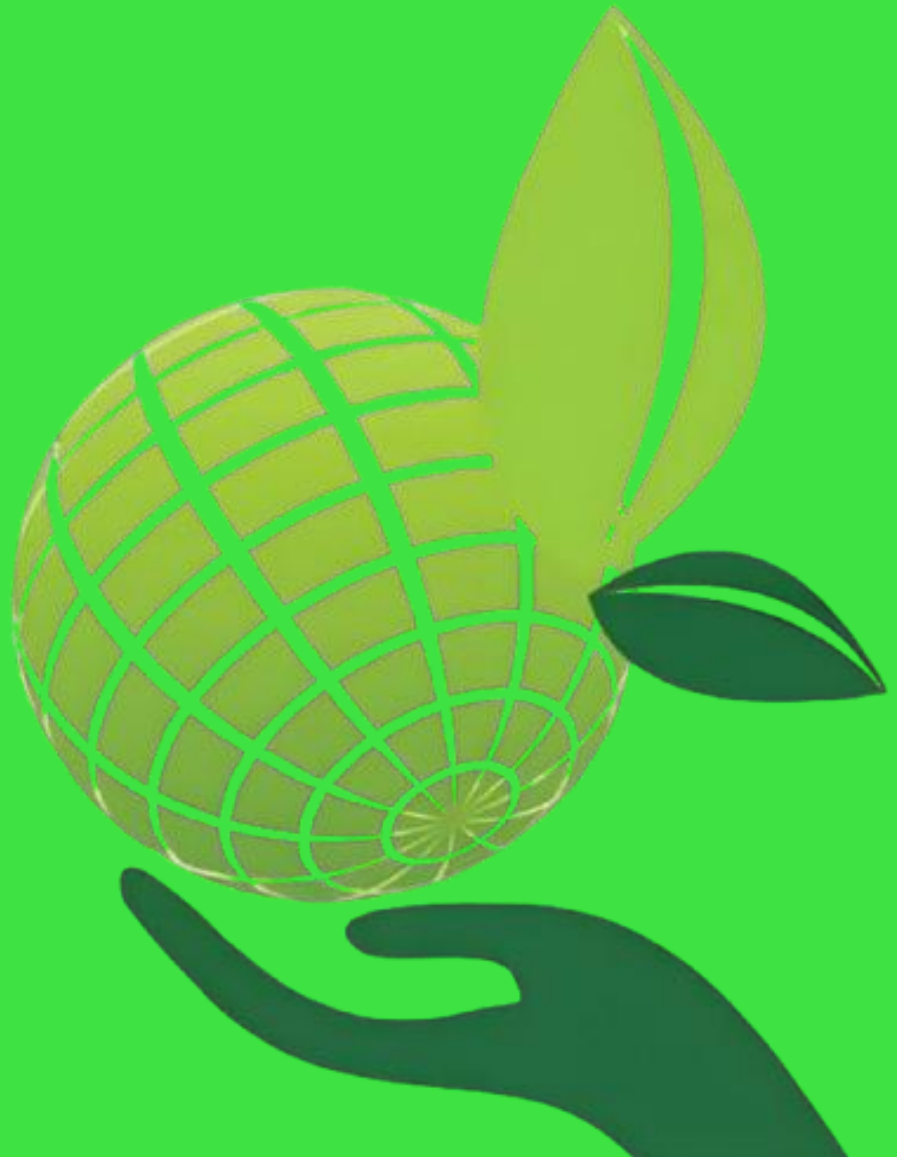




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*Department of Environmental Management
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Editorial Note - Journal of Tropical Environment

I am pleased to present Volume 2, Issue II of the *Journal of Tropical Environment*, a biannual publication dedicated to advancing scholarly discourse on environmental management, particularly within tropical ecosystems. The journal embraces an interdisciplinary approach, drawing from natural sciences, social sciences, management, and philosophy to address the pressing environmental challenges of our time. Our focus remains on research that engages with the complexities of managing tropical environments, encouraging innovative perspectives that span traditional academic boundaries. This issue showcases a diverse range of articles that have undergone a rigorous double-blind peer review process, ensuring the highest standards of scholarly integrity.

I extend my heartfelt gratitude to the authors, reviewers, and editorial board members, whose expertise and commitment have been crucial to the success of this journal. Their contributions have ensured that the *Journal of Tropical Environment* continues to be a valuable resource for researchers and practitioners alike. I hope this issue will inspire meaningful dialogue and inform sustainable development initiatives across both public and private sectors.

Prof. DMSLB Dissanayake - Editor in Chief
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Department of Environmental Management
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Rajarata University of
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Environmental management Accounting Practices: Case Study from Plantation Companies in Sri Lanka

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Abstract

The plantation sector contributes to Sri Lanka's Gross Domestic Product (G.D.P.), export performance, and employment levels. The primary environmental issues confronting Sri Lanka's plantation sector include water consumption, fuel consumption, and electricity consumption. As a result, plantation companies must safeguard and minimize natural resources while producing. In Sri Lanka, the plantation sector practices various Environmental Management Accounting Practices (E.M.A.), including water management, energy management, and waste management. There is a dearth of research in this area. As a result, this study will in-depth analyze the environmental management accounting practices used in Sri Lanka's plantation sector. The qualitative multiple case study method was used to analyze and present the data, which included three plantation companies in Sri Lanka. Data collection methods for this study's data triangulation approach included interviews, observations, and document surveys. The data is analyzed using narrative analysis. According to the findings of this study, there are many issues with E.M.A. in the plantation sector. Environmental protection and its practices are contingent upon company policies and regulations and employee attitudes.

The paper contributes to the growing body of research on E.M.A. in the plantation sector by providing empirical data from Sri Lanka, where empirical evidence is still scarce. The findings of this study benefit the Sri Lankan plantation sector by encouraging it to adopt E.M.A. practices to increase environmental sustainability and competitiveness

Keywords: *Environmental Management Accounting Practices, Plantation sector, Energy Management System, Water Management System, Waste Management System*

1. Introduction

In present world face different type of environmental problems. Such as desertification, waste disposal, ozone depletion, deforestation, climate change, loss of biodiversity. Manufacturing and another type of industries affect environmental problems. Gellers (2017) stated that "According to the Waste Management Authority of the Western Province, this region of Sri Lanka occupies less than 6% of the island, but is responsible for 60% of the waste generated. Perhaps more importantly, 35% of waste is not collected at all, and in a survey conducted for an environmental impact assessment report in 2012, 96% of the respondents admitted to burning their waste. Such practices have deleterious impacts on humans and the environment, as burning trash produces harmful gases released into the atmosphere. These gases can negatively impact human health and contribute to climate change." Since the tragic landslide that occurred in Methotamulla. After the tragedy of Methotamulla, the ministry of megapolis and Western development is implementing a project to build a large-scale sanitary facility in Aruwakkalu in Puttalam District. The landfill began expecting waste from Puttalam District. It is a score fuel expand to Colombo, Dehiwala, and Kollonnawa. Gellers (2017) highlighted that "Sri Lanka's inability to collect adequately, process, and reduce waste made national headlines recently when a waste dump in Colombo collapsed, killing at least 28 people."

Many of the researchers suggest actions take to address the waste management crisis. Kumanayake (2013) stated that civil society and government actors should work together to promote composting organic material, which could be used for energy or fertilizer (Gellers, 2017). Also, Hikkaduwa et al. (2015) suggest that the recycling industry should be formalized, and informal collectors should receive training to help them earn higher wages and improve coordination at local and national levels (Gellers, 2017). It is crucial to adopt environmental management accounting (E.M.A.) practices to reduce environmental problems.

Most of the research in E.M.A. practices conducted in Sri Lanka focuses on the hotel and

manufacturing sectors. For instance, Cooray et al. (2014) studied waste management practices in the printing industry, whereas Paranavithana et al. (2015) studied in the newspaper industry. Moreover, Peiris et al. (2014) and Alwis et al. (2014) examined the hotel industry's waste and water management practices. In the same vein, Edisooriya et al. (2014) studied E.M.A. practices in the financial service sector, and Thilakasiri et al. (2014) considered electrical item manufacturers. These studies examined how firms manage waste and how accounting practices are used to manage the environment. Other than that, some researchers explain the theoretical side of environment management and environmental management accounting.

The hotel industry has been the focus of the majority of E.M.A. research. For example, managing waste and water with the help of environmental management accounting done by Peiris et al. (2014), Solid waste and wastewater management in the hotel sector done by Alwis et al. (2014), an analysis of energy management practices and accounting implications in the hotel sector done by Hendehewa et al., (2014). In addition, challenges and barriers to implementing environmental management accounting practices in the hotel sector in Sri Lanka were identified (Gunarathne et al., 2016). These studies cannot be generalized to all the sectors because E.M.A. practices vary according to the sector.

Accordingly, there is a dearth of studies in environmental management accounting practices in the plantation industry. Therefore, this study explores the E.M.A. practices adopted in the Plantation industry by deeply investigating waste management, water management, and energy management practices. Since there is weakness in the accounting practices in the plantation sector, this research tries to find recommendations to overcome this issue.

2. Methodology

The primary focus of this study is to identify the environmental management accounting practices in plantation sector companies in Sri Lanka. In order to achieve the research objectives, this research applied a qualitative research method. The objective of the qualitative research is to gain a qualitative understanding of the underlying reasons and motivation of the selected topic, according to Yin (2009) that presented three features to be case study research. For research questions like "how" and "why," case study methodology is preferred because the researcher cannot control events in a direct, precise, or systematic way. It also has a current focus on real-life situations (Yin, 2009). Therefore, this research used the multiple case study analysis where multiple data collection methods are examined to several instrumental, bounded cases. As with experiments, case study findings can be applied to theoretical propositions rather than

populations or universes because the researcher's goal is to generalize theories rather than

to enumerate frequencies (analytic generalization) (statistical generalization)(Masanet-llodra, 2006).

This research aims to get information about the Environmental Management Accounting practices of the plantation industry. The Sri Lankan economy relies heavily on the plantation sector, primarily producing tea, rubber, and coconuts. Plantation crops cover approximately 870,000 ha of land. This industry employs nearly 30% of the workforce and generates about 20% of export revenue (Island, 2021). Therefore, the plantation companies were selected for this study. Among the plantation companies in Sri Lanka, three plantation companies are selected as samples: Company A, Company B, Company C.

The information for this study was gathered through the use of an interview protocol. Aside from that, data triangulation was employed. Structured interviews with open-ended questions were conducted according to the questionnaire to elicit information for the study. A wide range of data used as preliminary information is collected with its help and detailed information. 12 Interviews were conducted with companies, including the financial manager, the production manager, and other employees in three organizations. Field Observations were carried out in order to observe the processes of businesses two days per one organization. It helped to certify that processes of the company exist according to the company's objectives. This data collection method helped to protect the accuracy of primary data. Document review method used to collect secondary data and referred documents of companies to collect data about the accounting part of environmental management. Most concerned with accounting for the cost of environmental management practices and how benefits of the environmental management practices.

We used a narrative analysis method to analyze the environmental management practices under the waste, water, and energy management practices. Other than that, analyze reasons for why plantation companies implement environmental management practices. We use multiple sources of evidence using data triangulation to achieve construct validity. Replication logic is used to ensure external validity. Furthermore, the case study protocol is used to ensure reliability (Yin, 2009).

3. Data Representation and Discussion

Environment management Accounting plays a significant role in accounting systems. Water Management, Energy Management, and Waste Management are variables of the Environment Management Accounting system. Data collected from three companies were used for the analysis of under above three variables. Accordingly, the existing Environment Management practices recognized how the Water Management, Waste Management, and Energy Management procedures are scheduled in the production flow in the selected companies.

3.1. Production Processes of Companies

Company A produces tea from their estate, and other small-scale tea estate holders collect tea leaves from small-scale tea estate holders directly and through agents. Medagama Tea Factory welcomes the best quality leaves. The best plucking contains two leaves and the bud. However, according to economic parameters, three leaves and bud containing plucking are accepted. The following process is weighing. After that, the tea leaves are spread on withering troughs for 12 hours to remove 42%-45% of the water from tea leaves. The following process is rolling. Before the rolling process, withered leaves go through wither leaves swifter. Swifter separates contaminants like stones, tapes, and others from leaves in the wither leaves and sends the contaminants to separate containers. Then the tea leaves go through rolling machines. Through the roll-breaking process, get the inherent color, aroma, and taste of the tea. The rolled leaves were crushed and sieved through the range of meshes and 35 dules. The last dropping goes out through drainage lines into a segregation tank with water. In the drying process, firewood use as fuel after grading tea. There are 35 different modules according to the weight and the color of the dust.

