Medium
9	Chemical Storage area with no secondary containment	Spillage of chemical	1	2	Low
10	Toilet used by workers is not clean	Potential to infect workers	1	4	Low

Two observations show the risk is high, four observations show the risk is medium and four observations show the risk is low according to the risk assessment. Implementation of immediate action should be done for the three observations with high risk to reduce or to eliminate the risk. This is followed by observation of medium risk where proper action needed. The low-risk observation with lower priorities also need further action.

4.3 Carbon footprint Calculation for Mosquito Coils Production

Carbon footprint was calculated to estimate the release of CO_2 emissions based on the overall process. These emissions were calculated for diesel and electricity consumption and generation of scheduled waste. Equation (3), shows the formula to calculate carbon footprint:

$$CO_2 \text{ emission in total (kg } CO_2) = \text{data of total entity} \times \text{Emission factor} \quad (3)$$

Monthly production of mosquito coils is calculated as 83,200 kg. Thus, consumption of electricity, diesel, and solid and liquid waste were further derived for1 kg of product and the CO_2 emission was tabulated in Table 4.8.

4.3.1 Monthly and Annual Production of Mosquito Coils Calculation

Production of batch per day= 40 batches

Monthly production of mosquito coils = 83,200 kg

Annual production of mosquito coils = 998,400 kg

4.3.2 Consumption per 1 kg of Product Calculation

Electricity Consumption for mosquito coil manufacturing process

Monthly consumption = 31×10^3 kWh / 83,200 kg

Consumption for 1 kg of product = 0.373 kWh/ kg of product

Electricity Consumption non-manufacturing process

Monthly consumption = 16×10^3 kWh / 83,200 kg

Consumption for 1 kg of product = 0.192 kWh/ kg of product

Fuel Consumption

Monthly consumption = 9.4×10^3 liters / 83,200 kg

Consumption for 1 kg of product = 0.113 L / kg of product

Solid schedule waste

Monthly consumption = 1,300 kg / 83,200 kg

Consumption for 1 kg of product = 0.015 kg / kg of product

Liquid schedule waste

Monthly consumption = 240 kg

Consumption for 1 kg of product = 0.0028 kg / kg of product

Table 4.8: Overall CO_2 Emission from Mosquito Coil Production

Source (Monthly Consumption)	1 kg of product (mosquito coils)	Emission factor of carbon	Emission of CO_2 (kg CO_2 / kg product)	Emission of CO_2 from monthly production (8.32×10^4 kg)	CO_2 emission from annual production (9.98×10^5 kg)	Percentage of CO_2 emission per annual production (%)
31×10^3 kWh electricity in mosquito coil manufacturing process	0.37 kWh/ kg of product	0.67 kg CO_2/kWh	0.25	2.08×10^4	2.50×10^5	33.69
16×10^3 kWh electricity in non-manufacturing process	0.19 kWh/ kg of product	0.67 kg CO_2/kWh	0.13	1.07×10^4	1.29×10^5	17.39
9.4×10^3 liters of diesel	0.11 L / kg of product	2.69 kg CO_2/liter	0.30	2.53×10^4	3.04×10^5	40.98
1300 kg of solid waste	0.02 kg / kg of product	3.70 kg CO_2/ kg	0.06	4.66×10^3	5.59×10^4	7.53
240 kg of liquid waste	0.003 kg / kg of product	1.00 kg CO_2 / kg	0.003	0.25×10^3	2.99×10^3	0.41
Total			**0.742**	**6.17×10^4**	**7.42×10^5**	**100**

4.4 Proposed Cleaner Production Options in Mosquito Coil Premise

Based on the result in Table 4.7, the electricity consumption in manufacturing and non-manufacturing such as maintenance, lab and warehouse have highest CO_2 emission with a total of 51.08% based on annual production. The second highest CO_2 emission is from diesel consumption which is 40.98% followed by solid schedule waste (7.53%) and liquid waste (0.41%). Contribution of CO_2 emission from electricity is high as the equipment solely depends on electricity because it is the only energy source to run production.

4.4.1 CP Options to Reduce Electricity Consumption

4.4.1.1 CP Option 1- Solar Panel System

A solar panel system can be installed in the premise. Electricity source of solar panel or photovoltaic can be generated from solar power. It works by capturing sun's energy using photovoltaic cell and convert it into electricity. This can reduce the CO_2 emission from 35% to 40% based on basic level of electrical consumption and also can reduce up to 100% of electric consumption if combined with robust battery storage technologies. (Park, et al., 2020). Thus, installing a solar panel system at 350 kWp solar PV system, can reduce the electricity consumption in premise and emission of CO_2 can be reduced. A solar system of 350 kWp can generate approximately 564,000 kWh per year. Figure 4.1 shows the roof top that has power plant of NIT-Agartala (Bhattacharjee, et al., 2012).

