UNIVERSITY OF NAIROBI

SCHOOL OF ENGINEERING

DEPARTMENT OF ENVIRONMENTAL AND BIOSYSTEMS ENGINEERING

EVALUATING THE EFFECTIVENESS OF WASTE MANAGEMENT SYSTEMS FOR TEA FACTORY IN KENYA: A CASE STUDY OF MARAMBA TEA FACTORY IN KIAMBU COUNTY

By

AMOS MUKHWANA KOLA

Reg No: F56/75934/2014

(B.Sc. Environmental and Biosystems Engineering, 2013)

A thesis submitted in fulfilment of the requirements for the Degree in Masters of Science in the Department of Environmental and Biosystems Engineering in the University of Nairobi.

August 2019

DECLARATION

I, Amos Mukhwana Kola, hereby declare that this thesis is my original work. To the best of my knowledge, the work presented here has not been presented for a thesis in any other university.

………………………………………… …………………

Amos Mukhwana Kola Date

SUPERVISORS

This thesis has been submitted for review with our approval as university supervisor(s).

....

Dr. Christian Omuto **Date**

Department of Environmental &Biosystems Engineering

University of Nairobi

....

Mr. Stephen C Ondieki **Date**

Department of Environmental & Biosystems Engineering

University of Nairobi

DECLARATION OF ORIGINALITY

Name of student:	Amos Mukhwana Kola
Registration:	F56/75934/2014
College:	College of Architecture and Engineering
Faculty/School/Institute:	Faculty of Engineering
Department:	Environmental and Biosystems Engineering
Course Name:	Master of Science in Environmental and Biosystems Engineering
Title of work:	Evaluating the Effectiveness of Waste Management Systems for Tea Factory in Kenya: A case study of Maramba Tea Factory in Kiambu County

for examination, award of a degree or publication. Where other works or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements

3) I have not sought or used the services of any professional agencies to produce this work
4) I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her work
5) I understand that any false claim in respect of this work shall result in disciplinary action in accordance with University of Nairobi anti-plagiarism policy

Signature:

Date:

DEDICATION

I dedicate this research to my parents Mr Eliud Muwanga and Mrs Neddy Lichuma. My son Harvey Amisi Kola, my able beautiful sisters and all those people who have helped and encouraged me throughout the study. Thanks, and God bless.

ACKNOWLEDGEMENT

I would like to express my profound gratitude to my supervisors Dr. Christian Omuto and Mr.Stephen Ondieki, Environmental and Biosystems Engineering Department, University of Nairobi, for their great guidance offered to me through this reseach thesis

I would also like to recognize the effort of our inspiring chairman of the department Dr. Duncan Mbuge, immediate former chairman and the current dean school of engineering, Eng.Prof.Ayub Gitau through their continued advices.

I wish also to convey my sincere appreciaton to Mr. Simon Karanja and Mr. Allan Muigei the Tea Factory manager and assistant manager respectively for according me necessarily assitance during my data collection. Mr. Eli Mwachoni and Mr. Boniface Muliro, the Environmental and Biosystems technicians for assisting in processing wood for analysis. Mr. Specher my data collection assistant and other laboratory technician in Mechanical department and Environment laboratory in Civil Department University of Nairobi respectively for assisting in carrying out the necessary experiements

ABSTRACT

The Government of Kenya and the world has put emphasis on the need to invest in waste management systems. Much of the emphasis has been on Municipal and residential wastes management. However, agro industries (which includes tea factories) wastes management challenges is on the rise. Performance of the already existing management systems is therefore critical in sustaining our environment. A waste management system should be based on a clear characterisation of wastes, the quantities and qualities of the wastes and identification of waste sources. The study evaluated the effectiveness of existing wastes management systems in Maramba Tea Factory in Kiambu County, Kenya for solid, liquid and thermal wastes management systems using Benchmarking Method.

Primary data and secondary data were collected. Purposively and convenience sampling techniques were utilised when choosing the wastewater sample points in the lagoons, upstream and downstream of the river.

Existing liquid wastes (wastewater) were treated through naturally aerated lagoons. There were no clear systems to manage solid wastes, though most of the organic wastes are disposed in the banana garden, metal solid wastes were disposed of by selling and for thermal wastes, there was chimney for the boiler but no pipe lagging that would reduce heat loss.

Characterisation of waste generated was done through observation. The types of wastes identified were organic solid wastes, inorganic solid wastes, Liquid wastes and Thermal wastes. The quantities of wastes were determined by weighing. The Organic solid wastes from tea processing stages were 486.47 kilograms per month and inorganic solid wastes (sacks and polythene bags) were 15.38 kilograms per month. The amounts of liquid wastes generated for the study period were estimated at 80% of the amount of water used. The highest with major cleaning estimated at an average of 111.52m^3 per month and the least with minor cleaning averaged at 42.24m^3 per month. The quantity of thermal wastes generated at the factory was due to heat loss from the wood fuel used as a source of energy. The total amount of heat loss was found to be 1145.51kcal/kg representing 37.45%. of the Gross Calorific Value (GCV) of wood fuel. The highest heat loss being due to dry flue gas with 675.85kcal/kg representing a 22.09% of total GCV of wood fuel and the least being due to moisture present in the combustion air at 24.78kcal/kg representing 0.810 % of the total GCV of wood fuel.

The qualities of wastewater were achieved through analysing the BOD_5, COD, PH and Electrical conductivity (EC) and comparing the values to the standards recommended by NEMA. The BOD 5days at 20 ^oC at 83.7mg/L, COD at 106.63mg/L, EC at 31.87 S/CM and pH of 7.1 were established. The thermal waste systems were evaluated by determining the boiler efficiency. Boiler efficiency at Maramba Tea Factory was 62.55%.

The analysis with ANOVA showed significant differences in the water quality parameter values from source through to the lagoon to the river.

Investigating the efficiency of these systems contributed to the theory of waste management and provided the literature needed to document the state of waste management systems in tea factories in Kenya.

It was concluded that both solid, liquid and thermal waste management systems at Maramba Tea Factory are only partially effective. More studies need to be carried out in tea industries to enable development of guidelines for waste management in such industries.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abbreviations and Acronyms

ASDS	Agricultural Sector Development Strategy (of Kenya)
BMF	Broken Mixed Fannings
BOD	Biochemical Oxygen Demand
BOD_5^{20}	Five Day Biochemical Oxygen Demand at 20^0C
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board (of government of India)
CTC	Crush, Tear, Curl (a tea processing stage)
CIBO	Council of Industrial Boiler Owners
EATTA	East Africa Tea Traders Association
EC	Electrical Conductivity
EMCA	Environmental Management and Coordination Act (of Kenya Government)
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food Agriculture Organization
FDS	Factory Door Sales
GCV	Gross Calorific Value
HDPE	High Density Polyethylene
KGS	kilograms
KTDA	Kenya Tea Development Authority
LDPE	Low Density Polyethylene
LTWR	Leather, Textile, Wood and Rubber
LTP	Lawrie Tea Processor
MINAS	Minimal National Standards
ML	Min Lagoon
NEC	National Environmental Council
NEMA	National Environmental management Authority
PCC	Public Complaints Committee
PD	Pekeo Dust
PH	Potential of Hydrogen
PET	Polyethylene Terephthalate

S/CM	Siemens per centimetre
SCDA	Special Crops Development Authority
SL	Sub Lagoon
SEI	Stockholm Environment Institute
SEM	Scanning Electron Microscopy
SERC	Standards and Enforcement Review Committee (of National Environmental Management Authority)
SWM	Solid Waste Management
TBK	Tea Board of Kenya
TRFK	Tea Research Foundation of Kenya
USEPA	United States environment Protection Agency
UTKL	Unilever Tea Kenya Limited
WHO	World Health Organization
WRA	Water Resource Authority

1. INTRODUCTION

1.1 Background to the study

Waste management systems are processes involved in handling the wastes from source generation to disposal with minimal or no negative impacts to the environment or human health. The problems encountered in wastes management includes; some of the management systems are expensive, wastes generation are ever increasing, most regulations have vested interest and there is too much reliance on technologies that are out dated while some wastes are too toxic to handles with the current systems.

Agro-industries where tea factories fall under generate a large number of solids, liquids and gaseous wastes from their processing, treatment and disposal operations. The main pollution categories include; solid wastes, wastewater, and air pollution (Kittikun et al. 2006).

Wastes management systems in tea factories in Kenya includes: natural aerated lagoon for treating liquid wastes, landfilling to handle solid wastes, the thermal wastes are mostly managed by improving boiler efficiency and also lagging the pipes that deliver steam. However, the effectiveness of these systems is not yet established. The quality of wastes discharged to the environment is also unknown, due to scanty information on the state of waste management systems in tea factories Kenya.

Evaluation of waste management systems provides the management, authorities and relevant stakeholders with accurate data on devising ways to improve the existing systems or choosing the better alternative systems in managing the wastes. Wada et al (2008), in their study to evaluate the wastes disposal systems in Japan, focused on the environmental impacts resulting from the wastes after passing through the disposal systems and the second technique used was the cost of the existing systems compared to the proposed new technologies systems with cost of disposing the waste included. The impacts to the environment and costs for the systems were determined using lifecycle assessment (LCA) and lifecycle cost (LCC) methods in a model city. They concluded that a choice of any particular waste management system will depend on the nature and type of the wastes. However, they recommended that all new technologies in waste management systems should be based on a cost estimate and the impacts posed to the environment. Chung and Poon (1996), in the study evaluating waste management alternatives used a Multiple Criteria

Approach (MCA) in their evaluation. The methods analyzed included; landfilling, waste to energy, compositing, and source separation. The advantage of MCA is that it accommodates both quantitative and qualitative data, which gives a more subjective and implicit data for decision making.