Company B produces four top products. They are Coconut milk, Coconut milk powder, Virgin coconut oil, Fresh cow milk, and cleaned coconut kernels. Cleaned coconut kernels come from Kandy Plantations Ltd. It is a sister company of company B These kernels are washed and dry in lines. Then the kernels feed to a milling machine with water. Here they extract coconut milk from kernels. Then extracted coconut milk goes through a strainer and gets only liquid coconut milk. After that, coconut milk is pasteurized under an ultra-heated temperature method. Finally, they add recommended stabilizers and preservatives to coconut milk and send it to be packaging lines. Here the raw material is extracted coconut milk from kernels. The extracted coconut milk preheated to 63 Celsius degrees. Then milk fat is separated from milk. Coconut milk is pasteurized and let sit for evaporation. Coconut milk is homogenized under high pressure and then let to concentrate. This concentrated milk is feed as a spray to a massive cylinder for spray drying. Coconut milk powder comes from the spray dryer and sends to packaging lines. Packed coconut milk powder stored in

cool and dry stores before distributing. Coconut milk is extracted from kernels feed to the cylinder where the centrifugation process occurs. The output is filtered from several meshes and produces virgin coconut oil. The final product is bottled from machines under a controlled environment to ensure the hygiene of the product.

Cow milk is collected from Kandy Plantations Ltd and contracted farmers. The quality of raw cow milk is checked. Here P.H. level, density, odor, and color of fresh milk are concerned. Then pre-pasteurization takes place. This milk store in tanks for two hours. After that, standardization, pasteurization, homogenization take place in order. The product is stored in tanks and send to packaging lines. Packed cow milk checked for quality in the laboratory and stored in a cold store before distribution to market.

Company C's main products are Bottled fruits, Fruit juices, Lemming grass extract in king coconut, Passion fruit extract in king coconut. The primary customer of company C in Germany. Germany prefers organic products. So, company C is implementing Environmental Management Accountancy practices as they use organic raw materials, the chemical damage to the environment as fertilizer. Pesticides, herbicides are reduced. The company maintains its own standards of Environmental Management Accounting practices. Pineapples and mangoes are collected from their plantation or contracted farmers. These fruits are washed in the water while they convey to peeling lines. Fruits are peeled and send to the cutting section. Fruits are sliced and weighed. Then fruits are bottled under the temperature of 110 Celsius degrees. Then the product sends to the packaging line and stored in a store until they are shipped.

3.2. Identified Environmental Issues

Many environmental issues recognized the company A production process to be managed at different levels to enhance the system productivity. They are; Waste of Tea leaves, Water pollution, Air pollution, Cutting trees. company A is an environmentally friendly factory which is holding ISO 22000 certificate. Other than that, this factory maintains Orchard Intensity Standards. They follow an inspection checklist throughout the processing program to ensure a safe environment. To ensure the environmental standards, they maintain an Environmental Management System. Through this environmental management system, they follow strategies to reduce the above environmental issues.

company B is also experiencing some difficulties during the manufacturing process. Water pollution, air pollution, waste accumulation, and poor employee knowledge and attitudes are some issues. company B is located in the BOI zone of Wathupitiwala, which is surrounded by a large number of industrial companies. In the BOI zone, environment management is essential. The company must follow National environment act No 47 of

1980 and its regulations and obtain an environmental License. In addition to that, there are many environmental norms that a company in the BOI zone must follow. If the company disobeys this act, the Democratic Socialist Republic of Sri Lanka may file a case against the company. The Environmental regulations of 2008, made under the National Environmental Act, Renula Agri Foods Plc obtained Environmental Protection Licence. The chemicals used in the company are permitted by the Environment Management Director of the BOI after submitting chemicals Safety Data Sheets. This company follows the recommended standards for industrial wastewater, drinking water, air emission, noise-making, and chemical disposal.

Water pollution and waste accumulation are the Identified environmental issues of company C. The primary customer of company C in Germany. Germany prefers organic products. So company C is implementing Environmental Management practices as they use organic raw materials the chemical damage to the environment as fertilizer. Pesticides, herbicides are reduced. The company maintains its standards of Environmental Management practices.

3.3. Existing Environment Management Practices

3.3.1. Energy management system

Company A has two energy sources. They are electricity and firewood. The company estimates annual wood requirements, plants around the estate, and donate plants to small-scale farmers. Further, they monitor the growth of the plants to ensure eco-friendly management. The company uses variable speed drivers (V.S.D.'s) to monitor electricity usage. They use separate variable speed drivers in separate units. According to the V.S.D.'s readings, they can see if there is any abnormality in electricity usage. So, they can control and reduce the electricity. The variable speed drives (V.S.D.'s) reduce electricity consumption by reducing the number of revolutions per hour. For example, a standard machine rotates once every minute at 960 revolutions per minute. Depending on the moisture content of leaves, V.S. Ds can reduce the number of revolutions per minute of machines to low as 620 or as high as 300. Figure 01 depicts an illustration of a V.S.D. meter in operation.



Figure 1: V.S.D. Meter

Company B uses three primary energy sources. They are Electricity, Bio mas, Diesel. Mainly using energy source is electricity. However, to reduce energy costs, the company uses coconut shell chips for boilers heating activity. Company B bought coconut shell chips from Kandy plantation ltd, a sister company under Renua group of companies, to maximize the group's profit and reduce the cost of energy.



Figure 2: Coconut shell chips

The primary energy source of company C is electricity, and the company uses solar power as well. Solar panels power all the security lights and garden lights.

3.3.2. Water management system

Company A uses two ways to water management. These are not directly beneficial to the company but indirectly benefit the organization. They are Stream and water source management, purifying water before exiting the factory. The company does not use banned chemicals and does not allow small-scale farmers to use them to protect water sources. They maintain a chemical-free border along the rivers and streams. This border is called a buffer zone. The distance of 40 feet away from the midline of the Stream is called a buffer zone. Water comes out from the factory (appendix) sent to a segregation tank through a drainage line. Water is filtered at the segregation tank before outflow from the factor, and some filtered water re-consumes to wash the floor. So, the water consumption requirement is reduced, and therefore the cost of water requirement could be reduced.



Figure 03: Segregation Tank

The water management system of company B can be identified as follows. Coconut kernels washed water disposed of the washing tanks through draining lines to wastewater purifying unit. Impurities of water are removed before being sent to the water purifying unit. Drinking water that follows National Environment Act use as a raw material in the coconut milk-making process. As this company engages with food items, good hygiene must maintain. So, they wash stores with water to remove impurities. This water goes directly to the water treatment plant. Pasteurization is the foremost step in main packed beverages. Company use water I Ultra Heat Treatment process. Here water cools the pipe's outer line, which carries high temperate fresh milk and coconut milk.

The water around the pipe comes and goes as it conveys temperature with it. This heated

water cannot dispose of directly as it can harm living beings due to its heat. Water is cooled by air and recirculate to the ultra-Heat treatment process in order to reduce water cost. Water that purifies in water treatment plants uses as the flush water to reduce the cost of water.



Figure 4: Water Treatment Plant

The water management system of company C is as follows. Water used to wash fruits is the most harmful water as it is highly acidic after washing pineapple. The company reduces the acidity of water through a filtering and chemical treatment process. This treated water is used to water their plantation's irrigation system. company C follows the environmental license's guidelines for drinking water and water used as an ingredient in beverages. The company has a well, and it is used for sanitary activities. Water used in sanitary activities goes to a septic tank.

3.3.4. Waste management system

Company A uses its long-lasting containers to collect tea leaves. Otherwise, the company gets hundreds of poly bags or urea bags per day to the factory. Collectors of the factory go to small-scale farmers and collect tea leaves in their containers. In the transporting process, the company not allows transporting tea leaves with fuel, tea leaves with fertilizer, and tea leaves with chemicals to protect the quality of leaves. Transport agents are responsible for delivering the collected tea leaves directly to the factory. Vehicles must have been subjected to a carbon emission test.

The company keeps track of the vehicle's carbon emissions. In the quality checking process,

the factory looked best leaves. The leaves that are not of good quality are rejected and send back to the owners. The environmental effect step is drying. Because they cut many trees for firewood, and smoke from firewood may harm the environment. The residual ash goes to an ash pit and is re-use as a fertilizer. Ash contains phosphorous, which is the primary fertilizer nutrient. They mix the ash with compost or fertilizer, use it as fertilizer, and give it to smallholders free. In the wither leaves swifter separate contaminants and send the contaminants to separate containers.

Company B enhances to bring employees foods in lunch boxes to reduce the food waste. This company makes shallow waste as it buys cleaned Kernels from Kandy Plantations Ltd. Biodegradable waste in Kandy Plantations Ltd uses to make a fertilizer along with cow dung, gliricidia, coconut husks, and straw. Coconut husks use to improve water retention in the soil. The fertilizer uses to enhance the fruit-bearing of coconut trees. The ash of coconut shell chip remains after use as biomass fuel is sent to Kandy Plantations Ltd as it is a rich source of prosperity.

Company C harvests and collects only fully ripened fruits, according to their specifications. Obstacles were encountered in the field, and damaged fruits were rejected, and they did not contribute to the accumulation of unnecessary waste within the organization. Fruit peels and king coconut shells are the main waste of the company. So, company C implemented a compost project with the instructions of the Department of Agriculture to reduce biodegradable waste accumulation. Making compost benefits the company because they use compost for their plantation and reduce fertilizing costs. When pineapple peeling, the peel is separately taken as the first peel and the second peel. The first peels are directly going to the composting program, and the second peel is used as a raw material in the fruit juice-making process.



Figure 5: Second Peel of Pineapple

3.4. Environmental Management Accounting Practises

E.M.A. systems of the company A is at the middle level. The company uses V.S.D.'s to monitor and reduce electricity usage. V.S.D. has been recognized as an asset of the company. However, do not depreciate annually. In order to monitor and recognize the kilograms of green leaf for kilo wat per hour, the company keeps daily records of V.S.D.'s readings. They keep records in the physical term. Two persons of the factory were appointed to record V.S.D.'s readings and output. There is a purifying system. There is no accounting system to measure the water outflow from the factory and re-consume filtered water for clearing activities, but the purifying system's maintenance cost is identified as overheads in reports. In drying, process ash goes to an ash pit and measures in kilograms and the output of fertilizer measure in packets. Each packet contains 10 kilograms. In this process, ash mixes with compost or fertilizer. Compost and fertilizer buy from outside. Expenses for the fertilizers and compost are recognized as other expenses. Plastic and iron are collected and send for sales.

Daily collection record kept in physical terms. Medagama Tea Factory maintains E.M.A. records which will be supportive of maintaining the company standards like ISO 22000. Practicing E.M.A., the company estimates annual firewood requirements and ensures continuous firewood supply for the process by storing firewood. The company gains extra income by selling waste like plastic and iron. Through E.M.A. company monitor and

reduce electricity usage through V.S.D.'s. E.M.A. protects water resources and ensures a sustainable environment. By re-using water, the Medagama Tea Factory cut off the water requirement for sanitary activities. There are many issues to be faced when implementing an Environmental Management Accounting system practice through an accounting system to make the profit of Environment management intangible. The result is not directly visible to humans. Most small-scale farmers do not have a sound educational background, and they cannot understand the issues and do not think about the future. Company B combustion of coconut shell chips gives the energy to heat boilers. There are three central boilers. Coconut shell chips come in 18kg weight packets from Kandy Plantation Ltd. They keep the record in the physical term. Coconut shell chips transport weekly to company B. Storekeepers keep a record of when they get and how many packets give each boiler. At the end of the month, they calculate weekly records and summarise them. Payment is made at the end of the month. Transport cost account as overheads

Company B uses solar-powered bulbs for security and the garden. They calculated the cost of solar power as follows. They needed 35 external bulbs, one light consuming 1000w and works 12 hours per day. The total consumption of energy for the day is 12kwh. The total energy for a total number of bulbs is 480kwh if the unit cost is 10.8. Total cost per day 4884. The total energy cost for the month can be calculated from this. The second peel of pineapple is used for the fruit juice-making process. Because it uses an ingredient, it is measured in kilograms. The peels weight us vary day by day.

After analyzing the collected data, this research can be recommended following recommendations to the sample companies. In Medagama Tea Factory, there is no proper quantitative measure for output water and re-use water. So, it is impossible to calculate the number of units of water saved by re-using water for sanitary activities. That affects to E.M.A. practice of the company. Moreover, Manual errors may be occurring when taking V.S.D.'s reading as it is a manual record.

Company B uses a continuous flow of external water to boilers. The evaporated water from boilers goes out from boilers. They can use evaporated water after condensing vapor for boilers. The temperature of condensed water is somewhat high. So, the energy need will go down, and it will decrease the cost of energy.

Furthermore, there is no accounting system to track the amount of wastewater that has been purified and cannot determine how much water is discharged from the company to the BOI zone. If the company uses this filtered water for some activities like sanitary activities, the cost of water can be reduced.

On the other hand, input for composting and output from composting is not calculated in this company. So, the cost reduction and the profit gain by the company cannot be calculated. It is a point to improve.

Company C do not measure the water purified and send to irrigation purpose. So, the benefit received from the purifying system cannot be calculated. So, it is better to find a method for calculating the benefit. The amount of waste used for compost is not measured. So, the company cannot get an idea about how much waste is re-use and how much profit gain by re-using the waste. It is highly recommended to keep an accounting system.