Figure 4.1: Power plant at Roof Top with 60 kWp

Calculation on cost of investment and annual saving as below:

Cost of Investment : RM 1,000,000 / 350 kWp system of Solar PV

Annual Saving of Premise : RM 200,000

Payback period = Cost of Investment / Annual Saving of Premise

= RM 1,000,000 / RM 200,000

= 5.0 years

4.4.1.2 CP Option 2- Air Conditioner Temperature

The use of air conditioner should be optimized where the temperature should be set not lesser than and ranging from 24℃ to 26℃. This medium temperature can reduce the electricity consumption. Publics are recommended to tune the air conditioner temperature between 24℃ to 26℃ for more electricity savings (Elonkovan, 2019). 6% of energy can be saved by increasing one degree of air condition temperature (Kader, 2014). In this premise, electricity is consumed by appliances such as production's machineries, lights, air conditioners and computers. An estimation of total of 1.1×10^3 kg of CO_2 emission per month can be reduced by optimizing the temperature of 10 air conditioners at range of 24℃ to 26℃ in the premise.

4.4.1.3 CP Option 3- Motion Sensor

During the observation, it was found that the lights in production areas were left switched on for the whole day even at times there is no ongoing operations. It was also identified that there are 30% of areas of the premise which are not actively used. Therefore, motion sensor can be installed at the area with less production operation to reduce the energy waste. This installation enables an automated switching or turning on and off the lights, whenever motion detected and not detected respectively. 0.06 kWh can be saved by switching off these bulbs. Installing the sensor can minimize the operating time of lights from 8 hours to 2 hours (Peters, 2017). A sum of 25 kWh of electricity per day can be saved by turning off the light for 6 hours which is a saving of 91000 kWh estimation for one year. Moreover, reduction of 7% of CO every year which is 54 kg CO_2 per month can be obtain. Figure 4.2 shows the motion sensor that can installed on a building lighting for energy saving.

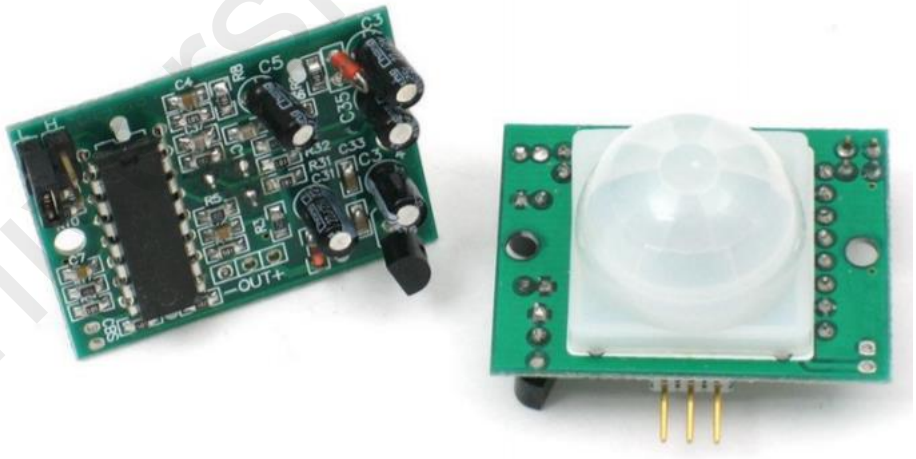

Figure 4.2: Motion sensor (Adafruit Industries, 2020)

Calculation on cost of investment and annual saving as below:

Cost of Investment : RM 510 (Adafruit Industries, 2020)

Annual Saving of Premise : RM 1,000

Payback period = Cost of Investment/ Annual Saving of Premise

= RM 510/RM 1,000

= 0.5 years

4.4.2 CP Option for Chemicals, Powders and Packaging Materials Optimization

4.4.2.1 CP Option 4- Lean Manufacturing

Lean manufacturing tool can be implemented in a premise as it helps to minimize generated waste, improve efficiency and accomplished target. In other word, it reduces environmental impact. Manufacturer of the premise uses 7S framework as a regular tool to lead and control the workplace. Each component in this framework starts with the letter S which are Sort, Set in Order, Shine, Standardize, Sustain, Spirit and Safety. Component of sorting describes that only needed tools should be in a specific work place and unnecessary tools and equipment should be moved to the other place. The Set in Order emphasizes on keeping the machineries part in a proper order based on how the process is conducted. The tools need to be located in a way that makes it convenient for the workers to access them when needed. The cleanliness of the tools and equipment is as described in Shine component. The component standardize is all about making sure that the equipment and machineries parts are standardized. Sustain component refers to the commitment in maintaining the ongoing basis whereas the spirit component refers worker's commitment toward their responsibility during working hours. Safety is the last component and it helps to create a safe work environment (Gupta, et al., 2015).