The alarming rate of environmental concerns on the waste management and in this case from tea factories in Kenya, calls for a combined study by scholars in assessing waste management systems in various tea factories. The studies will provide documented information on the state of waste management systems for Tea factories in Kenya. It is on this basis which this study aims at evaluating the effectiveness of the waste management systems for tea factories in Kenya with a case study of Maramba tea factory in Kiambu County. The finding of the study will go a long way in providing a benchmark and guidelines development upon which managerial decisions can be made.

1.2 Problem Statement and Justification

1.2.1 Problem Statement

The Government of Kenya and the world has put emphasis on the need to invest in waste management systems. Performance of the already existing management systems is therefore critical in sustaining our environment. Waste materials are generated from manufacturing processes, industries and municipal wastes much of the emphasis has been on Municipal and residential wastes management. Agro industries (which include tea factories) have been largely neglected (Kan 2009). Poor waste management strategies in Kenya are prevalent in the smallholder tea factories. This has led to adverse effects such as pollution of water sources (Norrington et al, 2011).

The main pollution categories include; wastewater, solid wastes, thermal wastes and air pollution (Kittikun et al. 2006). Poor waste management systems have adverse impacts on; environment, human health, economic development and quality of life. Often, these wastes are managed and regulated differently depending on the characteristics of the waste, the process of producing them and regulations. An efficient tea processing system must be based on a predictable raw material supply. However, with the liberalization of tea industry in Kenya and the repeal of tea planting license, tea growing has become unregulated making it difficult to absolutely predict the green leaf supply (TBK, 2008) and hence difficult to predict the wastes generated in line with the design capacity of waste management systems.

Tea processing generates different types of wastes. A waste management system design should be based on a clear characterization of these wastes, the quantities and qualities of the wastes and identification of sources.

In Maramba, the characterisation of wastes has not been done and the quantities and qualities are not known before they are discharged to the environment. Consequently, the efficiency of the waste management systems is also not known.

A single study cannot be used to generalize the state of waste management systems of all tea factories under Kenya Tea Development Authority (KTDA) and other privately-owned ones in Kenya. In order to profile waste management systems of tea factories in Kenya, more research in this field is required. This study therefore aims at evaluating the effectiveness of waste management systems of Maramba tea factory in Kiambu County.

1.2.1. Justification of the study

The emphasis has been put on the need to invest in waste management systems in Kenya. Reliable information on the state and performance of the existing ones are therefore critical. Currently the state of wastes management systems in Maramba tea factory is unknown. The quality of wastes being discharge in the environment is also unknown. In order to have guidelines development governing wastes management systems in small scale tea factory by policy makers and a realistic projection of information regarding the need to redesign the waste process regime. Accurate and complete information on the source, quantity and quality of wastes generated is needed (Kittikun et al, 2006 and Stockholm Environment Institute, 2009).

The study also will provide and increase the theory of knowledge on waste management in small scale industries. It will also provide the much needed literature and documentation on the state of waste management systems of tea factories in Kenya.

1.3 Objective of the study

1.3.1 Overall objective

The overall objective of the study was to evaluate the effectiveness of waste management systems for Maramba tea factory in Kiambu County, Kenya.

1.3.2 Specific objectives

The specific objectives of the study were:

i. To characterize the waste generated during tea production at Maramba Tea Factory

ii. To analyse waste management in the Maramba Tea Factory

iii. To evaluate the effectiveness of the waste management systems in Maramba Tea Factory

1.3.3 Research Questions

i. What are the types of waste generated during tea production?

ii. What qualities of wastewater, quantities of solid wastes, wastewater and thermal wastes are generated during the tea production?

iii. How effective is the existing waste management systems in the tea factory?

1.3.4 Research Hypotheses

i. There are no different types of wastes generated during the Tea production

ii. The quality of wastewater generated and discharged to the environment exceeds the maximum allowable levels

iii. The existing waste management systems is not effective

1.4 Scope of the study

The study involved evaluation of the effectiveness of waste management systems of Maramba tea factory in Kiambu County Kenya. The study only considered the wastewater, solid and thermal wastes during the tea production process. The study did not cover the air pollution and noise level in the factory.

2. LITERATURE REVIEW

2.1 Introduction

Chapter one outlined the need for evaluating the effectiveness of waste management systems of tea factories in Kenya. Investigating the efficiency of this system contributes to the theory of waste management and provides the literature needed to document the state of waste management systems in tea factories in Kenya. In this chapter, the need and timeliness of study is presented. The relationship between this study and the various guideline for waste management standards both notionally and international is outlined.

2.2 Waste Type and Waste Management

2.2.1. Definition of Waste

Waste can be definite as a material or substance which is unwanted, and is discarded after its primary use. According to Basel convention, waste is defined as substance or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

2.2.2. Waste Types

Maclaren (2000) and UNEP (2005), noted that wastes types can generally be; solid, liquid and gaseous wastes which can be further be aggregated as either hazardous (toxic) or non-hazardous (non-toxic wastes). The wastes sources are globally grouped as agricultural wastes, residential wastes, commercial wastes and institutional wastes (UNEP 2005).

United Nation Economic and Social Commission for Asia and the Pacific (ESCAP) categorize wastes into four major types namely: 1). **Municipal Solid Wastes**. These types of wastes are generated from households, offices, public and private institutions like hospitals, shops and, schools among others. 2). **Industrial Wastes**- these types of wastes can either be solid, liquid or gaseous in nature. The wastes are generated mostly from industries and factories. They include packaging materials and other waste from food processing among others. 3). **Agricultural Wastes** – these are the wastes resulting from livestock, agricultural and agro-industrial activities (Tea factory wastes fall under agro-industrial wastes). This type of wastes can be both solid wastes, liquid wastes and gaseous wastes respectively. 4). **Hazardous Wastes** – These are wastes that are toxic to human health. They may be from agriculture, health facilities and commerce.

2.2.3. Waste Management Systems

Wastes management systems are activities and administrative procedures that involve managing wastes from waste sources, wastes generation, handling, and storage at source, collection, transfer and transportation to waste disposal. The objective is to achieve an environmentally friendly management system.

The universal waste management practices include: waste source reduction; product reuse and recycling; waste collection; waste compositing, waste burning or incineration and waste sanitary landfilling or dumping (Hoornweg and Tata 2012). However, some of these waste management practices have their own befalling challenges. For instance, open burning contributes to air pollution, while incineration may prove to be expensive for individual waste households. Landfilling require lands while waste transportation vehicles have significant pollution to the environment (Agwu 2012).

The criterion for choosing a waste management system must be based on economic or a social and environmental factor i.e. the potential impact of the waste management system on the local environment (Generowicz, and Gaska, 2015).

Key Components of Waste Management Systems

According to Kreith (2008), an effective waste management system must be able to address the following key components, namely:

I. **Waste Generation Component** – This is the stage at which materials become valueless to the owner and they wish to discard them, since they no longer have any use for them.

II. **Waste Storage Component –** These are systems for keeping the material which are discarded prior to collection and transportation**.**

III. **Waste Collection Component–** This involves all methods and procedures in which waste is collected together for transportation to disposal sites. The methods used here depend on the type of waste generated**.**

IV. **Waste Transfer or Transportation Component –** This involves the actual moving of waste material from source to disposal site. The mode of transport depends on the localities and the regulation requirement. Also, it depends on the nature of waste being transported**.**

V. **Waste Disposal Component** – This is the very final stage of waste management. It encompasses activities aimed at systematic disposal of waste material in safe way that have minimal or no impact to the environment.

2.2.3.1.Solid Waste Management System

This refers to a system that controls the generation, storage, separation at source, collection, transportation, processing, recycling and disposal of both organic and inorganic solid waste (Kreith, 2008). The aim is to reduce and eliminate adverse impacts on human health and environment and at the same time supporting economic development and high quality of life.

For the purpose of this study, solid wastes management systems was adopted as activities and administrative procedures that are involved in facilitation of the collection, source separation and reduction, storage, transportation, transfer, processing, treatment and disposal of solid waste.

Tchobanoglous and Kreith, (2002), describe management of solid waste as a very complex process which involves a series of multidisciplinary agencies and technologies. The technologies vary from the solid material collection and handling, transportation and storage and finally processing and disposal of these wastes. Accordingly, they identify various ways used for solid waste disposal as outlined below:

1) Reduce, Reuse, Recycle

Waste reduction, reuse and recycling methods are the most recommended and preferred options of waste management. These methods of waste management are beneficial to the environment by reducing and preventing greenhouse gases emissions, reduction pollutants release, conservation of resources, saving of energy and reducing the demands of waste treatment technologies. They also reduce the demand for landfill spaces (Heimlich et al, 2001).