4. Conclusion

This study considered company A, company B, company C. All these companies are well reputed and maintaining their standards and have certification. The targeted markets of these companies are different. So, they maintain standards according to the target markets. Because company C has to maintain the standards that suit the European market. Company B is situated at the Wathupitiwala BOI zone. So, the company must obey the government acts and regulations. Company A Medagama Tea Factory produces only tea dust while company C and company B producing beverages.

The water consumption and water-polluting methods differ according to the producing product. One company is situated in Kaluthara District, while the other two are situated in Gampaha District. So, the weather factors, infrastructure facilities are different from company to company. Company A cannot use solar power as the power source due to the cloudy sky, while company C using solar power for security and garden lights. In most plantation companies, the laborers do not have an excellent educational background. So, record keeping, maintaining, and evaluating procedures are challenging to be done. In this study, all the companies had this problem.

Most of the environmental resources are intangible. So, water pollution, air pollution, and other environmental pollutions cannot be measured in units. This study found that all the companies do not seem much concerned about the environment. This study reveals that environmental protection, and its practices depend on employees' attitudes and the rules and regulations of companies. The management of all the companies does not enhance environmental management accountancy as it does not support maximizing profit. Three of the factories do not consider the environmental cost for their investment appraisal project.

We have identified that environmental and E.M.A. practices which are adopting at a slower

rate in the plantation sector. Furthermore, The E.M.A. varies from company to company according to the target market, producing a product, according to the weather, the initial cost, the education and knowledge of employees, the maintaining standards, and the company's location. Finally, we recommend recording wastages of electricity, water, and fuel litters and environmental cost identification for investing in appraisal as best E.M.A. practices adopted by businesses. We add to the growing body of knowledge on plantation environmental management research by presenting empirical evidence from Sri Lanka, where there is still a dearth of data.

We focused on three plantation companies out of the whole plantation industry in Sri Lanka. As a result, future researchers can expand more companies from Sri Lanka's plantation sector while also considering other previously studied sectors. In addition, the study only looked at qualitative data. Therefore, it is crucial to consider the quantitative approach by future researchers.

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A study of criminal activities against marine resources along Sri Lanka's coastline

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Abstract

The present research endeavours to delve into the intricate dynamics of marine resource threats in the context of Sri Lanka, an island nation whose socio-economic fabric is intricately interwoven with the integrity of its coastal ecosystems. Acknowledging the paucity of empirical investigations elucidating contemporary manifestations of criminal transgressions against marine resources, this study assumes the mantle of scrutinizing these modern trends while geographically delineating the area's most adversely impacted. Operationalizing within the theoretical paradigms of environmental criminology and blue criminology, this concurrent inquiry casts an illuminating gaze upon the nefarious activities afflicting the marine landscapes of Sri Lanka, underscoring the exigency of methodological precision and scholarly diligence in unravelling the intricate tapestry of marine criminality.

The temporal scope of this investigation spans the five-year period from 2015 to 2020, with data procurement facilitated by the esteemed National Aquatic Resources Research and Development Agency (NARA). Revelations gleaned from

this meticulous inquiry unveil a disconcerting array of illicit practices, including but not limited to dynamite fishing, bottom trolling, trafficking of sea urchins and turtle eggs, and wanton destruction of coral reefs. Of particular note is the demographic profile of perpetrators, with a discernible tendency among individuals aged 35 years and above to engage in such criminal acts. Geographically, districts such as Jaffna and Trincomalee emerge as focal points of heightened criminal activity. Root causes analysis attributes the proliferation of marine crimes to the pernicious nexus of poverty and inadequate maritime security infrastructure. In light of these findings, the imperative for proactive intervention looms large, necessitating the implementation of robust marine crime prevention strategies augmented by targeted socio-economic interventions aimed at uplifting the coastal communities ensnared in the throes of these illicit practices. In summation, this study furnishes a scholarly vantage point from which to apprehend the multifaceted dimensions of marine resource threats in Sri Lanka, thereby laying a robust foundation for informed policy formulation and strategic interventions aimed at safeguarding the sanctity of the oceans while fostering sustainable socio-economic development.

Keywords: *Crime, Criminology, Ocean, Fish, Resources, Study*

1. Introduction

The words sea belt, sea belt and ocean belt are not unfamiliar words to us Sri Lankans. There is a coastline around our country to save or destroy.

An ocean is defined by the Cambridge Dictionary as a vast sea boundary (Cambridge, 2010.). Sri Lanka belongs to such a sea system as an island in the Indian Ocean. The most beautiful and economically important sea area around Sri Lanka has attracted the attention of various nations since ancient times. Sri Lanka, an island surrounded by a beautiful sea belt from all four corners, is a state full of beautiful and attractive natural resources located in the Asian region. The sea screen around Sri Lanka is a prosperous marine ring of commercial value belonging to the Indian Ocean.

The attraction and importance of the coastline around Sri Lanka has been mentioned in written sources, starting from the works of the ancient Vedic period to today's international travel guide manuals. After the renaissance era, the European nations turned to land exploration and the Europeans who migrated to the East, the Portuguese, the Dutch, or the current Dutch, the English, as well as the French, were engaged in a non-stop struggle to acquire this sea border around Sri Lanka due to its economic and political importance. Those nations who possessed a very large military and naval power fought for the free right of this

small island because Sri Lanka was a pearl in the ultimate sense of the word in this ocean

region. We Sri Lankans have greatly benefited from the natural resources around the coast of Sri Lanka both politically and economically. The best example of this is the pearl industry associated with the pearl reefs around Sri Lanka. In the past, the world's most famous high quality large pearls were found in the waters around Mannar in Sri Lanka. Sinhala kings have always paid attention to its right.

Sri Lanka is located close to the equator in the tropics between the Tropic of Cancer and the Tropic of Capricorn. Sri Lanka is separated from India by a very narrow, shallow sea. It is known as Palk Strait. Sri Lanka is an island located in the Indian Ocean, close to the Indian subcontinent, separate from India.

Apart from Sri Lanka, other islands located in the Indian Ocean include Maldives, Andaman Islands, Nicobar Islands, etc. Sri Lanka also has a unique border and maritime boundary. According to the International Law of the Sea, which came into effect on November 16, 1994, every coastal state in the world inherited the right to a limit of 12 nautical miles from the coastal boundary (UNOCD,2011). It is known as national territorial sea. Beyond that lies the adjacent sea and the Exclusive Economic Zone. Although Sri Lanka is a small island, it has a very unique topography. The mountains in the center of the country, the surrounding inland plains and the coastal plains are the three main topographic zones of the island. Different complex heterogeneity features are seen in each of these regions. The natural beauty and favorable climate of Sri Lanka, which consists of such a topography, has led to the further confirmation of the geographical identity of our country. Sri Lanka's topography and climatic diversity have also managed to attract tourists. Since Sri Lanka is a tropical country, there is no winter. Being an island, Sri Lanka receives widespread rainfall throughout the year and receives it in three main ways. These are Monsoon rains, convective rains and monsoon rains. Sri Lanka generally experiences dry weather during the months of February and August. Paddy harvesting is also done in the paddies during this time.

Due to the widespread rainfall and temperature throughout the year, taller plants are spreading around the forests in the wet areas of the island. In arid and semi-arid regions with dry climates, thorn scrub forests and mangroves are found in coastal lagoons and estuaries. A

tourist traveling inland from a coastal area of Sri Lanka can see the diversity of topography, climate and forest cover as well as experience its beauty in a short distance of 70 km (Silva S.S,2016).

In this study, the first chapter focuses mainly on defining what is an ocean. What is a marine resource? This study is important to provide the necessary theoretical and conceptual light to

the study through a definitional introduction to what constitutes a criminal act against a marine

resource. There, the conceptual dimension is presented based on the opinions of scholars related to the field, the concepts included in the works written in this regard, the researches that have been fruitful in this regard, etc.

Accordingly, in this study we should primarily focus on what is a marine resource. Marine resources are the physical and biological materials found in the seas and oceans that are useful to humans. They include fishes, corals and crabs, fungi and aquatic plants etc. (slideshare, 2012). Conservation efforts are needed to protect these resources from destructive human activities.

Marine resources can be classified as physical resources, biological resources and energy resources. We can identify the resources belonging to them as follows.

Physical resources: mineral oil, Sand and gravel, evaporative salt and methane hydrate

Biological resources: coral reefs, fish, birds, aquatic mammals and aquatic plants

Energy resources: waves, tide and thermal power Series (United nation,1982).

We can identify as this study focuses mainly on the crimes and criminal activities that take place in Sri Lanka against the above-mentioned resources.

When asking about the importance of this study, it is an essential factor for us as Sri Lankans to have an understanding of the ocean surrounding an island. In the same way, it is our responsibility to protect this coastline, which provides a unique contribution to the economy of Sri Lanka, so the study of criminal activities against these marine resources is also a study of economic value. Who investigate the study will understand that this study has legal value as it also examines the utility of existing ocean protection laws. In the same way, from an environmental point of view, the environmental quality of the sea around Sri Lanka is repeatedly studied and every year an inquiry is made through sources related to its degradation and growth. Likewise, this study is important to identify biologically threatened

plant and fish resources and propose a new protection program through applied criminology. Similarly, the light that comes from this study to the encyclopedia of criminology is that this study can outline the criminological approaches needed to identify the criminal acts committed by humans against the environmental systems and control and prevent them. Through the subject of environmental criminology, this study provides guidelines for the

development of methods to protect Sri Lanka's marine ecosystem. In addition to this, it is

expected to conduct a criminological study on the groups that commit crimes against marine resources, and focus on theoretical issues such as anomalous theories, collisional theories, learning theory and interaction theory that study the causes of crimes. In addition, crime prevention through environmental development and crime prevention through social development, crime prevention through social development and control models such as Jeremy Bentham's principle of hedonism in order to prevent criminal acts against marine resources. Proposals are made here about the steps that can be taken.

In carrying out this study, it is possible to identify a main legal framework that mainly limits me. Here, a legal study is expected to be conducted regarding the legal ordinances enacted in Sri Lanka as per the constitution as well as the conventions that Sri Lanka has entered into internationally. As those legal sources,

- i. Animal and Plant Protection (Amendment) Act No. 49 of 1993
- ii. Fisheries and Aquatic Resources Act No. 2 of 1996
- iii. Fisheries and Aquatic Resources (Amendment) Act No. 25 of 2013
- iv. Government Gazette No. 1774 No. 27 of 2019
- v. Government Gazette No. 0303Ra31 of 2008
- vi. Antiquities Ordinance No. 9 of 1940
- vii. Animal and Plant Protection Act No. 22 of 2009
- viii. Customs (Amendment) Act No. 2 of 2003
- ix. 1982 United Nations Convention on the Sea

This study is conducted within the legal limits of Studying the usefulness of these legal sources and to what extent do they protect marine resources? If not, in this study it is necessary to make suggestions about what provisions are necessary for the protection of marine resources.

In that way, this study has a great importance both practically and criminologically. Since the environment is an essential factor for human existence, protecting it is an essential responsibility of man. Therefore, this study is not just an experimental study, it is also our responsibility as a human being.

2. Problem

As Sri Lanka is a country rich in marine resources, these marine resources make a significant contribution to the country's economy. In this way, we can identify a mine that uses legal methods that do not harm the ocean resources as well as illegal methods that are harmful to the ocean. That is, to what extent the things defined as marine resources in the law are protected at present, what are the main reasons for their insecurity, who contributes to the destruction of marine resources, how effective are the methods imposed for the

protection of marine resources, and how effective are the methods to protect marine resources? What are the current trends in marine resource degradation and whether new policies are needed?

3. Objectives

The main objectives

- To identify the most prevalent types of crime against marine resources in the present.
- Identify specific groups that commit crimes against marine resources.
- Discussing whether the laws in place to protect marine resources are adequate.
- Proposing new strategies to protect marine resources.

Sub-objectives

- Identification of red zones or risk zones of crimes against marine resources in Sri Lanka. Crime Hot Zones
- Assessing the utility of organizations that advocate for the protection of marine resources.
- Inquiring about the results of the measures taken by the international community for the protection of Sri Lanka's marine resources.
- Classification and identification of Sri Lanka's marine resources

4. Methodology

In this section, we detail the methodology employed in the research titled "Criminal Actions Against Marine Resources in Sri Lanka." The methodology encompasses the selection of the research topic, formulation of the research approach, data collection procedures, data analysis techniques, discussion of findings, and presentation of conclusions and recommendations based on empirical observations.

Topic Selection and Introduction:

The research aims to investigate criminal activities targeting marine resources in Sri Lanka, focusing on discerning prevailing trends in such activities. The selection of this topic is grounded in the imperative to assess the safety of marine resources within the region. Our study delves into the occurrence of reported crimes, seeking to illuminate patterns and dynamics underlying these incidents.