4.4.2.2 CP Option 5- Minimizing Transfer of Materials

Suggestion in minimizing the transferring of chemicals, powder and packaging materials. In this premise, the powders from supplier will be unloaded in warehouse. These powders will then be transferred to powder room for further processing. During the transferring of powders, there is 5% loss of raw materials is reported as some of the powders are obtained in jumbo bags. Therefore, it was suggested to unload the powder bags powder room instead of warehouse. Spaces or compartments for the process of unloading the powder in the powder rooms should be allocated and weighing of powders should be done in powder rooms before consumption. Besides, long distance between chemical mixing room and production area can cause spillage while transferring and an estimation of 3% of loss might happen. Thus, restructuring the chemical mixing area near to the production area can minimize the transfer.

4.4.2.3 CP Option 6- Zero Waste Strategy Program

Zero waste program was implemented in several countries even-though they are without any knowledge of zero waste strategy. Internal green supply chain management with customers and suppliers should be considered by companies. This is to have a good practice on environmental sustainability to optimize the use of materials by improving operational performance (Yong & Chin, 2018). This implementation in mosquito coil industries can help to manage the use of chemical and powder with less spillage during mixing and in making a tidier workplace. Proper handling of packaging materials can avoid rejects either by cause of machine or human error. This program also brings all workers commit and engage in creating a clean, safe and healthy working environment.

4.4.3 CP Options to Reduce Consumption of Diesel

4.4.3.1 CP Option 7- Rechargeable Forklift

Forklifts that are being used in this premise uses diesel to operate within the premise. Thus, CP option suggested to substitute to rechargeable forklifts which will eliminate diesel as a source of energy for forklifts. A fuel cell-powered or a battery powered forklifts can be substituted to reduce GHG emissions (Haghi, et al., 2019). It can reduce approximately 14% of CO_2 emission which is 3.497×10^3 kg CO_2 per month. Figure 4.3 shows the design of electrical forklift with its features.

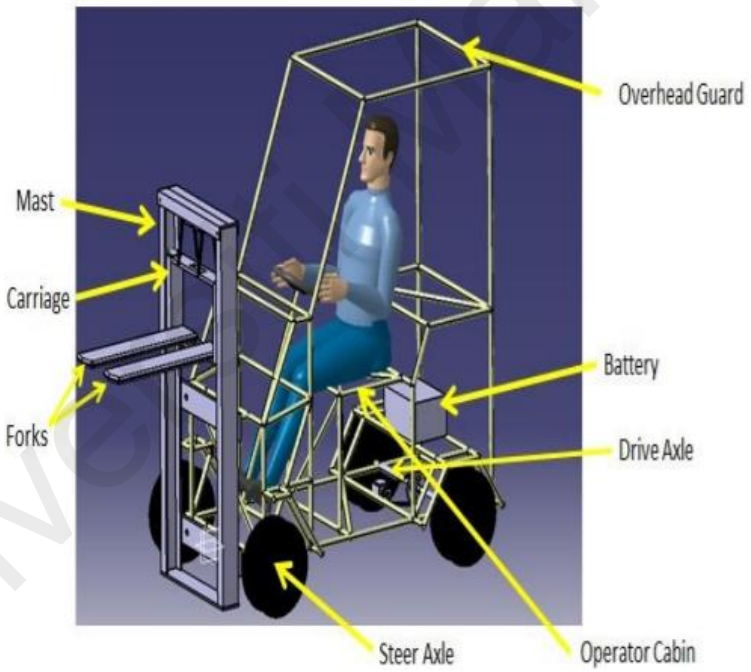

Figure 4.3: Electrical Forklift (Karan, et al., 2020)

Calculation on cost of investment and annual saving of premise as below:

Cost of Investment : RM 80,000 (Electric Counterbalance Forklifts)

Annual Saving of Premise : RM 15,000

Payback period = Cost of Investment / Annual Saving of Premise

= RM80,000 / RM 15,000

= 5.3 years

4.4.3.2 CP Option 8- Effective Chamber Room Operation

The number of stacks in a chamber room can be increased. Initially 15 stacks of wet coils will be placed in a chamber room and the heat supply will be turned on for 6 hours to let the coils dry. This process uses diesel for 6 hours for each chamber room. If more stacks are placed in a chamber room, the use of diesel in other chambers can be cut off. Therefore, instead of 15 stacks, an additional of 2 stacks can be placed in the chamber room. A total of 17 stacks placed in each chamber rooms can reduce the total number of chamber rooms used and can ultimately save the monthly diesel cost. At the same time, emission of CO_2 from burning of diesel can be reduced with 15% of reduction of diesel consumption for chamber rooms.