2) Thermal Treatment

Thermal Treatment involves use of heat to treat the waste material. The processes under thermal treatment include:

i. Incineration

Under this method, the waste material is combusted in the presence of oxygen. The resulting products are water vapour, ash and carbon dioxide. The method is regarded as an energy recovery, where by, the heat energy can be used for heating purposes and also supply of electricity. This method can also be used to reduce the volume of the waste, as a result reducing the transportation cost and also with an added advantage of reducing greenhouses gases of methane.

In the modern world, incinerators use the high-tech scrubbers to remove the harmfully gases and automatically collect the ash in a tray, hence reducing the old-fashioned labour-intensive method of incineration. The heat energy released can still be used to turn the steam turbine hence generating electricity (UNEP, 1996).

ii. Pyrolysis and Gasification

The two processes are similar, the waste material (organic in nature) are decomposed by exposing them to high temperature and low oxygen. The difference between the two processes is that, gasification uses low oxygen while pyrolysis does not allow any oxygen at all. Gasification provides energy recovery without polluting the air (Tchobanoglous and Kreith, 2002),

iii. Open Burning

This implies the burning of unwanted materials in open air without passing through the stacks or chimney

The advantage is that it also reduces the volume of the waste material and hence eliminating the transportation cost. The disadvantage is that the process releases many pollutants which can be toxic and harmful to human health (Tchobanoglous and Kreith, 2002).

3) Dumps/Compositing and Landfills

Compositing may involve the preparation of refuse and degrading the organic matter waste in to bio fertilizer by aerobic micro-organisms. Sanitary landfills are designed to greatly reduce the effect the waste disposal poses to environmental quality and general public health. The land barrier acts as natural buffer. Clay soils are recommended because of the impermeable nature and in areas with low water tables.

Landfilling is a waste management system which involves covering the waste with soil or other material to prevent animals and scavengers from the removing the material the landfill area (Tchobanoglous and Kreith, 2002).

2.2.3.2.Liquid Waste Management System / Wastewater Management System

Liquid Waste Management Systems, which are sometime referred to as Wastewater Management Systems are those that involves systematic administrative procedures and practices / actions whose objective is to prevent discharging of pollutants to storm water or any water courses as a result of source generation, storage, collection, transportation or transfer and disposal of liquid wastes (USEPA, 2004). Liquid waste treatment process is grouped into three stages namely: preliminary which is physical, primary which is involves physical treatment and secondary which is basically involves biological treatment). Disinfection can be done before discharging to the environment. In addition, depending on the type of the wastes, a tertiary treatment may be required which is a more advanced treatment (USEPA, 2004).

i. Physical Treatment Process

This method involves removal of solids debris from wastewater by passing it through a series of screens with varying sizes. (USEPA, 2004)

ii. Biological Treatment Process

This involves use of bacteria and other biological organism in water for the sole purpose of consuming the organic matter wastewater. The process will result into new bacteria and other by-products. However, this process takes place in the presence of oxygen. The process can be accelerated by addition of oxygen in the wastewater to speed up the growth of bacteria and hence increasing the breakdown of organic matter (USEPA, 2004).

iii. Chemical Treatment Process

This involves the use of chemicals to change the wastewater material or the solid wastes inside the water. This may even ease the removal by physical means once they have been broken done. The chemical used may include; lime, alum or iron salts, among others. The chemical industry has over the years developed polymers which are more synthetic and inert in nature to improve the physical separation. They are normally used in the later stages of wastewater treatment to improve settling of excess microbiological growth (USEPA, 2004).

2.2.3.3. Gaseous Waste Management System

These are systems whose objective is to prevent causing hazardous impact to the environment from the generation, handling, collection, storage, transfer or transport and disposal of gaseous wastes (USEPA, 2004).

2.2.3.4.Waste Heat Management Systems

These are systematic administrative activities and procedures or ways that prevent the discharging of heat waste to the environment. The wastes heat sources include but not limited to fluid heating, drying, steam generation, metal heating among others. Waste heat management is an important aspect of energy conversion facilities which includes steam electric power facilities, liquefied natural gas facilities and coal gasification plants. Three important aspects of waste heat management are: the effect on the environment, the control and utilization of waste heat emissions (USEPA, 2004).

2.3 State of Waste Management in Kenya

The literature on Kenyan Tea waste management and other sectors is scanty with the exception of Nairobi County which dwells on household waste generation behaviour, performance description and causes and waste characteristics (Ikiara et al, 2004).

To achieve an integrated waste management i.e. an advanced concept of waste management optimization in an industry; a reliable data on the waste quantity and quality are required (Franke, 1999). Operation and planning of waste management systems depend on accurate data of waste quantities produced. The knowledge of waste types, qualities and quantities is essential for the planning of waste management systems, policy formulation and designing of appropriate control measures (Tipton et al., 1990).

There is a need to determine material recovery potential, waste generation sources, designing of process and collection tools, determination of physical, thermal and chemical properties of the wastes, and compliance with known regulations. Unfortunately, there is insufficient data on these wastes' aspect in Kenya. This is partly a consequent of poor coordination in the management which leads to missing of wastes data generation and composition or up to date records. Lack of data on waste quantities, qualities and compositions, decisions on equipment and landfills space and capacity, recycling or compositing methods and wastewater treatment ponds designs cannot be factually made. Therefore, estimation of the waste qualities, quantities and their characteristics is key in development of waste management strategies which are cost effective.

2.4 Waste Generation and Management in Tea Factories

2.4.1. Tea Waste Generation

Chowdhur, et al (2017) noted that waste is generated in tea factories during tea processing from the fiber portion of leaves which is removed and discarded. The waste also contains some tea leaves and dust. This is mostly solid waste.

Studies have been done by Jackson (2006) on waste management approaches in tea processing factories, and Oirere (2015), on state of waste management systems for tea factory in Nyamira County. Their studies observed that wastes are not only generated from tea processing fibers. They observed the following are categories of wastes generated in most tea factories:

i. Solid wastes as a result of tea fiber discarded during the tea processing stages
ii. The solid wastes that includes packaging sacks and bags used for packaging tea
iii. The solid metals, newspapers and other polythene bags
iv. The heat wastes generated as a result of steam production in the boilers
v. The liquid wastes/wastewater as a result of various cleaning processing that take place in the tea factories.
vi. Noise wastes generated in the factories

2.4.2. Tea Waste Management

Chowdhur, et al (2017), in their studies, indicated that tea factory wastes (discarded tea fibres, dust and left-over tea leaves) can be disposed of through various methods. They stated that, wastes can be sold or exported as poultry and fish feeds, used to separate bioactive chemical components, used as bio fertilizer and bio nutrients by burning.

They noted that tea waste is an important and huge by-product of tea factories and as such it should be utilized in an effective management program by factory owners.

Different types of wastes have different waste management system and wastes generated from tea factories are no exception. For instance, in a study done by Oirere (2015), the author found that, wastewater in a tea factory in Nyamira County is treated through lagoons before discharging them to the water course. The study also indicated that, solid wastes are managed through landfilling and thermal waste is management by lagging the steam pipes to reduce the loss of heat.

A tour to Mudete Tea Factory in Vihiga County under KTDA and Ngorongo tea factory private owned by Ngorongo Tea Company Limited in Kiambu County and a brief overview of the other 66 factories under KTDA showed that most tea factories in Kenya utilize the naturally aerated lagoon system for treating their wastewater.

Aerobic lagoons work in the presence of dissolved oxygen throughout its depth of the lagoon. They can either be naturally aerated or mechanically aerated. This type of lagoons is shallow in order to allow oxygen to penetrate, hence that mean large parcel of land is required (Miller *et al*, 2011).

1). Naturally Aerobic Lagoons: In this type, the oxygen penetrates the lagoons without the help of any mechanical devices for instance pumping. These types of lagoons are shallow in a nature and require large parcel of land as a result of being shallow. According to Zhang, (2001), the dimensions are typically of 1 to 2 feet deep and no more than 5 to 6 feet. By design, the volume is usually 4 to 5 times that of an anaerobic lagoon. (Miller *et al*, 2011)

2). Mechanically Aerated Lagoons: In these types of lagoons, the oxygen is added and mixed with help of mechanical devices that increases the degree of aeration. The depth of the lagoon can therefore be deeper compared to naturally aerated lagoon and hence reduce the pressure on land. Depending on the depth of the lagoon and extend of aeration, this type of lagoon can work as either anaerobic and an aerobic lagoon (Miller *et al*, 2011).

2.5 Waste Characterization Approaches

Wastes characterisation is simply a process in which different waste stream are analysed by composition. Characterisation of wastes helps to decide which treatment and disposal methods are to be employed.

Brunner & Ernst, (1986) states that; there are three methods in which the composition of wastes can be determined; 1). **Waste Product Analysis:** This approach involves, analysing the chemical composition of the waste products for various elements.**2). Market Product Analysis:** in this approach, the expected waste quantity from a product is determined from taking a materials balance.**3). Direct waste sampling and analysis:** in this approach, the particular waste stream is manually sorted into different waste type.

However, globally waste characterization practices are done using two approaches, by considering the following;

i. The form of the material (this involves the physical appearance of the waste material, i.e. as solid, liquid and gaseous).

ii. Analyzing the chemical composition of the material

iii. According to the pre-classification based on the code standards set by the relevant laws and regulations (i.e. hazardous goods and non- hazardous goods).