Formulation of Methodology:

The methodology adopted for this research is predominantly based on secondary data analysis. Given the nature of the study, which examines trends in criminal activities, secondary data serves as the primary source of information. The methodology involves a

structured approach encompassing the following steps:

a. Data Collection:

Data collection was facilitated through collaboration with the National Aquatic Resources Research and Development Agency (NARA), a key institution tasked with monitoring marine activities in Sri Lanka. The agency provided access to records documenting reported criminal incidents against marine resources over a five-year period (2015-2020).

b. Sampling Technique:

A sample of 68 reported criminal incidents was selected for analysis using a simple random sampling method. This sample size was determined based on the frequency of incidents reported to NARA, which typically ranged between 50 and 80 per year. By selecting a sample spanning five years, we aimed to capture a representative snapshot of criminal activities affecting marine resources.

c. Interview:

In addition to secondary data analysis, primary data was gathered through an interview with Dr. Sisira Haputantri, Director of the Marine Biology Division at NARA. Dr. Haputantri's insights provided valuable context and expertise to augment our understanding of the subject matter.

d. Case Study Method:

Sixty case studies were conducted to gain deeper insights into specific instances of criminal activities across different regions of Sri Lanka. These case studies were instrumental in identifying high-risk crime hotspots and elucidating patterns of criminal behaviour.

5. Data Analysis

The collected data underwent rigorous analysis employing three distinct methods:

a. Univariate Analysis:

This method involved analyzing crime incidence across different geographic areas using analysis of variance (ANOVA). By examining data from the 60 case studies, we identified crime hotspots and discerned trends in criminal activity. Additionally, univariate analysis enabled the identification of age groups associated with perpetrating such crimes.

b. Bivariate Analysis:

Bivariate analysis focused on examining the relationship between reported crime incidents and their respective occurrence years. Through the utilization of tables, graphs, and statistical methods, we analyzed variations in crime patterns over time, thereby enhancing our understanding of temporal dynamics in criminal behavior.

c. Multivariate Analysis:

In multivariate analysis, we explored the interplay between key variables such as geographic location and temporal trends in criminal activity. By discerning underlying trends and factors influencing crime occurrence, this analysis provided valuable insights into the broader dynamics shaping criminal actions against marine resources.

Discussion of Analysed Data:

The findings obtained from data analysis were critically examined and discussed in relation to the research objectives. Insights gleaned from the analysis were contextualized within existing literature and theoretical frameworks to provide a comprehensive understanding of the phenomenon under investigation.

Presenting Conclusions and Suggestions:

Based on the research findings, conclusions were drawn regarding the safety of marine resources in Sri Lanka and the prevailing trends in criminal activities. Additionally, practical recommendations were proposed to mitigate the incidence of such crimes and safeguard marine ecosystems.

In summary, the methodology employed in this research encompasses a systematic and rigorous approach to investigating criminal actions against marine resources in Sri Lanka. By integrating both primary and secondary data sources and employing diverse analytical techniques, we aimed to provide a comprehensive understanding of the subject matter while addressing the concerns raised by the reviewers.

6. Results and Discussion

The analysis on activities targeting marine resources in Sri Lanka. It becomes evident that illegal fishing practices, particularly those involving the use of explosives such as dynamite, pose a significant threat to marine ecosystems within the region. Notably, the Jaffna district emerges as a hotspot for environmental crimes against marine resources, likely influenced by factors such as proximity to South India and competition from illegal fishermen encroaching upon Sri Lankan waters (Figure.1). This section provides insights into the prevalence and nature of criminal ac

Furthermore, an examination of crime reports indicates a slight increase in incidents in 2020 compared to previous years. However, this trend is accompanied by a decrease in crimes such as bottom trawling, attributed in part to disruptions caused by the COVID-19 pandemic within the mining industry. Interestingly, the analysis reveals that individuals aged between 30 and 50 years are most commonly involved in such criminal activities.

This observation underscores a complex interplay between economic factors and criminal behaviour. The economic downturn exacerbated by the pandemic has disproportionately impacted certain demographic groups, particularly those supporting families.

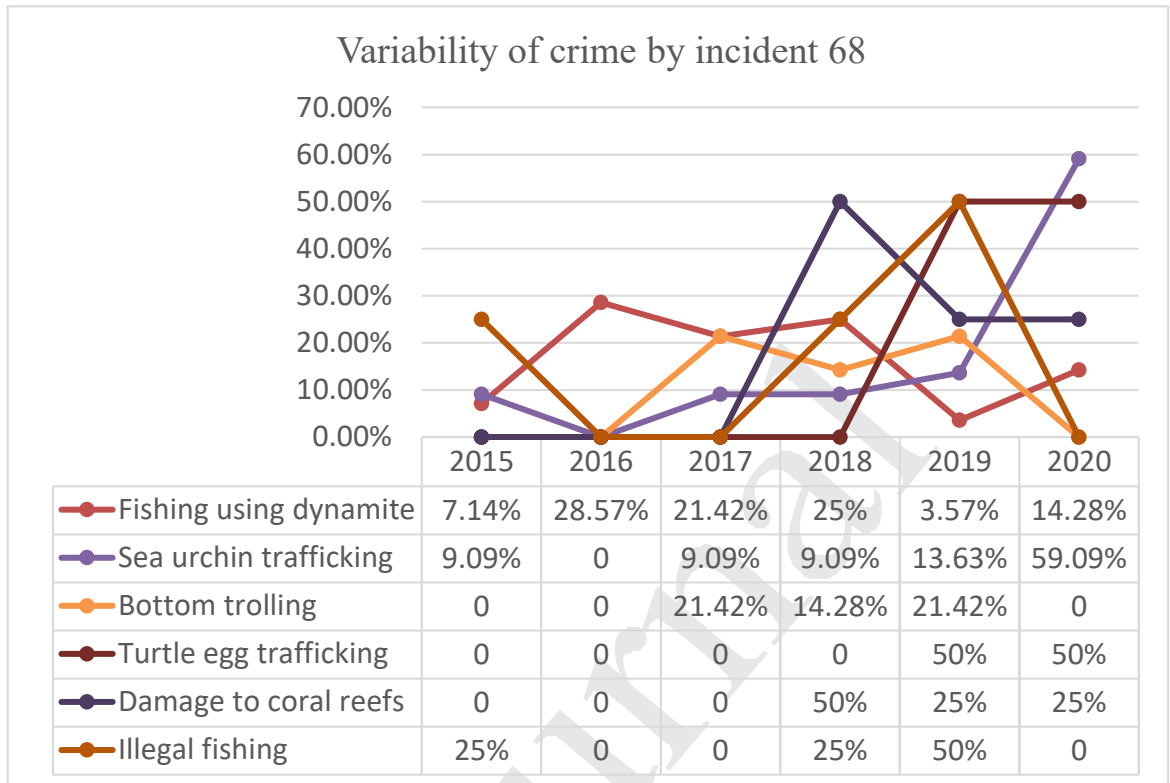


Figure 1: Dotted line diagram Variability of crime by incident 68 (Source: Field test)

In this context, individuals within the aforementioned age bracket, often representing marginalized communities reliant on the fishing industry, may resort to illegal tactics as a means of securing livelihoods amidst economic hardship.

The convergence of economic strain, dwindling opportunities in the fishing sector, and heightened competition underscores the urgency of addressing systemic issues contributing to criminal activities against marine resources. Initiatives aimed at bolstering sustainable fishing practices, enhancing law enforcement measures, and providing alternative livelihood options are imperative in mitigating the root causes driving such crimes.

In conclusion, the findings highlight the multifaceted nature of criminal actions against marine resources in Sri Lanka. By elucidating the underlying socioeconomic dynamics influencing criminal behaviour, this analysis underscores the need for comprehensive interventions to safeguard marine ecosystems and promote sustainable resource management practices.

7. Conclusion

The culmination of this study prompts several noteworthy conclusions, though it is essential to acknowledge the critique provided by Reviewers 1 and 2 in shaping the depth and specificity of these findings.

Dynamite Fishing Emerges as a Grave Concern:

The data underscores the alarming prevalence of dynamite fishing as the foremost threat to Sri Lanka's marine resources. This destructive practice poses a significant risk to marine ecosystems and warrants urgent attention from policymakers and enforcement agencies.

Demographic Insights into Criminal Activities:

Analysis reveals a notable demographic trend, with fishermen aged between 30 and 50 predominantly implicated in criminal activities against marine resources. This demographic insight underscores the importance of targeted interventions and enforcement strategies tailored to address specific age groups within the fishing community.

Weak Enforcement of Marine Resource Protection Mechanisms:

A concerning finding is the apparent inadequacy of enforcement measures pertaining to the Marine Resource Protection Mechanism, particularly in the Northern Province. This weakness in enforcement compromises the efficacy of existing regulations and highlights the need for enhanced monitoring and enforcement efforts to safeguard marine resources effectively.

Identification of Criminal Hotspots:

The study identifies Jaffna, Mannar, and Trincomalee as criminal hotspots characterized by heightened incidences of crimes against marine resources. These areas, termed as commercial hotspots or "red zones," warrant targeted interventions and intensified law enforcement initiatives to curb illicit activities and preserve marine biodiversity.

Fish as a Vulnerable Marine Resource:

Among the marine resources studied, fish emerges as the most threatened, primarily due to illegal fishing practices. The widespread exploitation of fish stocks underscores the urgency of implementing measures to regulate fishing activities and promote sustainable fisheries management practices.

Imperative for Legislative Reform:

The findings underscore the pressing need for legislative reforms aimed at enhancing the

protection of marine resources in Sri Lanka. New laws and regulatory frameworks should be devised to address emerging threats and strengthen the legal mechanisms governing marine resource conservation and management.

In addressing the concerns raised by Reviewer 1 regarding the specificity and contribution of findings, it is acknowledged that while some conclusions may align with existing theories within criminology, the study provides valuable empirical insights into the context-specific dynamics of criminal activities against marine resources in Sri Lanka. Furthermore, as highlighted by Reviewer 2, the study contributes to the field of Environmental Criminology by shedding light on the intricate interplay between environmental factors, socio-economic dynamics, and criminal behavior in the context of marine resource exploitation.

In conclusion, the findings of this study underscore the multifaceted nature of the challenges confronting marine resource conservation in Sri Lanka. By elucidating key trends, identifying vulnerabilities, and advocating for targeted interventions, this research seeks to inform evidence-based policies and interventions aimed at promoting the sustainable management and preservation of Sri Lanka's invaluable marine ecosystems.

8. Suggestions

The following suggestions can be made to control and prevent the criminal situations identified in this study on the criminal activities against marine resources in Sri Lanka.

- Enactment of laws to regulate the sale and use of dynamite.

This study identifies the illegal tactic of dynamite fishing as the main identifiable crime when studying trends in criminal activities against marine resources. Accordingly, first of all, these fishermen have to find out how to get dynamite. According to the data published by the Fire Unit of the Indian Institute, mostly these fishermen get dynamite through the quarrying industry (stone drilling). Accordingly, a proper work arrangement should be made for the professionals in that profession to obtain dynamite and a legal system with penalties should be established for the alienation of that dynamite. It can reduce marine damage caused by using dynamite by restricting the circulation of explosives in the hands of fishermen in an unauthorized manner.

- Implementation of a project to uplift the economy of 2nd married fishing families.

In this study, it was revealed that married fishermen between 30 and 50 years of age are most prone to crime. This group is motivated by crime because the income from the illegal fishing profession is not adequate to cover the cost of living. Because of this, there is a need to introduce a new strategy to empower these people with government intervention. Accordingly, the Ministry of Fisheries should propose a system to build the economy to meet the cost of living of the married fishing families. Programs such as introducing new fishing

techniques to them, giving advice to increase fish farming, providing subsidized loans, providing petrol and diesel subsidies and providing family development loans and educational assistance should be proposed and implemented.

Creation of a crime prevention plan aimed at crime hotspots (economic crime) against marine resources including the 3rd Northern Province.

In this study, it was primarily revealed that there is a wave of crimes against marine resources based in Jaffna, Mannar and Trincomalee. Accordingly, there is a need for a crime prevention plan based on that area. Basically, the Sri Lanka Police, Navy, Coast Guard and Ministry of Fisheries should take the initiative. In this process, the main reasons for this fishing community to turn to crime should be identified and prevented. There, a good understanding of the economic, social, political and cultural conditions should be taken and necessary remedies should be applied. In the same way, those tactics should be applied so that the people who are transitioning back to the state after 30 years of civil war will not be affected by hard power and the situation of being overwhelmed by political pressure will be reduced on their legal enforcement. The state machinery should try to implement these policies very delicately and sensibly so that there is no public opposition.

- Enact new laws targeting illegal fishing and strengthen existing laws.

One of the findings of this study is illegal fishing that we can identify as the most common crime against marine resources. Mostly the reason for using these methods is the scarcity of fish farming. Accordingly, a proper program should be implemented through the Ministry of Fisheries to promote fish farming, and at the same time, special laws should be imposed prohibiting fishermen from keeping ammunition near bottom trolling equipment, and for this, the existing laws should be further strengthened. Rather than the benefit of the crime, it is necessary to develop the regression of the crime. Then, according to the rational choice theory of criminology, the angler will be less likely to be tempted to commit the crime.

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Tank Cascade System Analysis of Maximum Resource Recovery from a Municipal Solid Waste Management System: A Case Study of the Kandy Municipal Council, Sri Lanka.