4.4.3.3 CP option 9- Electric Pallet Jack

Suggestion to minimize the forklift use in the operational areas for short distance travel and transfer of material. Forklift use should be restricted only to travel for long-distance or lifting heavy materials while short distance travel should use an electrical pallet jack as shown in Figure 4.4. This electrical pallet jack can roll and level the table. It can also be used for picking orders and it has double stacking (STILL GmbH, 2019). This action can help to minimize the consumption of diesel for forklifts and thus the CO_2 emission can be reduced to 5% which is 1.26 x 103 kg CO_2.

Figure 4.4: Electrical Pallet Jack (STILL GmbH, 2019)

Calculation on cost of investment and annual saving of premise as below:

Cost of Investment : RM 10,000 (STILL GmbH, 2019)

Annual Saving of Premise : RM 5,000

Payback period = Cost of Investment / Annual Saving of Premise

= RM 10,000 / RM 5,000

= 2 years

4.4.4 CP Options to Minimize the Generation of Liquid Waste

4.4.4.1 CP Option 10- Drum Handler

During premix of chemicals, the possibilities of spillage to occur is high as the chemical drum is lifted manually to pour the chemicals into the mixing tank. This causes a total 5% due to mishandling. The mixing of chemicals should be convenient for the mixer to avoid any spillage. Thus, a drum handler can be used to avoid manual lifting but it causes ergonomics problem. Figure 4.5 shows a drum handler which is used to transfer and pour content out from the steel drum.

Figure 4.5: Drum Handler (Drum Handling Equipment, 2021)

Calculation on cost of investment and annual saving as below:

Cost of Investment : RM 8,000 (Drum Handling Equipment, 2021)

Annual Saving of Premise : RM 5,000

Payback period = Cost of Investment / Annual Saving of Premise

= RM 8,000 / RM 5,000

= 1.6 years

4.4.4.2 CP Option 11- 3R Initiatives in Liquid Waste Generation

Implementation of 3R initiatives in the premise is an option to minimize the generated liquid waste from the manufacturing process of mosquito coils. 3R is an approach that helps to balance both environmental and economic concerns by reduce, reuse and recycle the liquid waste generated. It also creates an awareness among workers for segregation on waste and eliminate the hazardous waste disposal in domestic areas or vice versa (Kallay, et al., 2015). For example, during the cleaning of stamping machine, the water used to clean the machine can be used back to soak the wet material that will be used for the next day. 3R program need to implemented to handle liquid waste in a correct way and to keep the place clean without any spillage.

4.4.4.3 CP Option 12- Minimization of Fresh Water Usage

Minimization the use of fresh water is a good practice of housekeeping. Water audit need to carried out form product and process redesign. The most effective way is to minimize the consumption of fresh water and maximize water reuse (Sachidananda, et al., 2016). For example, the chemical and perfume bottles can be rinsed using the water prepared to be used during mixing and pour back into the mixing tank. This can avoid the consumption of freshwater to rinse the bottles.

4.4.5 CP Options to Minimize the Generation of Solid Waste

4.4.5.1 CP Option 13- Optimize the Use of Gloves and Tissues

Suggestion to optimize the use of gloves, tissue and papers for cleaning and operation. Excessive use of those items to carry out cleaning process will eventually generate high quantity of waste. Thus, the solid scheduled waste can be reduced by optimizing used of gloves and tissue as a cleaning tool. For example, if there is any emulsifier spillage in the chemical room, cloth can be used to wipe up the spillage, instead of using tissue as cloth can be washed and used back.

4.4.5.2 CP option 14 – Enhance quality of Input Material

A raw material also known as a feedstock is a basic material which is used to produce finished goods. This feedstock are bottleneck assets and are very important in giving profit to the company (Dhumal, et al., 2017). Thus, enhancing good input quality can reduce the generation of solid waste. For example, purchasing good quality powders and starch makes the stamping machine to operate smoothly. Poor quality of powders causes the wet material to crack during stamping. These mixed materials will not be able to be added in into the mixing as it will spoil the whole batch of the premix. Thus, this

material that contains chemicals will be placed under schedule waste. Good quality materials can reduce carbon emission to 40% which is equivalent 1.9×10^3 kg CO^2.