Furthermore, according to BOMA Quebec Task Force (2016), on waste management in order to establish the minimum standards required in a waste characterization, wastes can be classified into the four distinct categories based on the sources of waste, namely: 1). **Consumer Products**: these waste materials that come from everyday user consumer products and includes but not limited to food waste, plastics, packaging papers and containers. **2). Durable Goods:** These are goods and objects which last longer, these include and not limited to electrical appliances, computers, furniture, etc. **3). Hazardous Materials;** these are materials that are termed hazardous depending on the prevailing regulations. They may include but not limited to chemical products. **4). Construction/Renovation/Demolition (CRD):** These are waste material from resulting from building operations.

Classification of waste can also be by the path of disposal (either by compositing, recycling, incineration, onsite, or landfill) and the source of generation (industrial wastes, agricultural waste, commercial waste, or building demolition wastes).

2.6 Studies of Waste Management from Factories in the World and Kenya

Chowdhur, et al (2017), in their study on tea waste management in West Bengal, India, which aimed at finding out the type of wastes generated, the quality and quantities of the tea wastes and their proper management systems at tea factory. The authors utilized random sampling by selecting 20 out of the 30 factories in West Bengal, India. Both Primary and Secondary data were used. The authors collected data using questionnaires, interviews, observations and study photos. Their findings indicated that there was a lack of comprehensive and uniform guidelines towards tea waste management. Secondly, they noted that, the tea waste could be effectively managed by utilizing the waste as poultry and fish feed, garden manure and caffeine extraction.

Halder (2016), studied other methods of disposing of tea waste. This study aimed at characterization of tea waste and cooked waste as a potential feedstock for Biogas production in India. The author noted that some tea waste in combination with cooked waste can be utilized as an alternate feedstock to cow dung for production of biogas, a promising alternative energy source for the limited fossil fuels. The author carried out a detailed analysis of the tea waste to find out its suitable as a raw material for biogas generation. The moisture, volatile matter, carbon, and ash were described by approximate analysis. While carbon, nitrogen, potassium, phosphorous and hydrogen were described by ultimate analysis criterion. Furthermore, a morphological analysis of the wastes was done by scanning electron microscopy (SEM). The temperatures of the wastes were determined through thermal gravity analysis. The BOD and COD of the tea wastes were determined. He concluded that by using tea waste and cooked wastes the biogas production would be more compared to cow dung.

Oirere (2015), carried out a research on state of waste management systems for Nyansiongo tea factory in Nyamira County, Kenya. She utilized both primary data and secondary data in her study. The author observed that the wastes generated were not characterized; the quantities and qualities being discharged to the environment were not also known. The author also concluded that the wastewater treatment systems (especially the aerated lagoons) were not effective based on the BOD_5 levels of 101.1mg/L and COD level of 340mg/L against the National Environment Management Authority (NEMA) recommended maximum discharge levels of 30mg/L and 50mg/L respectively.

Chowdhur, et al (2017) noted that there was a lack of comprehensive guidelines on tea waste management. Furthermore, Chowdhur, et al (2017), focused on the fibre content tea waste at the factory. However, there are other wastes generated at the tea factory apart from those resulting from the tea leaves fibre. Halder (2016), also focused on utilizing the waste resulting from the tea leaves fibre. This study failed to identify other type of wastes such as thermal and liquid waste generated at the tea factory.

This study aimed at addressing the management systems of all types of wastes generated at the tea factory.

Oirere (2015), focused on all the type of wastes generated at the tea factory apart from those resulting from the tea leaves fibre. However, the author's focus is on a single study with emphasis on Tea Factories under KTDA. The findings of the study should not be used to generalize the state of waste management systems of all tea factories under KTDA and other privately-owned ones in Kenya. In order to profile waste management systems of tea factories in Kenya, more research in this field is required. This study therefore aims at evaluating the waste management systems of Maramba tea factory (which is a privately owned factory) in Kiambu County.

2.7 Evaluation of Waste Management Systems

Most waste management systems are not 100% effectively dealing with wastes, however, the objective of every single institution is to have its waste management systems effectively reducing the wastes impacts to environment and human health to recommended levels or not toxic. Evaluation of waste management systems provides the management, authorities and relevant stakeholders with accurate data on devising ways to improve the existing systems or choosing the better alternative systems in managing the wastes. The objective of every waste management systems is to be realistic, sustainable systems which are consistent with the national and international regulation and environmental policies.

Wada et al (2008), in their study to evaluate the wastes disposal systems in Japan, focused on the environmental impacts resulting from the wastes after passing through the disposal systems and the second technique used was the cost of the existing systems compared to the proposed new technologies systems with cost of disposal the waste included. The impacts to the environment and costs for the systems were determined using lifecycle assessment (LCA) and lifecycle cost (LCC) methods in a model city. They concluded that a choice of any particular waste management system will depend on the nature and type of the wastes. However, they recommended that all new technologies in waste management systems should be based on a cost estimate and the impacts posed to the environment.

Chung and Poon (1996), in the study evaluating waste management alternatives used a multiple criteria approach in their evaluation. Different wastes waste management methods were analyzed by use of Multiple Criteria Approach (MCA). The methods include; landfilling, waste to energy, compositing, and source separation. The advantage of multiple criteria approach is that it accommodates both quantitative and qualitative data, which gives a more subjective and implicit data for decision making.

Gabler (2014), describes Benchmarking which is an evaluation or assessment tool as a continual comparison of products, services, methods, or processes to identify performance gaps, with the goals to learn from the best with a note on possible improvements.

2.7.1. Evaluations of Waste Management Systems in Tea Factories.

Tea factories produces different types of wastes as earlier stated in section 2.4 of this report. This therefore requires different management systems depending on the waste type.

a. Evaluation of Wastewater Management Systems.

The wastewater management systems for most of Kenya Tea factories are natural aerated lagoons (Jackson, 2006). In order to evaluate the effectiveness of the wastewater management systems for tea factories, the various parameters which give an indication of the quality of water are analysed. These parameters include: BOD_5, COD, EC and pH. pH is an indication of the acidity or basicity of water. Electrical conductivity, (EC) is an indicator of the total ionized constituents of water. BOD_5 at 20° is a measure of the biodegradable organic matter in the wastewater. BOD value gives an indication of the amount of organic carbon. Oxygen depletion is as a result of adding wastes with high value of BOD to aquatic ecosystems. The higher the BOD of the source wastes the greater the polluting power of that waste. The values of these parameters are compared to the standard allowable limits by NEMA in Kenya.

Metcalf et al, (2003), in the book Wastewater Engineering, the authors estimate the amount of wastewater from the amount of water consumed for domestic and industrial purposes. The authors noted that 80-90 % of the water consumed for domestic consumption is wastewater. 80% of the water usage in paved industrial place is wastewater.

b. Evaluation of Solid Wastes Management Systems

The solid wastes disposal systems in most of the tea factories in Kenya are done by landfilling and compositing. However, other tea factories do not have a proper solid wastes management system.

Design parameters of landfills must be evaluated to check their compliance with standards designs. According to Chung and Poon (1996), alternative methods of solid wastes can be evaluated in terms of life cost and lifecycle of each system.

c. Thermal Wastes Management Systems in Tea Factories

The source of energy in most tea factories including the Maramba Tea Factory in Kenya is firewood. The boilers are used in most of these factories. Thermal wastes occur as a result of losses of heat through conduction, convection and radiation. To evaluate the thermal wastes systems, the boiler efficiency is analyzed and compared to the standard recommended efficient.

For this assignment, the boiler heat loss indirect method was used to determine the boiler efficiency. According Mallick (2015, the total heat loss supplied to the boiler by fuel is not fully utilized. He argues that various losses take place in the boiler. He applies the indirect method for determining the boiler efficiency. Accordingly, the data required for the calculation of the boiler efficiency using indirect method was: Ultimate analysis of fuel (H_2, O_2, S, C, moisture content, ash content), Percentage of oxygen or CO_2 in the flue gas, Flue gas temperature in °C (Tf), Ambient temperature in °C (Ta) and humidity of air in kg/kg of dry air, and GCV of fuel in kcal/kg.

2.8 Legal Framework

2.8.1. National Legal Framework

2.8.1.1. Environmental Management and Coordination Act (EMCA).

Environmental legislation in Kenya is provided under EMCA. It was enacted as a framework law and contains provisions on environment management systems on the proposed and on-going projects and activities in Kenya. Under EMCA a number of institutions were created. The following are subsidiary legislation under EMCA.

i. Waste Management Regulations, 2006

The waste Management regulation of 2006 comprehensively covers the management of various types of waste in Kenya. It requires a waste generator to segregate the waste by type, transport using a vehicle approved by waste transport license issued by NEMA before disposing them in an environmentally friendly manner. The disposal facility must also be licensed.

ii. Water Quality Regulations 2006

The regulations were enacted in 2006. It applies to water used for: drinking, fisheries, recreational industrial, agricultural and wildlife and other purposes. The same regulations also provide for guidelines on effluent being discharged to the environment from industrial activities.

Table 2-1: NEMA Standards for Effluent Discharge to the Environment

Parameters	**Maximum permissible levels**
Suspended solids	30 mg/L
Total dissolved solids, TDS	1200 mg/L
PH	6.5-8.5
Oil and Grease (mg/L)- where conventional treatment shall be used	Nil
Biological Oxygen Demand, BOD_5^{20} .	30 mg/L
Chemical Oxygen Demand, COD.	50 mg/L

Source: EMCA 2006

2.8.1.2. Water Resource Authority (WRA)

WRA is a state corporation which was established under section 11 of water Act 2016. It was operationalized in 21 April 2017. It was formerly known as Water resource management authority (WRMA). The Authority is mandated to regulate and manage all water resources in an effective, equitable and sustainable manner.