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Abstract

Resource recovery from waste is a saving of resources for next generation. In this study, we examine the possibility of promoting recycling, composting and incineration. Four scenarios are developed, and the environmental impact of each scenario is analyzed using life cycle assessment (LCA) tool. The best maximum resource recovery is expected from proposed scenario-4. In this scenario, only 18.26% of total waste input will be sent to the final dumping site. Sorted material recovered in this scenario is 4,361 tons/year. 2,619 tons/year of material is recovered in biological treatment. Total material recovered is 11.49% and combusted waste will be increased to 70.26% out of total waste input to the system. Final solid waste, Methane emission and greenhouse gas emission are comparatively lesser in proposed scenario-4.

Further, SWOT analysis is also conducted to understand the strengths, weaknesses, opportunities and threats of the Kandy Municipal Council (KMC) on proper waste management. Main strengths of the Kandy municipal solid waste management system is trained work force according to the SWOT analysis. Implementing cooperative plan to mitigate the negative impacts and promote maximize resource recovery are successful steps of promoting circular economy and for sustainable future of municipal solid waste management.

Keywords: *Scenario analysis, maximum resource recovery, life cycle assessment, SWOT analysis, circular economy*

1. Introduction

If most of the waste could be sidetracked for material and resource recovery, then a significant amount of reduction in final waste volume could be attained and the recovered material and resources could be employed to generate income to subsidize waste management [1]. United Nation's Global Partnership for Waste Management (UN-GPWM) introduced to achieve better waste management in six thematic areas [2]. It was anticipated that in 2006 the total sum of municipal solid waste (MSW) generated worldwide reached 2.02 billion tonnes, representing a 7% annual boost [1]. In the contemporary world, an emerging problem which creates multiple impacts in diverse sectors, is Municipal Solid Waste [3], [4], [5]. However, the main attention of municipal solid waste (MSW) management in many developing countries is on waste collection, with tactlessness for waste treatment or disposal [6], [7]. Influences to the environment and socio-economic context and human wellbeing of a society are being critical, especially in the developing countries because of increasing waste generation due to population growth and unavailability of proper waste management systems. Hence, developing countries face mounting challenges to appropriately deal with their waste with most attempts being made to decrease the final volumes and to produce sufficient funds for waste management[1]. Different international entities attempted to address this phenomenon, introducing different treatment methodologies; for example, the end products of the biological treatment can, depending on its quality, be recycled as manure and soil improvement[8]. Some of the leading developed economies attempt to achieve maximum resource recovery in different ways. For example; Japan attempts to form a material-recycle society that produce as little waste as possible and recycles and reuses wastes as resources[9].

In Sri Lanka, municipal solid waste management (MSW) systems are rather hectic for the required framework for developing an appropriate waste management system in the country [10]. The predicted augmentations of MSW generation replicate the potential risks associated with the local environmental issues [11], [12], [13]. The waste generation can also differ with the urbanization trends, cultural variations, level of income, social and lifestyle changes, the food habits and seasonal variations [14].

Limited researches have been conducted on resource recovery from waste management systems. Out of them, household waste source separation and promote recyclable fractions is a requirement for making available waste apparatus as precious resources, and it is also a public health concern [15]. Also, Palistinina discussed main tribulations and barriers that thwart development of the circular economy through which an optimal waste management system [16].

Linear economic practices of 'take, make, dispose' activities have been practiced in most of the economies of the concurrent world. In this practice, demand for the extraction of natural resources has been increasing. However, to get rid of this conventional practice, the circular economy concept can be utilized aiming to promote circularity of the resources. Moreover, this promotes closed-loop systems and minimize waste and limit negative environmental impacts. Hence, the utilization of the circular economy model helps promote recycling as well as composting to make path for the environmental protection and conservation in a waste management system. Also, the cost-effective trade-offs between the cost of virgin inputs and the cost of material that has been kept in the cycle via circular flows would always errand the circular setup [17]. Further, resource recovery from waste and increase recycling and composting in a municipal solid waste management system, can assist to achieve the sustainable development goals. Not only that, but it limits broadening landfill site space requirement. Further, these enable to create innovative circular business models. Moreover, the circular economy (CE) model encourages the concept that an artifact which has been distinguished to have its end-of-life in a specific system that might be used as a raw material in a different or the same system [18].

Life Cycle Sustainability Analysis (LCSA) framework is an incorporative assessment of environmental mechanisms, economic mechanisms, technical relations, physical relations: constraints and options as well as social, cultural and political relations of a product system. Scenario analysis is also interconnected with LCSA under the methodological development [19]. The D20 blue paper [20] on LCSA has prepared road map and discussed broadly about waste management has been taken as an example by broadening and deepening the concept. Amalgamating interactions among social,

economic, and environmental dimensions of the results of LCSA decision making improve

the sustainability of an operative system[20].

Waste management interconnects with diverse sectors, dispersing negative impacts rather than recompenses. Also, this phenomenon inherits global attention, especially because, its accelerated trend of waste generation along the time and space. In 2015, the United Nations declared '2030 Agenda for Sustainable Development'. In it, the sustainable development goals (SDGs) and targets are described to tackle identified triggering challenges to be fulfilled by 2030 [21]. Out of all, 76% of UN SDGs hold targets with a direct demeanor on waste and managing resources signifies its consequence for a broad multiplicity of environmental and socio-economic factors and associated actors[22]. Sustainable cities and communities-Make cities and human settlements inclusive, safe and resilient and sustainable (Goal-11),and Responsible consumption and production- (Goal-12) [21].The target number 6 of the goal no. 11 is by 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

These are the catalysts of a successful economy and a way towards circular economy. Solid waste management systems that promote resource recovery from waste, will amplify the provision of precious and important resources, eventually dropping their cost and affording more equivalent resource access. Consequently, an attention on manipulating, reusability, recoverability and recyclability to expand employment, thereby diminish poverty [22]. This study aims to quantify the potential reduction on environment impact though maximum resource recovery of materials from the municipal solid waste management stream.

The municipal councils are the legislative entities established by the law [23] which have power over the major cities and the first level local bodies in Sri Lanka. These institutes are accountable for the administration of all affairs related to the public health, common services and public access roads and usually with the safeguard and backing of the relieve, convenience, and wellbeing of the people and the facilities. Kandy Municipal Council is, one of the twenty three main local government bodies in Sri Lanka[24]. Also, especially being the cultural capital of Sri Lanka, Kandy was declared as a world heritage site by the UNESCO in 1987. Moreover, the National Waste Management Policy for Sri Lanka (2018) [25] guided to solve rapidly aggravating solid waste problems, hence section 8.2.1.1(e/i) policy statement pointed out that, land filling should be bounded to non-recyclables, non-compostable and inert materials remained through waste treatment process. By laws related to municipal solid waste management have been imposed by the Kandy Municipal Council and to administrate proper waste management activities in the

Kandy Municipal Council area in 2002. Source separation is indispensable at the source of waste generation, and it has been executed and a penalty has been initiated by the KMC for

whom the regulations are not followed.

1.1 Legal framework on waste management in Sri Lanka

An initial attempt for waste management has been taken in the Urban Council Ordinance No. 61 of 1939, the sections of 118,119 and 120 [26] and also, comparatively larger cities' waste management activities are assigned from the Municipal Council Ordinance No. 29 of 1947, in which the sections of 128,129 and 130[27]. Also, for waste management related activities in rural areas, Pradeshiya sabha (local government) Act No. 15 in 1987, sections 93,94 and 95 [28] and the Section No. 23 of the National Environmental Act No.47 in 1980 [29] are the main influencing tools for better solid waste management practices in Sri Lanka.

1.1.1 Policies on solid waste management in Sri Lanka

The National Waste Management Policy for Sri Lanka [25] and the National Policy and Strategy for Cleaner Production[30] are two main policies convince the Solid Waste Management systems in Sri Lanka. The National Waste Management Policy for Sri Lanka-2018 [25] to make certain environmental accountability and social responsibility of all waste generators, waste managers and service providers and stipulates the active involvement of all individuals and institutions toward integrated solid waste management. This policy stresses on maximizing resource recovery through the appropriate management of municipal solid waste and the second policy of, the National Policy and Strategy for Cleaner Production-2005 [30], which articulates that cleaner production principles should apply to develop efficiency of natural resource handling while maintaining and improving environmental quality. This policy specifies that waste generation should diminish at source, thereby assisting in reducing the quantity of solid waste, which would have to manage by a municipality.

The primary objective of this study is to investigate possible ways to maximize resource recovery from present solid waste management system while mitigating negative environmental impacts. Hence, to make path to minimize pressure of the present overloaded land filling site by promoting recycling and composting in different stages of the municipal solid waste management system using different scenario developments. More than 126 tons [31] of Kandy municipal solid waste is being accumulated to the present waste dumping site at Gohagoda, daily. There is a possibility to collapse the present land filling site due to the height, volume and other related factors, if the present

situation continues. It has been noticed that, there are various kind of techniques introduced by different scholars for resource recovery from municipal solid waste.

2. Methodology

2.1 Study Area

Sri Lanka is a South Asian country in which Kandy is considered as the cultural capital. The Kandy Municipal Council (KMC) area is the study area of this study which administratively 2,853 ha in area, lies between $07^{\circ} 17' 47''$ N and $80^{\circ} 38' 06''$ E and located in the central highlands, shown in **figure-1**. According to the Koppen-Geiger climate classification, the study area is in Af (Tropical rain forest) climatic zone[32]. Climatic conditions especially, long wet season of the study area urges waste management due to short decomposition condition.

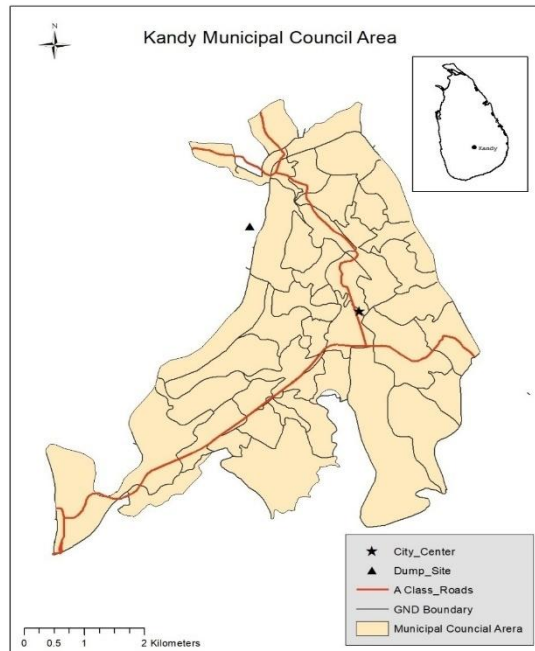


Figure 1: The Kandy Municipal Council Area

Though, the population of the study area was 102,500 according to the decadal census of population and housing in 2012[33], daily floating population is about 400,000 [31] due to Kandy is the cultural capital in Sri Lanka and a world famous tourist destination. Municipal solid waste generation by 2019 was 185 tons per day according to the KMC sources [31]. Uncollected waste percentage is about 18% in the study area. This uncollected waste is affected by animals like and also a breeding ground for insects. Blockage of drainage system

owing to terrain and soil erosion is a challenge during and after rain. Selection of alternative dumping site and site selection for establishing recycling facility is a timely requirement due to series of complex reasons [34].

2.2 Municipal solid waste management in the KMC area

2.2.1 Waste composition

Municipal solid waste composition of the KMC area is almost similar to other municipalities in Sri Lanka as well as other developing countries. The organic waste represent the highest percentage, especially in household waste. The value is 78 percent. Moreover, paper (28 per cent) and plastic(17 per cent) which comparatively higher percentages in the commercial waste composition as shown in the **table 1**. Households, commercial places, hotels, industries, markets, institutions and others are considered as waste sources in Kandy. Hazardous waste and construction debris are collected separately according to a survey conducted by the KMC in 2015. Commercial waste comprised of 66% and household waste contributed 34% of the total waste generation in the study area.

Table 1 : Waste composition of the KMC, 2015

Waste Category	Household (%)	Commercial (%)
Organic	78	38
paper	6	28
Metal	1	2
Plastic	7	17
Glass	1	2
Textiles	2	2
Other	5	11
	100	100

2.2.2 Kandy waste management process

The Kandy Municipal Council area is divided in to five zones to maintain better waste management process. Out of them, Kandy city hinterland area is divided in to two zones, as Zone -1A (Kandy commercial city area), and Zone-1B (Temple tooth area). Zone II (Mahaiyawa area), Zone III (Suduhumpola area), Zone IV (Katugastota area) and Zone V (Aruppola area). Until 2010, waste collection was carried out through drop off centers. However concerning different environmental and social impacts, these centers were

removed from the places and introduced separation at source and household composting project. Degradable waste is collected during week days and non-degradable is collected weekends by the Kandy municipal council. Per capita waste generation in Kandy municipal council area is 0.333kg/p/d (2013) [31] Source separation and on site composting (according to the bylaw introduced on 28 June 2013) have been introduced for the households aiming to waste minimization. Compost bins have been introduced to households in collaboration with the Central Environmental Authority of Sri Lanka. Separated recyclables are sold either to the municipal council or for informal recyclers. A bio gas project have been introduced to large scale hotels. Different waste treatment activities for example, recycling, composting, bio-gas generation, have been carrying out to generated waste, during different stages in the present waste management process, related to waste sources, in detail, such as; households, commercial, market, hotels, private institutes, governmental institutes, schools, hospitals religious places, tobacco company, saw mills, and other sources according to the field survey conducted.