4.4.5.3 CP Option 15- 3R Initiatives in Solid Waste Generation

3R initiation should be implemented to reduce, reuse and recycle the solid waste generated from the manufacturing process of mosquito coils. Reduction of 0.5% of CO_2 emission per month can be estimated by implementing 3R program to handle scheduled solid waste. This is equivalent to 46.1 kg CO_2 (Kallay, et al., 2015). For example, the dry mosquito coil waste can be crushed into powders and reused during mixing of powder premix. It is feasible as the dried coils contain the same chemical that will be used to do mixing in kneading machine. Therefore, it will not affect the AI content of a mosquito coil and at the same time the waste will not be accumulated as it will be used all the time.

4.4.6 CP Options in Improving Overall Process

4.4.6.1 CP Option 16- Upgrade Machinery

Upgrade the machineries and high efficiency equipment in the premise for more energy savings and to reduce the its consumption and man-hour required for the operation. This is because, machineries in industrial sector consumed major part of energy. To reduce energy consumption, modification on the machineries need to be done (Hoque, et al., 2017). Before implement a technology in plant, the process and operation to be studied well to make sure the technology is suitable and worth purchasing. Product efficiency and reduction of material loss in the equipment can be improved from this selected technology. The estimated total cost to upgrade machinery is RM 200,000.

Calculation on cost of investment and annual saving as below:

Cost of Investment : RM 200,000

Annual Saving of Premise : RM 20,000

Payback period = Cost of Investment / Annual Saving of Premise

= RM200,000 / RM 20,000

= 10 years

4.4.6.2 CP Option 17- Training for Workers

Selected workers should be trained on how to repair minor problems in machineries and the spare parts of the machineries should always be available. This will be very helpful as the trained worker can repair the machine on the spot without waiting for the maintenance staffs to come and repair it. Management can allocate fun the send workers for workshop training. This will avoid loss in production output.

4.4.6.3 CP Option 18- Barcode Scanning System

Barcode scanning system can be implemented in warehouse to substitute the work of manual handling for material inventory. Related features can be added to the current ERP system to implement this barcode scanning system. The feature added can assist in controlling the FIFO of raw material and finished goods to avoid misplace and material loss. Besides, it can also reduce errors upon receiving goods and speeding up the process where it can automatically determine storage location. It also helps to identify lack or excess quantity of goods and determine the quality of goods to be shipped (Istiqomah, et al., 2019). Moreover, this system is estimated to eliminate 1 hour of operation by avoiding manual inventory recording and allocation of storage where human error can be eliminated. The investment cost for this feature will be RM 40,000. Figure 4.6 shows an example of barcode scanner that can be purchased.

Figure 4.6: Barcode Scanner (Frusman & Wibisono, 2014)

Calculation on cost of investment and annual saving of premise as below:

Cost of Investment: RM 40,000 (Frusman & Wibisono, 2014)

Annual Saving of Premise: RM 5,700

Payback period = Cost of Investment / Annual Saving of Premise

= RM40,000 / RM 5,700

= 7 years

4.4.7 Safety, Health and Environmental Management

Ensuring worker's safety and health at work place is an important aspect in Safety, Health and environmental management. The working environment should be safe and convenient to conduct work. During this audit, few issues were identified. To control the identified issues, appropriate action should be taken by the management before it is too late. Thus, action plan should be evaluated once the CP options are implemented to ensure the solution offered for the issue was appropriate. Table 4.9 shows the safety issues identified in the premise, risk level and action taken based on CP options. CP implementation in the angle of Safety, Health and Environment provides a safe working conditions for workers and workers feel secured during work in this premise.

Table 4.9: Issues of Safety, Health and Environment and Action Taken

No	Safety Issue	Risk Level	Action
1	Lack of enforcement on usage of PPE at stamping department	High	CP option 19 Safety, Health and Environment team should emphasize the usage of PPE during operating hours. Memo regarding this enforcement should be pasted in every department to make sure the workers comply towards usage of PPE. Inspection and monitoring on the use of PPE by workers should be done regularly.
2	Non authorised person driving forklift	High	CP Option 20 Management should outline a stern memo on the forklift usage only by authorised and trained workers. Punishment should be given to those workers who disobey the rules and to the supervisors who instruct the workers to drive the forklift. The forklift key should be kept in warehouse and those who holds the key should record their names in a log book.
3	No proper wiring system as wires are found on floor	Medium	CP option 21 Safety and Health and Environment officer or executive should inform the maintenance to do a proper wiring system by giving the timeline to compete it as soon as possible.
4	First aid box which is incomplete in production area	Low	CP option 22 Safety and Health and Environment team should form a first aid team to be in-charge of the first aid box. A checklist form needed to be established. First aid box should be checked and refilled with all the required items for every month.
5	Chemical bottle was found in production without any label	Medium	CP option 23 Supervisor of chemical department must make sure all the chemical bottles are labelled and kept in an appropriate place to avoid any misuse of chemicals. Empty chemical bottles need to be labelled as well. Only authorised workers are allowed to enter the chemical room.