Table 2-2: WRA Standards for Effluent Discharge to the Environment.

Parameters	**Maximum permissible levels**
Suspended solids	30mg/L
Total dissolved solids, TDS	1200 mg/L
PH	5-9
Oil and Grease (mg/L)- where conventional treatment shall be used	Absent
Biological Oxygen Demand, BOD_5^{20}	30 mg/L
Chemical Oxygen Demand, COD.	100 mg/L

Source: WRMA 2006

2.8.2. International Standards by International Bodies.

The bodies include: United States environment Protection Agency (USEPA), Central Pollution Control Board (CPCB), World Health Organization (WHO) and Food Agriculture Organization (FAO) among others.

Table 2-3: Wastewater Discharge Standards by CPCB

Parameters	**Discharge limits**
PH	6.0-8.0
Total suspended solids TSS	100
Oil and Grease	10
Biological Oxygen Demand, BOD_5^{20} (mg/L)	30
Chemical Oxygen Demand, COD (mg/L)	250

Source: CPCB (2008)

Table 2-4: Wastewater Discharge Standards by WHO

Parameters	**Discharge limits**
PH	6.0-9.0
Total suspended solids TSS	30mg/L.
Oil and Grease	15mg/L.
Biological Oxygen Demand BOD_5^{20}	30mg/L
Chemical Oxygen Demand, COD	40mg/L.

Source: WHO (2006)

2.9 Tea Production Overview

According to Yamammoto et al (1997); tea is defined as an evergreen plant of the Camelia genus. It is stated that, there are about 200 different species of tea plant around the world. It is one of the non-alcoholic beverage drinks worldwide and has been gaining popularity as a 'health drink' in view of its purportedly medicinal value. It serves as a morning drink for nearly two-thirds of the world population on a daily basis. Globally, the leading five tea producing countries accounts for over 77% of the total tea produced. Kenya is third largest producing tea country annually after China and India. According to TBK, (2015); the country produced 444.8 metric tons of tea in 2014.

Tea production makes significant contribution to Kenyan economy. It is among the leading cash crops.

Black Crush, Tear, Curl (CTC) tea is the major product being produced by Kenya Tea factory. The international unit market for black CTC tea has stagnated, hence a need for researchers to offer the country a diversified product field and quality improvement for tea production. Currently, the research and other tea development outputs have largely been developed by the Tea Research Foundation of Kenya (TRFK 2014). Tea was introduced in country by a European settler G.W.L Caine in 1903 from India. Kenya has grown into a formidable world tea producer over the years.

In Kenya, tea is grown at high altitude regions of about 1800 metres and 2700 metres above the sea level. The annual rainfall ranges from 1800mm to 2500mm. These areas lie at the west and east of the Great Rift Valley (Owour et al 2008).

2.10 Tea Processing and Waste Generated

i. Leaf Collection

The manufacturing process starts the moment tea leaves are plucked. The plucked leaves start to wither and at this point inadequate handling and transport would result in bruising of the leaves, heat development and initiation of uncontrolled fermentation leading to reduced quality. Care should be taken when transporting green leaf to avoid heat accumulation and bruising. The use of suspended gunny sacks about 10kg of green leaf usually allows enough ventilation to avoid heat accumulation during transport from the field to the factory, provided the leaf does not overstay in the field or in the transport vessel.

Transportation to the factory can be in any other convenient containers if tea is transported within an hour. The standard of plucking also affects the quality of produced tea. A finer plucking that is two leaves and a bud standard would produce higher quality tea that will fetch a better price. It is important to have a constant supply of leaf with consistent plucking standard so that the factory does not have to change the manufacturing conditions (TRFK, 2002). The wastes generated during this process is tea leaves that falls off during unloading to the troughs for withering process

Plate 2.1: Leaf collection and transportation

Source (Author)

ii. Withering

After the tea leaf is plucked from the tea plant, it naturally starts to wilt. However, in the factory the leaves withering are controlled. The objective of controlled withering is preparation for further processing. This is done by reducing the leaves moisture content and subsequently allowing for the development of the leaves aroma and flavour compounds.

Withering processes is not much understood but it forms the basis of black tea processing. Withering is presumed to occur after the freshly plucked shoots are placed in the withering trough and air is blown through them for 14 to 18 hours. During this process, most noticeable changes is moisture loss which is accompanied by cell wall permeability changes which make subsequent maceration easy. This process of moisture loss and cell wall permeability changes is called physical wither (TR 2002)

However, less obvious is the chemical wither. This starts immediately the leaf is detached from the bush and chemical reactions involved in senescence start. The chemical wither reactions include changes in the activity and nature of polyphenol oxidase (the enzyme responsible for turning green tea leaf to brown- black) hydrolysis of terpenoid glycosides to release terpenes, breakdown of proteins to amino acids, hydrolysis of lipids to free fatty acids, the breakdown of carotenes to simple terpenes. Although these changes may affect black tea aroma, they also affect plain black tea quality parameters. Chemical withering is mandatory for production of high quality black tea. However, it is very difficult to control chemical wither duration in a commercial factory processing situation. Optimal chemical withers vary from 6 to 20 hours. Shorter chemical wither durations produce green and harsh black teas, while longer withering durations results in dull black teas with low sensory evaluation (TRFK, 2002)

In Kenya plain teas are produced during peak crop periods while flavoury black teas are produced mainly from the clonal leaf from some areas of the country during the slow growth season. Plain teas were presumed to benefit only from physical withering. However, it is now known that both plain and flavoury black teas are affected by physical wither. Hard physical withers (high moisture loss below 72% moisture content) enhance the quality of the production of the flavoury teas. However, for plain teas the hard-physical wither reduces the leaves of some plain tea quality parameters like theaflavins, brightness and thearubigins. Thus, plain black teas benefit from controlled physical wither, the quality actually deteriorates when too much moisture is lost from the leaf (TRFK, 2002)

Physical wither enhances factory throughput. The softly withered leaf is bulky and this slows down rotorvane output, and dryers may not cope with excess moisture in the leaf. Consequently, withered leaf should have up to 72% moisture content if the dryers are to give optimum throughput.

During periods of increased tea production, many factories usually face constraints in processing especially in the withering section. Studies have shown that two-stage withering technique where chemical and physical withers are done at distinct stages make black teas with similar quality as black teas made through conventional one- stage withering technique where physical and chemical withers are don concurrently. However, in a two-stage wither, chemical wither must be done before physical wither and during the process, the black tea quality can be enhanced by using cold air to achieve physical wither. This knowledge has led to development of tanks which occupy less space but hold more leaf and use less electricity as suitable vessels for chemical wither. Where tanks are not installed, factories can alternate over-loaded withering troughs with normal loads.

Upon achieving chemical wither; the normal-loaded troughs can be subjected to forced physical wither using high speed air current. After physical wither has been achieved the leaf is removed for maceration, while the leaf in the over-loaded troughs is subdivided into those emptied troughs then subjected to forced physical wither. This process allows the factory to hold up to 35% more leaf in the factory than it could under traditional trough withering system.

The constraint in withering space is more acute during peak crop seasons when the black teas produced are generally plain. Such teas can be manufactured without quality loss if chemical withering time would permit factories to start processing early and thus create extra processing time. Additionally, the same enables the factory to use one withering trough more than once a day, thus enabling the factory to hold more leaf

Since leaf processed during tea crop periods produces plain black tea, and because for such teas softer withers make superior teas, factories which can cope with soft withers without suffering reduction in throughput at the rotor vanes or dryers as a result of some engineering modifications, can use tank wither only. In such manufacturing processes, all moisture is removed during drying. Due to increased surface areas macerated leaf, energy may be more efficiently utilised as moisture losses through evaporation are achieved faster. Economic survey has shown that it is more cost effective to install some withering tanks in factories than to build new factories or expand old factories with traditional withering technique (TRFK, 2002)

The wastes associated with this process are minimal as a result of broken hessian nets or holes on the troughs.

Plate 2.2: Leaf withering
Source (Author)

iii. Leaf Maceration

The teas are bruised or torn in order to promote and quicken fermentation. Almost all tea produced in Kenya is by unorthodox maceration, usually using one rotorvane and three Crush, Tear and Curl (CTC) machines in series or on rotorvane and Lawrie Tea Processor (LTP). This is most suitable because the teas produced are mostly plain teas, and it is not necessary to preserve all delicate flavour components

Teas made by unorthodox maceration are generally much smaller in particle size than those made by traditional (orthodox) maceration, and they give brighter, brisker and more coloured infusions. This is also of advantage to the tea market which has moved towards tea bags and “quick brew teas” over the last twenty years. It seems probable that more and more teas from Kenya would be processed using unorthodox techniques with only a small percentage of specialist tea utilizing orthodox methods of maceration (TRFK, 2002)

The object of the maceration step is to mix up the catechins and the enzymes in the tea leaf tissues, and to allow free access of oxygen. This allows fermentation to proceed, producing theaflavins and thearugins respectively. In delicate flavoury teas, other chemical reactions may be of equal importance, but this is not thought to be the case in Kenya plain teas. Thus, it follows the rapid, severe maceration would cause maximum leaf disruption and lead to a finished product that has the characteristics desired of Kenya tea

The first step in maceration is usually the use of a rototrvane. It consists of a cylinder containing a rotating central shaft. Spiral vanes on the shaft propel the leaf along the cylinder, and distortion and twisting of the tea leaf tissues occur by rubbing and shearing action of the leaf against projections coming out of the cylinder casing. This whole process is designed to disrupt the cellular structure of the leaf

After rotorvane maceration leaf usually passes through a series of CTC machines which consist of two rollers rotating at different speeds in opposite directions. The surface of the rollers is serrated and their rotation in different directions produces more leaf cellular disruption by crushing and stretching and cutting it into small particles.