In addition to the source recycling through separation at source, in different stages of the waste flow, separation and recycling are practiced. They are by private recyclers after disposal at source before collecting by the municipal council, However this amount is considered negligible, while waste transportation to the final dumping site by municipal council workers to sell to “Sampath piyasa” (recyclables collecting centers conducted by the municipal council) about two/ tons per day, and at the final dumping site after final disposal by the dwellers near the final disposal site about two tons per day. About one ton of food waste is directed to pigsties[31].

he major necessity of maximum resource recovery from solid waste is the limitation of space of the excessively overloaded final dumping site at Gohagoda. In 2003, Japan International Cooperation Agency(JICA) launched a rehabilitation project and guaranteed for only two years. However, still the same site is used for dumping waste. A private company has signed for a project to generate electricity from waste and to develop bio- char from waste in 2010. Due to lack of funds, the project was also, failed.

2.2.3 Administrative hierarchy of the KMC waste management

The chief of the solid waste management division is the mechanical Engineer of the Kandy municipal council. The Cleaning Superintendent and the Administrative Officer carry out duties under him. Six Physical Health Inspectors carryout their duties including 45 officers who carry out their dutie in each Grama Niladhari Division. The major duties of these officers are to activate all the solid waste management projects which have been launched in respective Grama Niladhari Divisions and to organize the environment committee. Apart from those zonal labor inspections also to be done. Out of all the waste collection zones, zone IA is the highest generator of solid waste as shown in the **figure 2**. Therefore, Kandy

commercial city area is the most influencing waste management zone compared to the other zones. Different stages of the KMC waste management activities are shown in the **figure 3**.

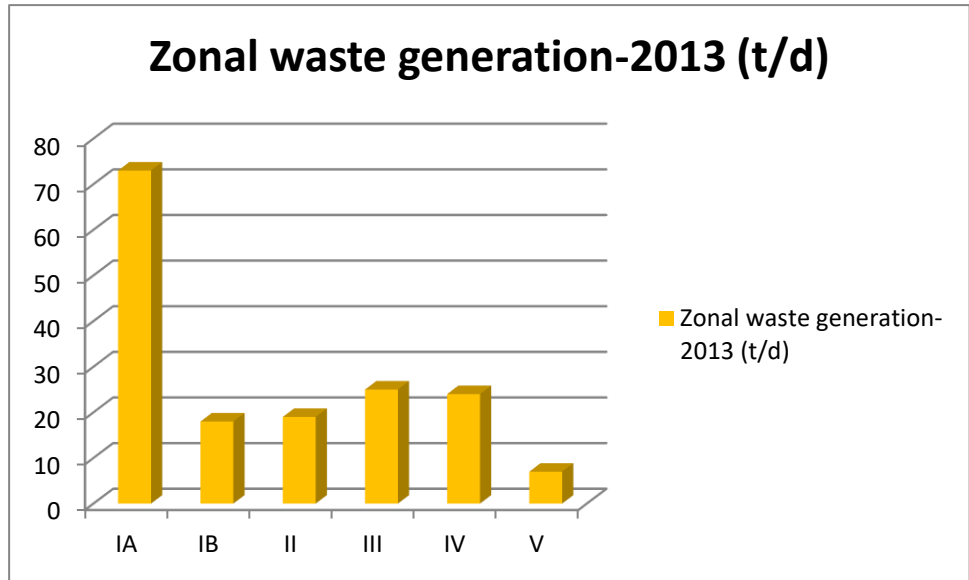


Figure 2 : Figure showing zonal contribution (IA-Kandy commercial city area, IB-Temple tooth area, II-Mahaiyawa area, III-Suduhumpola area, IV-Katugastota area, V- Aruppola area)



Figure 3 : Municipal waste management activities of the KMC

2.3 Methods

2.3.1 Overall methodology

Overall methodological framework of this study is shown in **figure 4**.

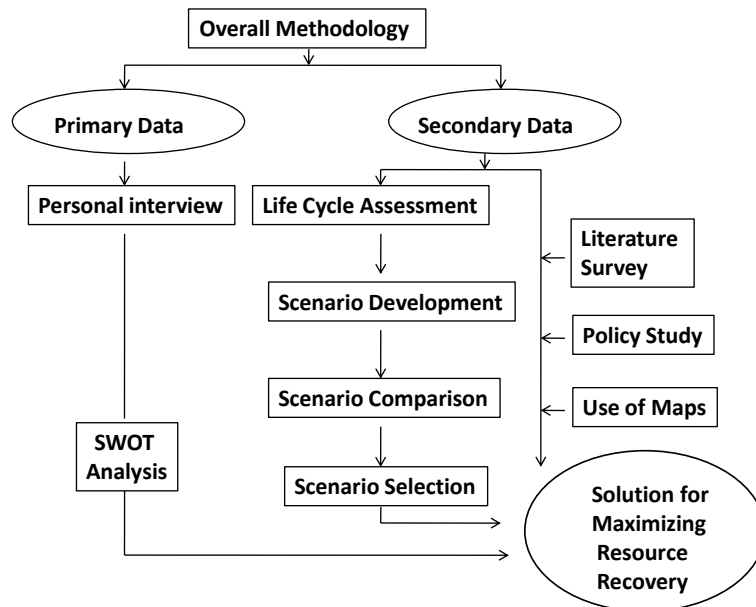


Figure 4 : Overall methodology of the study, use of primary data and secondary data.

In this research we use both quantitative and qualitative methods as follows;

2.3.2 Qualitative research base

28 personal interviews were conducted to achieve the objectives of the study. Both officers and the general public engaged in the waste management process in the municipal council area, were interviewed. Aiming to reach the goal, the Municipal Engineer, two officers related to documentation activities, three informal recyclers, two officers from material recovery facility, and related two researchers, to represent each zone, six people from the general public, six waste collectors, six waste transport vehicle drivers, were selected to represent every stage of the waste management process. Then, the information was streamlined and evaluated the present solid waste management system using SWOT analysis method.

2.3.3 Quantitative research base

2.3.3.1 Scenario analysis

Present integrated solid waste management system in the KMC was examined and developed four scenarios, using life cycle assessment tool of Integrated Waste Management-II [35].

2.3.3.2 Model implementation

There is no seasonal variations in the study area, as it is located in the tropical area, and the measuring unit used in this study is tons of municipal solid waste per year in the life cycle inventory. Present waste management system of the Kandy Municipal Council area generated 64,605 tons/year in 2013, according to the official report of the Kandy Municipal Council (31). This amount will increase up to 67,160 tons/year in 2020 and 70,810 tons/year by 2030 respectively with the annual population growth of 0.5% in the study area.

2.3.3.3 Scenario designing methodology

Proposed four scenarios of this study differentiate each other in different treatment methodologies and dissimilar technological levels. The scenario design is incorporated with the targets of the Kandy Municipal Council's waste management targets. Life Cycle Assessment (LCA) was utilized to generate scenario results.

Figure 5 shows the Scenario-1, in 2013, amount of sorted waste at households by the waste generators and during waste collection by the municipal council's waste collectors was 3,022 tons/ year. Only, 96 tons/year of waste was used to generate organic compost as a biological treatment. Total material recovered in this situation is 1,559 tons. All the rest waste, 95.42% of total waste was sent to final dumping site.

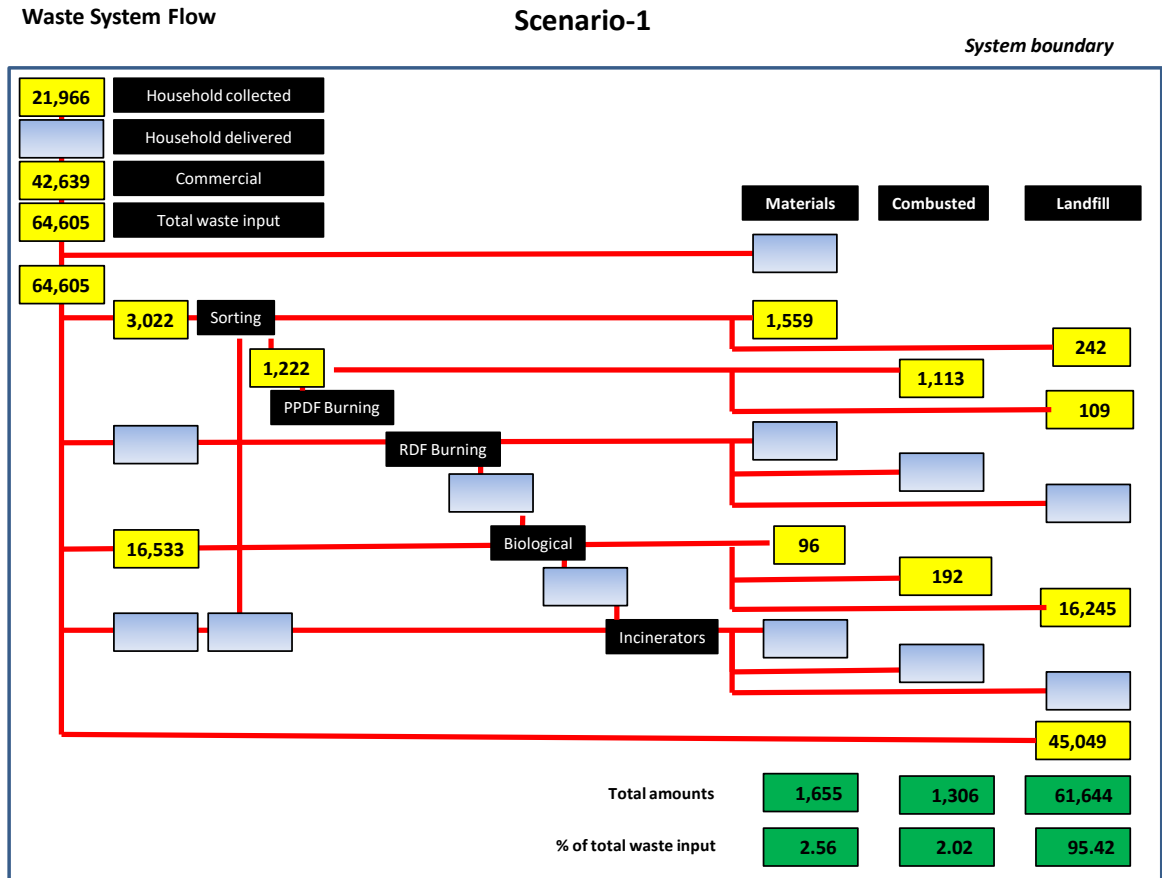


Figure 5: Scenario-1, Baseline scenario displaying the waste management system, values in tons/ year in the Kandy Municipal Council area by 2013.

This study concerns in scenario-2 as shown in **figure 6** where, the materials recovered increases to 2,571 tons/ year from biological treatment and 439 tons/year materials recovered from sorting. This scenario limits the total waste send to the final dumping site to 58,864 tons/year. This is 2.10% growth of total material recovered from the system and 4.3 % reduction of final solid waste send to final dumping site than scenario-1.