Table 4.9: Issues of Safety, Health and Environment and Action Taken

No	Safety Issue	Risk Level	Action
6	Toilet used by workers is not clean	Low	CP option 24 Management must hire a contract worker to clean the toilet daily to avoid any infections to workers. Workers must be educated on the cleanliness and hygiene. Signs such as "Wash your hands" and "Flush after use" should be pasted at every corner in toilet to create awareness among workers.
7	First Aid box is not within reachable distance	Low	CP option 25 A suitable location which is nearby to production area should be identified to install the first aid box. The location must be easy to access during an emergency.
8	Waste to be disposed has no proper labelling	Medium	CP option 26 Colour coding can be applied to waste bins to segregate general waste and hazardous waste. Those bins need to have proper labelling with symbols.
9	Workers carry heavy cartons at packing department	Medium	CP option 27 Workers should be educated with ergonomic approach to lift and handle heavy cartons. Two workers should be allocated to carry the heavy load. Buddy system and work rotation should be implemented in packing department.
10	Chemical Storage area with no secondary containment	Low	CP option 28 Secondary containment must be built in chemical storage area to prevent the spread of any spillage. If the chemical drum is used in production, make sure the drums are on secondary containment pallets as per requirement from DOSH.

4.5 Cleaner Production Options Evaluation

CP options which were proposed will be rated according to ROI and required time for the implementation. The CP options, required time, investment that required, reduction of carbon footprint per month and year and ROI are tabulated in table 4.10. CP options that required shorter time for implementation and with lower ROI are rated accordingly. The CP options which required longer time to implement and with higher ROI are held and monitored for future premise improvement plan. Implementation of CP options was rated using five measures as listed below:

Type 1: Immediate implementation

Measure: Risk is high / no cost needed / additional resources are not required / gives profit to the process / ROI which is less than 2 years

Type 2: Implementation in a period of 6 months

Measure: Risk is medium / cost needed / additional resources are required / gives profit to the process / further study and analysis needed to take action / ROI which is more than 2 years

Type 3: Implementation only with allocation of budget

Measure: Risk is low / high cost needed / additional resources are required / gives profit to the process / ROI which is more than 5 years.

Type 4: Future improvement plan

Measure: Risk is low / high cost needed / additional resources are required / gives profit to the process / ROI which is more than 4 years.

Type 5: Keep in view at least for 10 years

Measure: Risk is low / high cost needed / additional resources are required / gives profit to the process / ROI which is more than 10 years

Table 4.10: CP options with Relevant Details

No	Aspects	CP Options	Time Required	Investment needed (RM)	Reduction Carbon Footprint per Month (tons of CO_2)	Carbon Footprint Reduction per Year (tons of CO_2)	ROI per Year	Priority Measure
1.	Electricity in Mosquito Coils Manufacturing process	i. Installation of solar panel system	3 months	1,000,000	20.8	250.0	5.0	Type 3
2.	Electricity other than mosquito coil manufacturing process	i. Optimization the temperature use for air conditioner	Immediate	0	1.1	13.0	-	Type 1
		ii. Installing motion sensor for light control	Immediate	510	0.053	0.636	0.5	Type 1
3.	Chemical, Powder and Packaging Materials Consumption	i. Minimization transfer of materials	Immediate	0	-	-	-	Type 1

Table 4.10: CP options with Relevant Details

No	Aspects	CP Options	Time Required	Investment needed (RM)	Carbon Footprint Reduction per Month (tons of CO_2)	Reduction Carbon Footprint per Year (tons of CO_2)	ROI per Year	Priority Measure
4.	Diesel Consumption	i. Purchase a rechargeable forklift	12 months	80,000	3.5	42.0	5.3	Type 4
		ii. Effective chamber room operation	Immediate	0	3.8	45.0	-	Type 1
		iii. Purchase electric pallet jack	4 months	10,000	1.3	15.0	2.0	Type 2
5.	Liquid Waste Generation	i. Purchase Drum handler	3 months	8,000	0.012	0.144	1.6	Type 2
		ii. Minimization of water usage	Immediate	0	-	-	-	Type 1
6.	Solid Schedule Waste Generation	i. Optimization on the use of gloves and tissues for cleaning purpose	Immediate	0	-	-	-	Type 1
		ii. Enhance Quality of Input Material	Immediate	0	1.9	22.0	-	Type 1