The LTP is an alternative to CTC and maybe used in conjunction with a rotorvane. It is based on the principle of hammer mill, with the rotating hammers disintegrating the leaf very quickly. In some factories this is considered sufficient for fermentation, but in others an extra cut with a CTC, usually in the middle of fermentation is thought to be an advantage.

The next result of these maceration processes is to produce small particles of leaf and stalk that have had their internal structure broken down to allow air easily reach the internal structure of the leaf, leading to even fermentation. The macerated leaf is known as dhool.

The waste generated from the process is mainly rejects dust and stalks/ fibres.

Plate 2.3: Leaf Maceration

Source (Author)

iv. Fermentation/Oxidation

Fermentation requires allowing oxygen to permeate the macerated leaf so that the endogenous catechins can be converted through enzyme catalysed reactions to theaflavins and thearubigins. Some of the aroma compounds are also formed during fermentation.

Initially, the procedure was for leaf to be left in thin layers on slabs, so that air would penetrate naturally. However, oxygen requirement of leaf macerated by unorthodox means is much higher than that processed by orthodox means. This leads to use of air forced through the fermenting dhool to increase the oxygen level available for fermentation. The air also helps cool the dhool, as the chemical reactions of fermentation generate heat (TRFK, 2002)

The most fermentation system in Kenya utilises George-Williamsons (G.W) trolleys. These have perforated metal base with a plenum chamber underneath. After loading with dhool the G.W trolleys is then attached to a duct with humidified air forced through its plenum chambers and hence through dhool, thus aerating the fermenting leaf. Since the air is humidified, the fermenting dhool does not dry out. It is possible that humidification could be dispensed with at the later stages of fermentation, causing a slight loss of moisture from the dhool, and reducing the load on the dryer. At these later stages there are fewer chemical reactions generating heat and oxygen demand is lower.

The second effect of humidification is that of temperature control, use of correct temperatures for fermentation is very important. The reason for this lies in the nature of the biochemical reactions producing theaflavins and thearubigins. Increasing the temperature does not produce the same result in a shorter time. Higher temperatures favour the production of thearubigins, thus producing a strong coloured tea that can easily turn out flat and muddy. Lower temperature favour the production of theaflavins, higher flavour index and brighter coloured teas. Thus temperature control can change the type of tea produced.

The fermentation of dhool in deep fermenting beds can easily lead to the formation of 'balls' of dhool, which in turn lead to uneven fermentation. This has resulted in many factories using a mild-fermentation ball break, although doubt has been expressed as its usefulness. While there is often no detectable difference between teas that have or have not received such ball break, it is still a useful precaution for those times when processing conditions are not ideal

A more recent development is the use of continuous fermentation machines. There are a number of different designs, but the three basic types include:

The moving belt fermenter- Dhool is fed onto the first of a series of variable speed moving belt (usually 3 to 4), usually humidified air blowing through. Transfer from one belt or form one part of the belt to the next can be accompanied by ball-breaking, and fermentation time controlled by the speed of the belt.

Trough fermenter (Linsay fermenter): The dhool is fed into a trough and moved along by longitudinal or transverse rotating screws or vanes. The turning of the dhool allows aeration and also prevents ball formation

Fixed bed fermenter: The dhool is fed into a trough a perforated base plate through which air is blown. The dhool is then mechanically dragged along the length of the trough.

The waste produced from the process is the fermented liquor

Plate 2.4: Fermentation / oxidation

Source (Author)

v. Drying

Drying stops the fermentation process and produces stable product with low moisture content which can be can be safely shipped and for storages purposes. Changes do occur in black tea after drying, but they are small and have negligible effect on tea quality if drying is done well. Drying tea involves exposing the tea to the flow of hot air blown in the drying chambers. Traditionally in a conventional dryer the system is designed such that the driest tea is exposed to the air first and the wettest tea (straight from fermentation) last. This is usually achieved by having the tea pass on a belt through the same stream of air 4 to 6 times, with the wettest tea farthest from the air inlet. This allows the maximum utilisation of the air, but recycling is not possible because of moisture pickup (TRFK, 2002)

A recent development in drying technology is the advent of the fluid bed dryers. In this form of drying the tea enters a horizontal tunnel, the base of which is a perforated plate. Hot air is blown vertically through the plate, and the dhool forms a fluid bed, it is suspended in a fluidizing hot air. This not only gives rapid, even drying, but a combination of the air pressure and decline in leaf density forces the drying tea along the tunnel, thus removing the need for moving tray. There are various advantages of this system; moving parts are few leading to easier maintenance. The exhaust air from the end of the tunnel can be recycled at the beginning of the tunnel, thus saving on fuel. Considerable fibre can be extracted during drying using a cyclone. Finally, the tea produced has a greater bulk density; therefore, more mass can be packed in a standard container. As shipping cost depend on volume, not weight, shipping costs are reduced. Fluid bed dryers are slowly replacing conventional dryers in the Kenya tea factories

The major source of energy in Kenya tea factories is wood fuel. However, it is possible that a considerable proportion of energy can supplied by solar energy collectors built into factories. This would release land currently used for fuel wood for productive purposes.

The possible wastes at this stage of drying are heat losses.

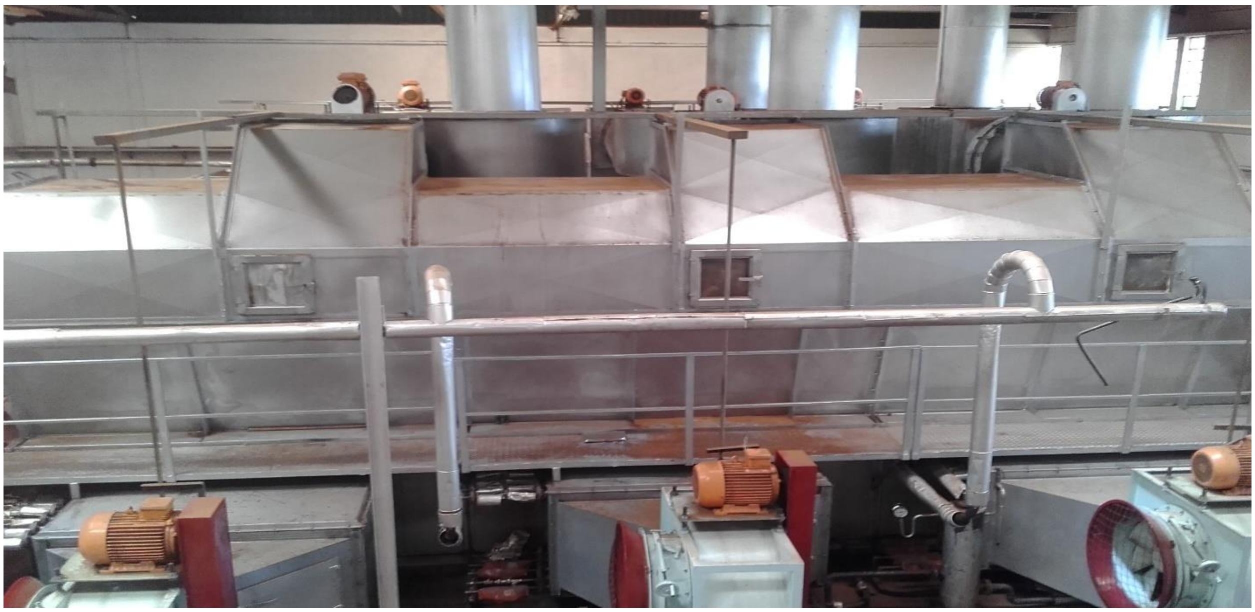

Plate 2.5: Drying

Source (Author)

vi. Sorting

After drying, the fibre is removed from the tea before it is graded by size. The fibre is removed by conveying teas on electrostatic fibre extraction rollers. This enhances the tea value and quality. Main grades, which are also called primary grades and comprises of 85-95% of the tea are fibre free, sold at much higher prices than fibrous off grades. The grade distribution as ratio of primary to secondary grades, which affects the total income of the factory is heavily influenced by the original plucking standard, with coarser plucking leading to more secondary grades. The size distribution can also be manipulated by adjustments of CTC settings so that the factory maximizes on the grades it sells best (TRFK, 2002)

The primary tea grades include:

i. Broken Pekeo 1 (BP1),

ii. Pokeo Fannings 1 (PF1)

iii. Pekeo Dust (PD) and

iv. Dust 1(D1)

While the secondary tea grades include;

i. Fannings 1 (F1) and

ii. Dust and Broken Mixed Fannings (BMF).