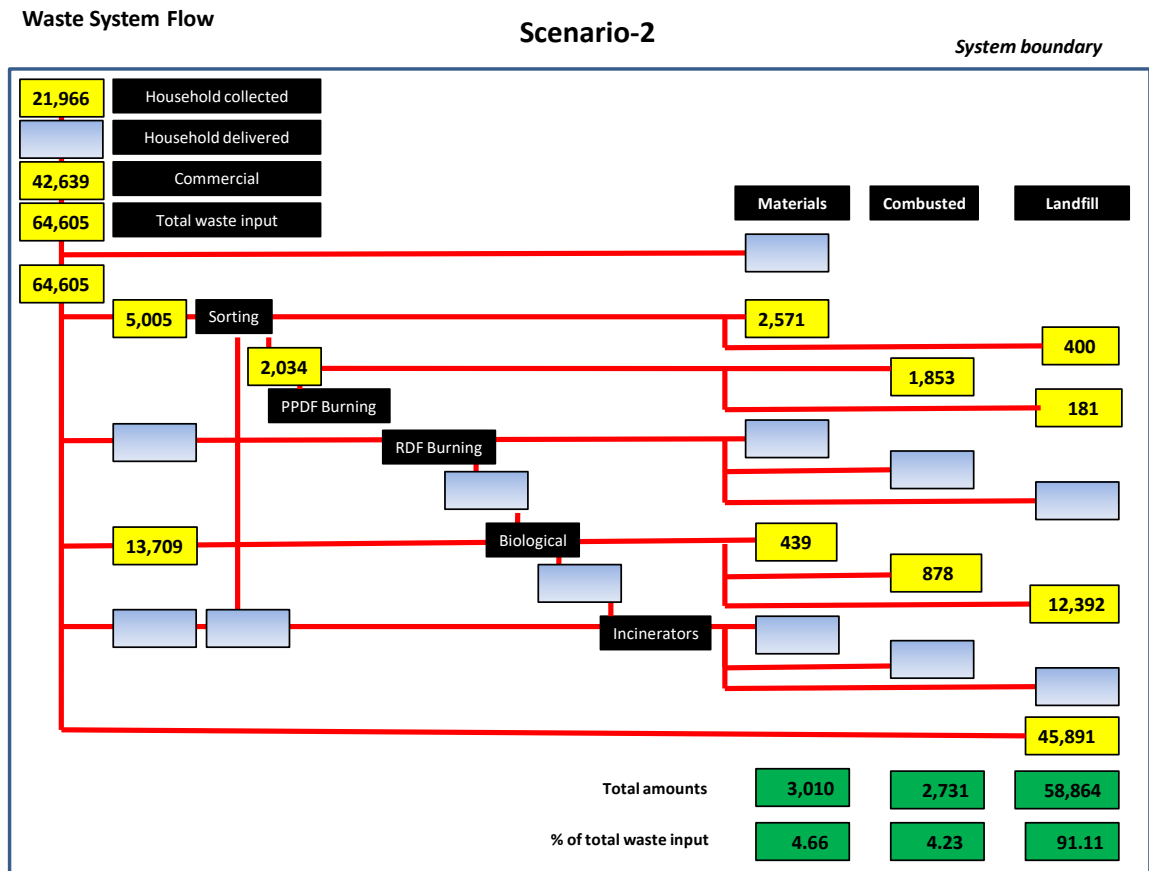


Figure 6 : Scenario-2, Scenario displaying the waste management system, values in tons/ year in the Kandy Municipal Council area by 2013.

In scenario-3, **figure 7**, materials recovered have been increased to 3,896 tons/year though sorting and 839 tons/year of materials recovered through composting and bio-gasification. This amount is 2.67% increase of total material recovered than scenario-2.

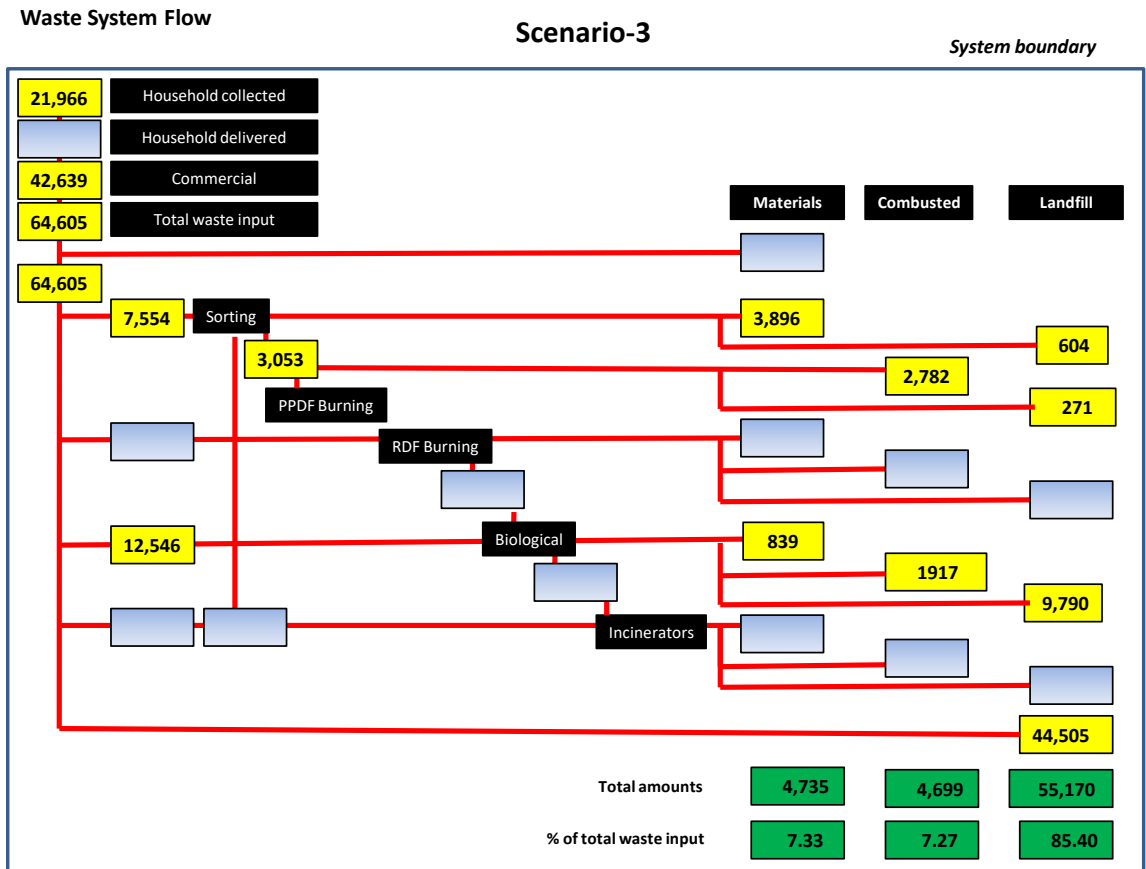


Figure 7 : Scenario-3, displaying the waste management system, values in tons/ year in the Kandy Municipal Council area by 2013.

Scenario-4 as shown in **figure 8**, introduces incineration and therefore no more waste will be added to the final dumping site at Gohagoda without any treatment. However, 18.26% of total waste input will be sent to final dumping site. Sorted material recovered in this scenario is 4,361 tons/year. 2,619 tons/year of material is recovered in biological treatment. Total material recovered in this scenario is 11.49% and combusted waste will be increased to 70.26% out of total waste input to the system. It is proposed that, to utilize energy generated from combustion to boil water and to generate electricity [8].

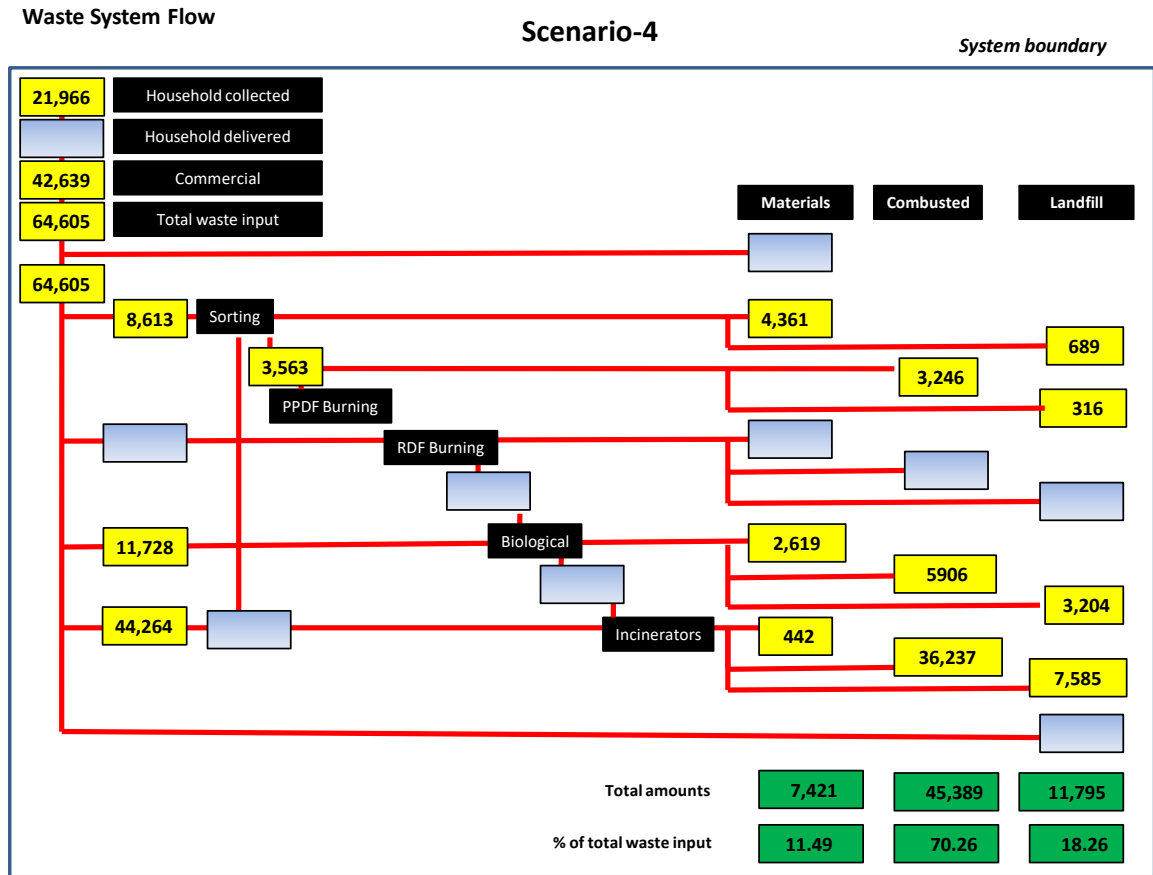


Figure 8 : Scenario-4, Scenario displaying the waste management system, values in tons/ year in the Kandy Municipal Council area by 2013.

3. Results and Discussion

3.1 Scenario comparison

Developed scenarios revealed different levels of technology utilization through results generated. Final solid waste generated in different scenarios is shown in **Figure 9**. Scenario 4 produces the least amounts of final solid waste compared to other scenarios. Total final solid waste generated in the scenario 4 is 2,382 tons/year.

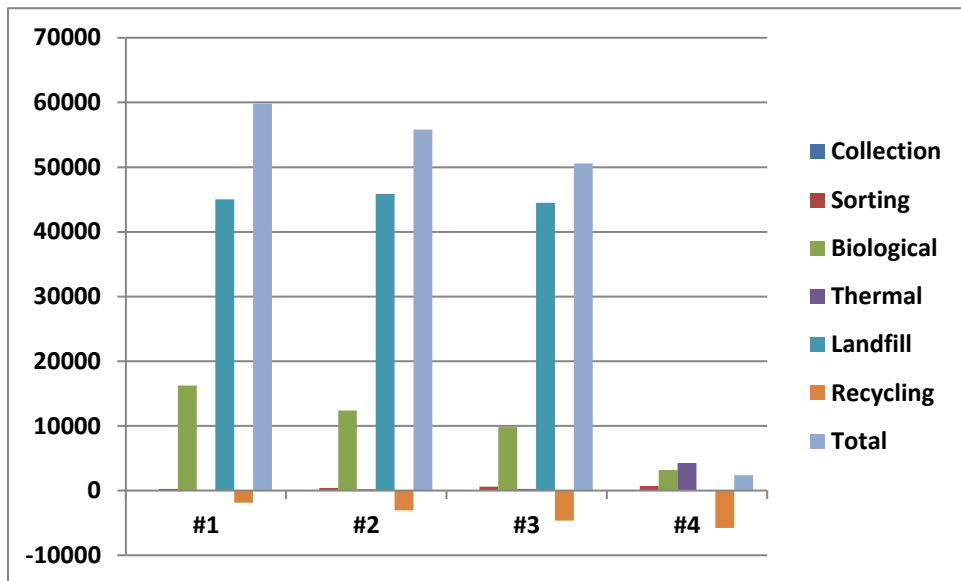


Figure 9 : Final Solid Waste (Tons/Year)

Amount of emissions of CO₂ of different scenarios are an evidence of the level of contribution for environmental negative impacts. **Figure 10** shows the level of CO₂ emission in each scenario. The highest contribution is from the developed scenario with the value of 15,183 tons/year.

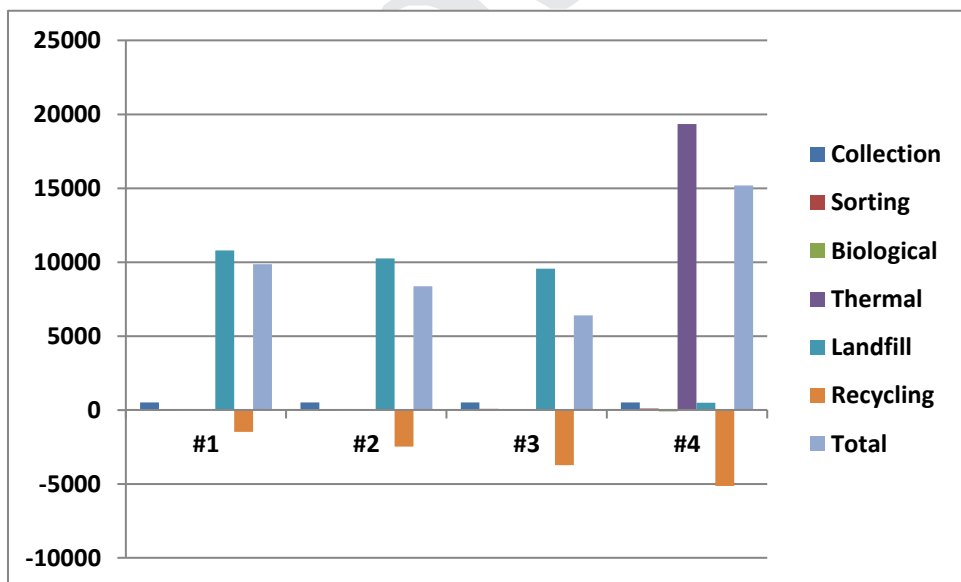


Figure 10 : Carbon Dioxide (CO₂) emission (Tons/Year)

Carbon Monoxide (CO) emission in scenario four is greater than the other scenario developed. **Figure 11** shows the CO amount of emissions from designed each scenario. The least value is from developed scenario-4 and the value is -12 tons/year.