Table 4.10: CP options with Relevant Details

No	Aspects	CP Options	Time Required	Investment needed (RM)	Reduction of Carbon Footprint per Month (tons of CO_2)	Carbon Footprint Reduction per Year (tons of CO_2)	ROI per Year	Priority Measure
7.	Process of Production	i. Upgrade Machinery	12 months	200,000	-	-	10	Type 4
		ii. Train worker on how to repair minor problems in machinery to avoid loss of time in production	6 months	-	-	-	-	Type 1
		iii. Implementation of barcode scanning system to avoid manual handling of material inventory in warehouse	7 months	40,000	-	-	-	Type 3
8.	Liquid Waste Generation and Solid Schedule Waste	i. Implementation of 3R program for waste handling	Immediate	0	0.009	1.0	-	Type 1

4.6 Recommended CP Options to be implemented in the Premise

Based on the finding of CP options and estimation of carbon footprint, electricity in manufacturing process of mosquito coils and non-manufacturing process of mosquito coils are the major source of CO_2 emission per month. Recommended CP options for electricity consumption can reduce emission of CO_2 and can green the premise. This recommendation of CP is selected according to the priority measures which belongs to Type 1, 2 and the reduction of higher CO_2 for implementation stage of CP options. CP options that belong to Type 3 and 4 could be performed in the up-coming year.

CP options that were recommended will be implemented as tabulated in Table 4.11. Table 4.11 also depicts emission of CO_2 before and after implementation of CP options and payback period. This implementation required four main guidelines as shown below:

Guideline 1: Preparation of implementation plan

During the plan of implementation, a checklist consisting a complete evaluation with CP options, required resources, and responsibility of relevant personnel should be developed. Routine meetings should be organized to follow up and monitor the performance of CP option's progress and issues to be encountered.

Guideline 2: Top management's approval to brief collaborator

The plan which was prepared need to be submitted to the higher authority in the premise for review and approval before implementing CP options.

Guideline 3: Drafting Implementation Schedule

Draft an implementation schedule and include the measures such as awareness promotion and updated process of implementation. Main objective of implementation of CP options, selected CP options, area of implemented CP options and number of staff participated should be covered in the awareness promotion. The documented CP implementation progress must be shared to all the workers. Minutes of meetings, assessment form and collected data should be included in the documentation prepared. All these documents will be utilized to generate a report on implementation CP that is submitted to the top management.

Guideline 4: Executing Training

All the workers should be trained upon the implementations of CP options. The training includes safe handling of material and processes, environmental issues, effective operational process and requirement of safety and health. Every training provided to the workers must be recorded for evidence and evaluated after a month to make sure the workers really understood the material thought during the training. Workers must also be monitored to ensure their working performance is fit for the task as per required after the training.

Table 4.11: Selected CP Options for Implementation

No	Selected CP options	tons of CO_2/ month (Before)	tons of CO_2 / month (After)	Payback period (Year)
1.	Installation of solar panel system	20.8	0	5
2.	Optimization use of air conditioner temperature to reduce electricity consumption	10.7	9.5	-
3.	Motor sensor installation to control light to reduce electricity consumption			0.16
4.	Electric Pallet Jack to minimize use of forklift	25.0	20.0	3.75
5.	Effective chamber room operation to reduce diesel consumption			-
6.	Minimization transfer of materials to reduce liquid waste generation	0.25	0.24	2.6
7.	Drum handler to avoid liquid waste generation			
8.	Minimize Water Usage to reduce liquid waste generation			
9.	Gloves and tissues optimization for cleaning purpose to reduce solid schedule waste generation	4.7	2.8	-
10.	Enhance quality of input material			
11.	3R program implementation to handle waste to reduce liquid waste and solid waste generation	0.5	0.4	-
	Total	**61.9**	**32.9**	**11.51**

Based on the Table 4.11, the best way to green the mosquito coil premise is by implementing recommended CP option in the premise. 46.8% of CO_2 emission can be reduced that is equivalent to 29 tons of CO_2 per month and 348 tons of CO_2 per year. Before implementation, the total CO_2 calculated was 61.9 tons of CO_2 per month and the emission after implementation is 32.9 tons of CO_2 per month. The payback period was calculated based on estimation of investment cost from CP options and annual saving. The estimated payback period to be implemented is shown below:

Total cost of investment	= RM 1,018,500
Total annual saving of premise	= RM 211,000
Payback period	= Cost of Investment/ Annual Saving of Premise
	= 4.8 years

Once the recommended CP options are implemented in the premise, the working area in the premise will be organized with standard operations. CP strategies plays an important role in reducing the loss of electricity, fuel, chemicals, powders and packaging materials. At the same time, it helps to improve the productivity of the workers. For example, workers will be more committed towards work and will produce more output if their working environment is safe and convenient for them. This will increase premise's reputation and remain competitive in world market.