The waste generated from the process is mainly rejects dust and stalks (fibres)

Plate 2.6: Sorting

Source (Author)

vii. Packaging and Shipping

Most tea is transported from the producing country to the consuming country which may be far. The packaging must be designed to maintain the quality of the tea during transportation of more than three months. The two major factors to be considered in designing the packaging material are the prevention of moisture uptake (to avoid mould growth) and to prevention of taints

Traditionally, this has been achieved by the use of wooden tea chests lined with aluminium foil. There are however, moves in various parts to replace these chests. The chests are expensive and non-reusable wooden containers which consume large amount of wood in their production.

The replacement of the tea chest is polyethylene or aluminium foil lined multi-wall paper sack. The sack is an effective barrier to moisture and taint, and can be transported in containers. The sack also costs less than half the price of a tea chest. It is also possible that sacks can be used with slip-sheets, thus allowing more tea to be shipped per container. The usage of this system could result in a considerable saving in packaging costs, especially is tea is containerized at the factory

Plate 2.7: Packaging

Source (Author).

Figure 2.1 showing the schematically diagram on the processes involved in tea processing, and the type of waste generated at each stage of the processing.

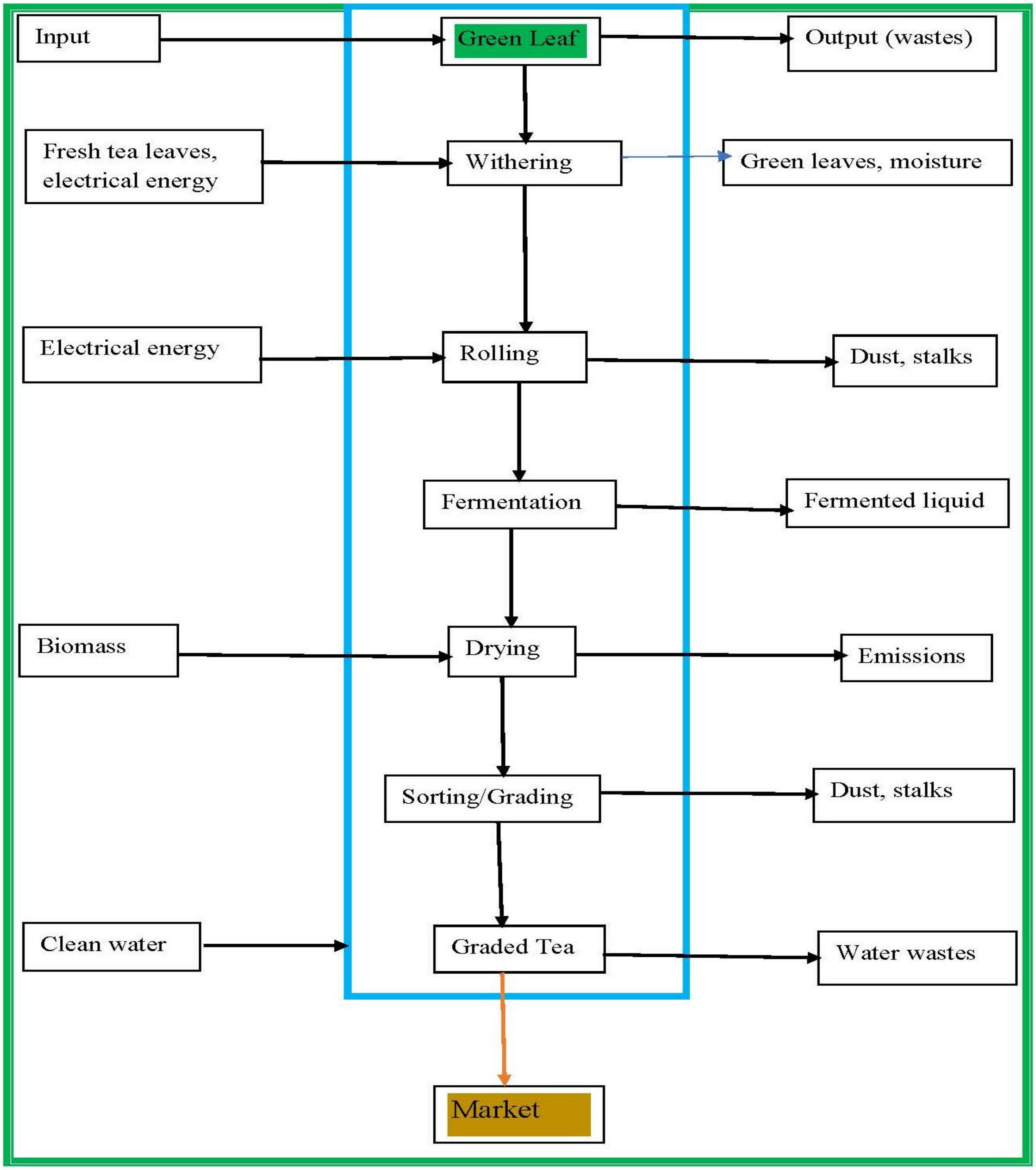

Figure 2-1: Schematic diagram for Tea Processing and Waste generated

Source (Author)

2.11 Tea Industries in Kenya

In Kenya, tea is mainly grown in the following areas; Bomet, Kericho, Nandi, Kiambu, Thika Muranga, Maragua, Nyambene, Sotik, Kisii, Nyamira, Meru, Nyeri, Kerinyaga, Embu, Nakuru,Kakamega, and Trans-nzoia.

The common types of tea products in Kenya are Black CTC tea and Instant Tea. Black Tea is produced by Cut, Tear and Curl method. According to Maramba Tea Factory Management, they manufacture Black CTC tea, which makes it similar to most Tea factory in Kenya. A similar study done by Oriere in 2015, showed that Nyansiongo Tea Factory also produces black CTC tea which. Most of the 66 factories under KTDA, produce the black CTC tea, and have similar tea processing stages as Maramba Tea Factory which is a privately-owned factory.

A tour to Mudete Tea Factory in Vihiga County under KTDA and Ngorongo tea factory private owned by Ngorongo Tea Company Limited in Kiambu County showed they have similar wastes generation with black Tea production as in Maramba Tea Factory. It can therefore be said that Maramba Tea Factory is a typical tea factory in Kenya.

2.12 Factory Waste Management in India

Implementation and formulation of rules and regulations on pollution prevention and control in India is done by Central Pollution Control Board (CPCB). CPCB came up Minimal National Standard (MINAS) in respect of the liquid wastes and emissions for Tea Processing Industry (CPCB 2008).

Factory waste is categorized into solid waste; wastewater and air emissions. In India, the waste emanating from tea are used as fertilizer and for producing other by products, which includes; Pigments, Caffeine, Polyphenols, Animal feeds among others.

In India, to manufacture 1 kilogram of Black Tea, requires 4.5- 5 kilograms of green tea. This means 1 kilogram of green tea, manufactures 0.22kilogram of black tea, out of which, 2% of black tea is solid waste which cannot be reused and 0.3% of wastes which can be recycled. To manufacture 1kilogram black tea on an average 4.5-5.0 kilogram of green is required. Alternatively, it may be noted that 1 kilogram of green tea produces nearly 0.22 kilogram black tea. The total solid waste which can in the process is 2.0% of the black tea produced, out of which only 0.3% of this waste is. For instance, to produce 800 tons of Black CTC tea annually, 16 tons of wastes are generated. (Masuskar, 2009). Figure 2.1 shows wastes generation and utilization in India.

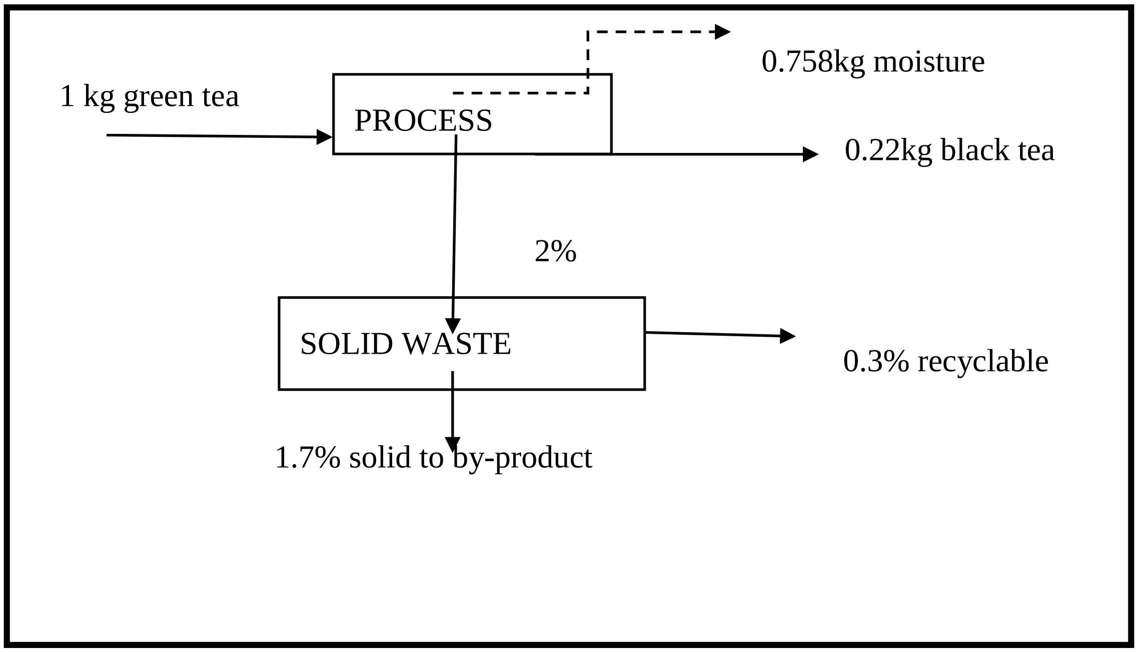

Figure 2-2: Waste generation and utilization in India.