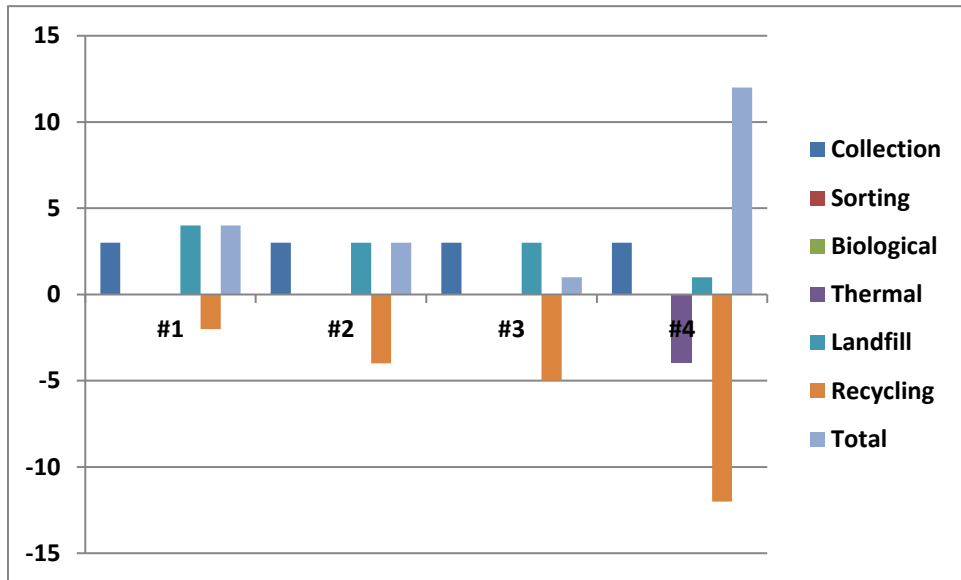


Figure 11 : Carbon Monoxide (CO) emission (Tons/Year)

Figure 12 shows the emissions of NOx of designed each scenario. NOx emissions from scenario 4 has a greater saving potential of the value of -65 tons/year and utilization of heat energy generated from the incinerator facility and resources recovery of materials which saves others fuel and materials from ores which would have been utilized as an substitutes .

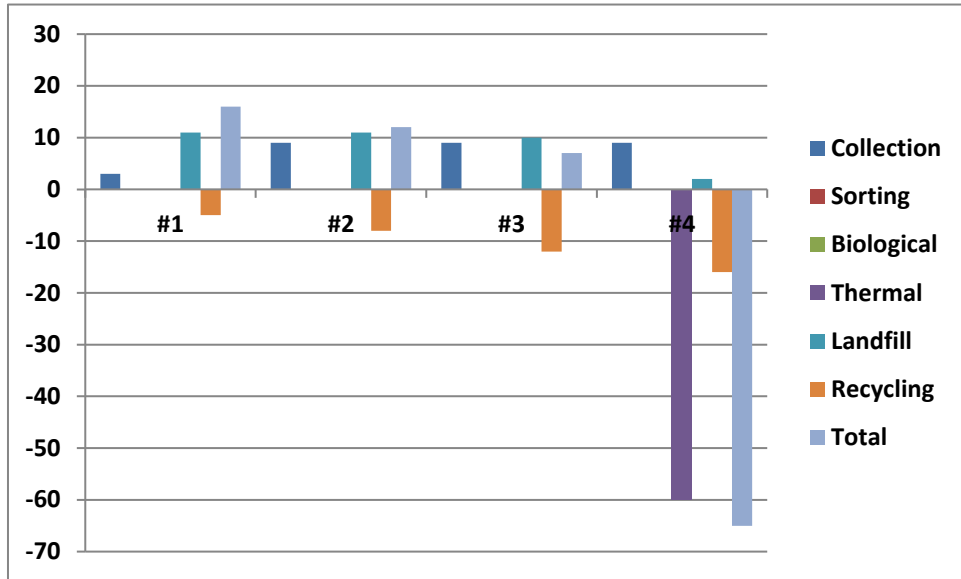


Figure 12 : (NOx) emission (Tons/Year)

Methane is 24 times higher in contribution for global warming potential rather than CO₂ emissions. **Figure 13** shows the contribution of CH₄ of the designed each scenario. Least value of CH₄ is generated from proposed scenario-4 and the value is 161 tons/year.

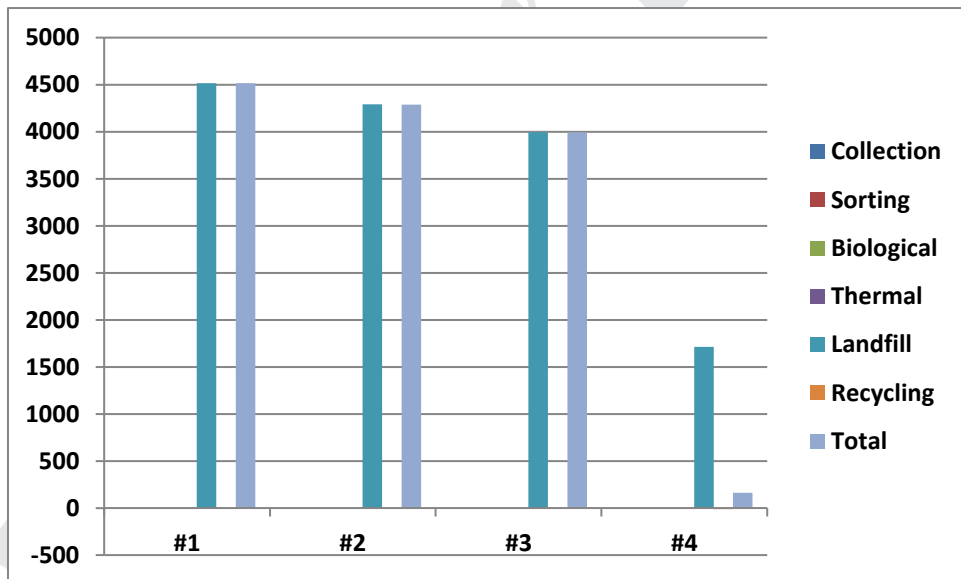


Figure 13 : Methane emission (CH₄) (Tons/Year)

Figure 14 shows the contribution for Global Warning Potential of designed each scenario. According to the information Least contribution is from the developed scenario 4 and the value is 18,512 tons/year.

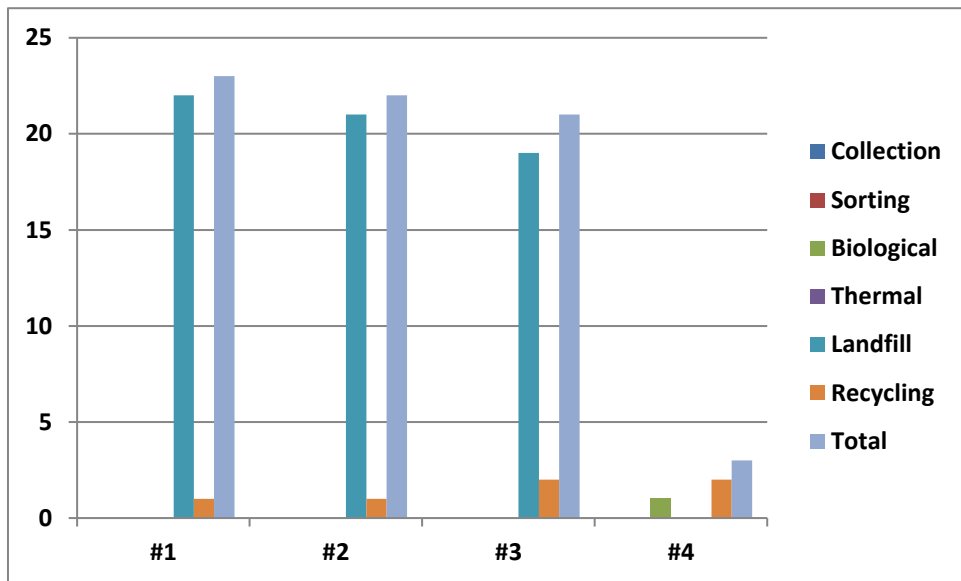


Figure 14 : Global Warming Potential (GWP) (Tons/Year)

Figure 15 shows the Chemical Oxygen Demand of designed each scenario. Designed scenario 4 is the lowest contributor for COD. COD total of the developed scenario-4 is -79 tons/year.

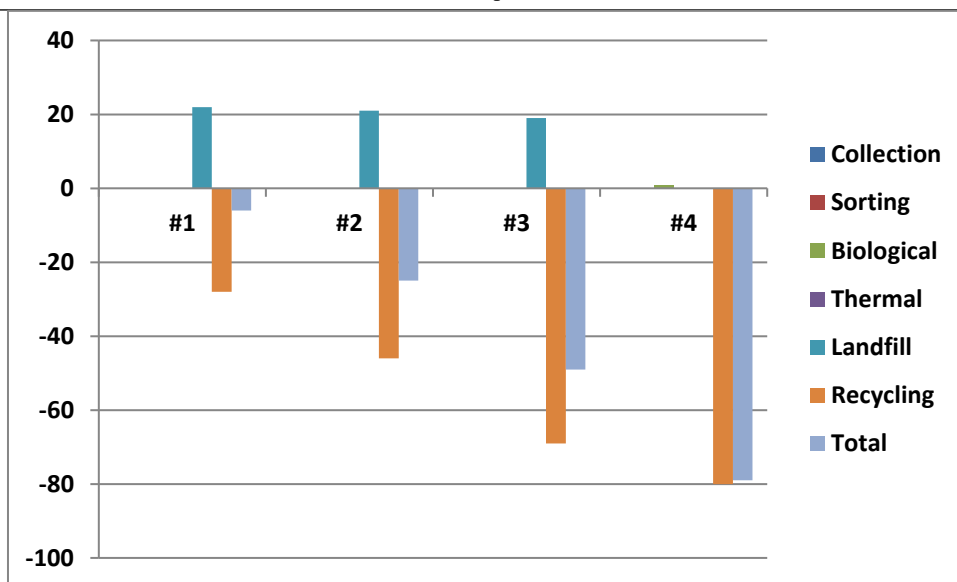


Figure 15 : Chemical Oxygen Demand (COD) (Tons/Year)

The results of the scenario analysis revealed that the S1, S2, S3 and S4 have comparatively different environmental consequences in different levels. These findings are investigated in final solid waste (FSW), CO₂, CO, NO_x, CH₄, global warming potential (GWP), and COD. The selection of the best scenario is depended on the waste management targets of the waste management system planners, decision makers and administrators.

3.2. Coping the Kandy Municipal Council's waste management targets with the study results

The vision of the Kandy Municipal Council's waste management master plan is to develop Kandy city as an eco-city. In achieving the goal, short-term, mid-term and long-term goals have been streamlined. Under each category, subcategories have been arranged according to the priority levels considered. Scenarios developed in this study focused on these goals and the proposed scenarios vary in each scenario with different technology levels from the present situation to proposed combustion of solid waste in developed scenario-4. This technology development is done in relation with the socio- economic context of the study area. Similarly, limited financial background is a hindrance for sustainable solid waste management activities in Sri Lanka.

4. Conclusions

Developed four scenarios generated dissimilar technological solutions to promote maximum resource recovery from different solid waste treatment scenarios through life cycle assessment methodologies to succeed in circular economy activities to achieve SDGs in municipality level. Moreover, it can be concluded that, the most of the causes for improper MSW management services are the short of proper government policies and legislation, inadequate

political involvement and public dedication, lack of technical capability, low-level financial capabilities, and lack of suitable lands for waste disposal sites and waste treatment facility establishment. Promoting proposed technological solutions for the Kandy Municipal Council is essentially important to achieve SDGs and circular economy concept related to the municipal solid waste management in municipality level.

Future research directions can be developed through the proposed solutions in this study, if the goal of the future studies lie on maximum resource recovery from waste management system to achieve the SDGs through circular economy perspectives.

Author Contributions

Concept was developed by SKBG and SRK also, NSKH contributed to write the paper with SKBG and SRK.

Conflicts of interest

Authors declared no conflict of interest.

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