4.7 Overall Opportunities in Malaysia

In this fast-growing world, Malaysia is significantly known for the carbon emission. However, Malaysia has committed itself to reduce the intensity of carbon emission by 40% by 2020 and 45% by 2030. This percentage is based on the year 2005. According to the latest update, Malaysia's ambition is to have "net zero" in 2025. There are many possibilities that Malaysia can achieve their ambition as Malaysia is listed as a country which is developing and has a rigid initiative in protecting the environment. Besides, sustainable development can be promoted for a better management of premise.

Implementation of CP strategy is one amongst option for various sectors to reduce pollution through their operational activities. Malaysian government need to enforce the implementation of CP as a guideline to minimize the pollution from manufacturing industries. A small change in working process can help to reduce carbon emission and increase productivity. The study from this premise can be set as a guideline for other mosquito coil manufacturing industries in Malaysia as they can green the premise by reducing CO_2 emission from their operation. The audit findings from this premise are believed to be informative and could use as a reference for similar manufacturing sectors in implementing their studies on CP strategy.

There are at least 10 manufacturing companies of mosquito coils in Malaysia that have similar methods of processing coils detailed in this study. One mosquito coil manufacturing can reduce carbon emission up to 348 tons of CO_2 per year. Thus overall, in Malaysia we can reduce about 3,480 tons of CO_2 per year creating more greenery industries in Malaysia. This is equivalent of planting about 110 thousand of trees in Malaysia as 1 tree can absorb about 31.5 kg CO_2 in average.

CHAPTER 5: CONCLUSION

5.1 Conclusion

Through this study, it can be concluded that implementation of cleaner production strategies can green the mosquito coil premise by reducing the emission of CO_2. It helps to minimize the waste generation and optimize the use of resource. It also improves online process to run effectively and smoothly. CO_2 is estimated to reduce from 61.9 tons of CO_2 to 32.9 tons of CO_2 per month with the reduction of 348 tons of CO_2 per year. Based on the analysis, electricity consumption from mosquito coil manufacturing and electricity consumption other than mosquito coil manufacturing shows major contribution of CO_2 emission with a total of 31.5 tons of CO_2 per month and 378 tons of CO_2 per year. CO_2 emission for electricity consumption can be reduced to 30.5 tons of CO_2 after the implementation of CP options.

A total of 28 options have been identified in this study. This includes improvement in manufacturing process, optimization on the material usage, electricity and diesel, housekeeping and minimal generation of solid waste and liquid waste. However, 11 options have been selected based on priority measures to be implemented in the mosquito coil manufacturing premise. Total investment of RM 1,018,500 is required for this recommended implementation with 4.8 years of payback period.

The CP options which were not selected for implementation are suggested to be kept in a view to be implemented in the coming years. Based on the analysis, the premise is attainable in the angle of environmental management, economy development, technical and operational improvement. The CP options also improved the efficiency of overall operation with more outputs. The data analysis of this study serves as the primary model

for other mosquito coil manufacturing premises and mosquito repellent manufacturing premises in establishing and implementing CP strategies.

5.2 Recommendations for Future Study

In future, the manufacturing process of mosquito coils can be considered by minimizing the usage of powders. Powders used in this process is from the deforestation of tree. Using less powders in manufacturing process can reduce the emission of carbon dioxide as processing of powders from tree emits carbon dioxide to the atmosphere. Thus, a formulation with the less usage of powders or usage of recycle powders can be formulated.

Besides, instead of using a stamping machine to stamp the coils, a designated printed machine can be used. As mentioned earlier in the report, consumption of electricity is high during the use of stamping machine which emits more carbon dioxide. Thus, using a designated printing machine can save the electricity and at the same time the efficiency can be increased. The coils can be printed on a fiber roll sheet or any other material that can help to burn the coil. These printed sheets can be easily dried in a chamber room with lesser time. By this way, the usage of diesel can either be reduced or eliminated from the process.

Moreover, mosquito coils with less smoke can be formulated to green the premise. This is mainly due to the release of carbon monoxide during mosquito coils burning. A formulation of coils with thinner diameter can reduce the emission of carbon dioxide. A thinner coil with high tendency to repel mosquito will be very effective and beneficial to the environment as well as the users.

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