2.13 Waste Management Challenges

Though there have been various studies done on waste management in tea factories in India, fewer studies have been done in Kenya.

The state of the general waste management systems of tea factories in Kenya remains unclear because of scanty documented research on various wastes. The characterisation of wastes is not done and hence there is no factual data on which the relevant stakeholders can make policies on. The quantities and Qualities of wastes generated is not known and these wastes find its way to the environment without its impact level being determined.

Furthermore, the focus has majorly been on municipal solid wastes management, thus neglecting other agro-industrial waste generating industries and factories.

Having very few studies done in tea factories, generalization can be relied upon for the whole tea industries in Kenya.

2.14 Conclusion

Tea wastes are generally characterized as Solid, Liquid and Gaseous Wastes which can be further be aggregated as either hazardous (toxic) or non-hazardous (non-toxic wastes). Waste management systems are classified according to the type of wastes; hence we have solid. Liquid and gaseous wastes management systems respectively, accordingly the effectiveness of a waste management system is based on clearly and accurate collected data on the type, quantity and quality of the wastes themselves.

According to Brunner & Ernst, (1986), Wastes characterizations are either by Waste Product Analysis, Market Product Analysis and Direct waste sampling and analysis.

Most waste evaluation techniques are focused on the environmental impacts resulting from the wastes after passing through the disposal systems and the cost of the existing systems in comparison to the proposed new technologies systems with cost of disposal the waste included. The impacts to the environment and costs for the systems can be determined using life cycle assessment (LCA) and life cycle cost (LCC) methods. Multiple criteria analysis (MCA) can also be adopted, which involves both qualitative and quantitative data.

In Kenyan, the state of tea waste management is scanty with the exception of Nairobi County which dwells on household waste generation behaviour, performance description and causes and waste characteristics (Ikiara et al, 2004). Much focus has been on municipal solid wastes. In addition, a similar study done in 2015 in Nyamira County at Nyansiongo Tea Factory which is owned by KTDA. A single study can be should not be used to justify all waste management systems in Kenya. Many studies are hence required both privately owned one's tea factories and KTDA owned factories to provide a realistic waste management situation in our Tea processing factories in the country.

The Indian comparison was relevant in the study because both studies focused on black tea production with similar tea production stages.

The study focused on waste types generated at the factory, the quantities and also analysis of the various management systems at Maramba Tea factory (which is privately owned).

The information will go a long way in providing the relevant stakeholders with factual data to help them redesign and or improve the existing waste management system. In evaluating the waste management systems, benchmarking method was adopted.

3. MATERIALS AND METHODS

3.1 Study area

The study was carried out in Maramba Tea Factory in Kiambu County. Maramba Tea Factory Ltd is located in Limuru/Banana Rd, Karuri, 1412-00217 Limuru, Kenya. Maramba Tea Factory is a black tea factory. The factory was founded on 14 March 2002 and is fully owned by Maramba Tea Company Limited. It is located along the Limuru/Banana Road, Karuri in Kiambu County on a geographical coordinate which extends from latitude 1°8'063" and longitude 36°42'230" to latitude 1°8'103" and longitude 36°42'284", with an elevation of 2074.16 m above sea level (asl). It is 3.5 km from, Limuru Country Club. The factory has a production capacity of around 72,000 kilograms of green leaf per day, equivalent to about 18,000 kilograms of black tea per day. This represents 75% of the total green leaf result in waste generation per day. Its annual production capacity is around 4,320,000 kilograms of black tea. The factory receives green leaf from the farms of the Maramba Tea Estates. To supplement on this leaf, the factory has subcontracted small scale farmers (out growers) to supply leaf to help optimize the factory's design capacity.

The area has a mean annual rainfall of approximately 904.2 mm with the following weather conditions: a mean annual temperature of 21.6ºC, an average daily wind speed of 7.8 mph and an average Annual Relative humidity 62.2%

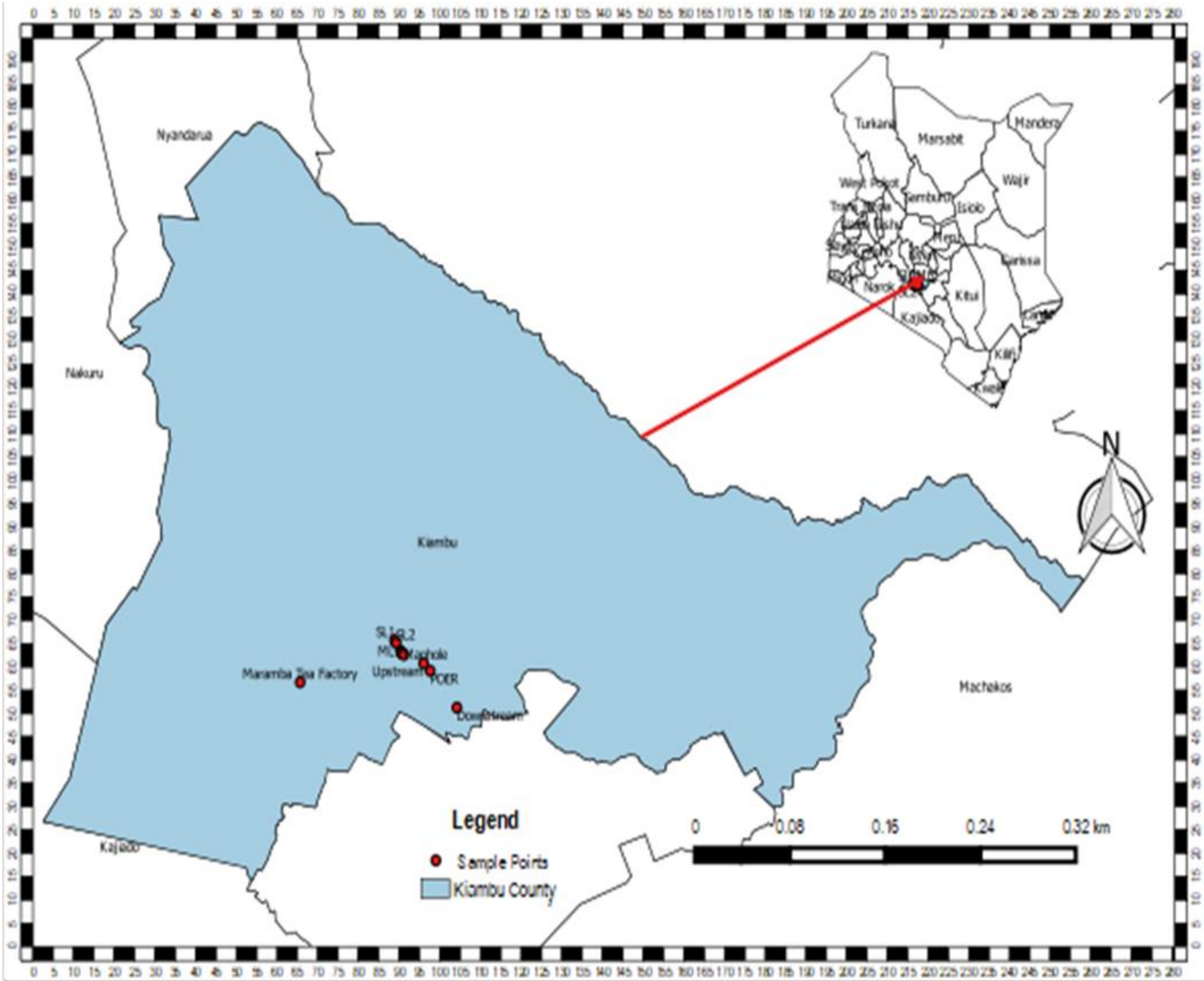

Figure 3-1 Study Area Map
The maps show the wastewater sampling points in Tea Factory located in Kiambu county Kenya.

3.2 Data Collection

3.2.1. Data Type

The data types utilized for this study were both primary data and secondary data. The secondary data was obtained from literature and studies done in the past while primary data were collected from Marimba Tea Factory.

3.2.1.1. Primary Data

The primary data include:

i. The type of wastes generated at the Maramba Tea Factory through observations

ii. The quantities of wastes generated at the factory through measurements

iii. The qualities of wastewater generated at the factory through laboratory analysis of the samples

3.2.1.2. Secondary Data

The secondary data were obtained from the already existing data, both published and unpublished data. These data included:

i. The amount of green tea processed at the Maramba tea factory for the study period. This was obtained from the Maramba Tea Factory management records.

ii. The standards values set by various bodies for acceptable wastewater qualities to be discharged in the environment. This was obtained from various published sources including government.

iii. The standard acceptable wood fuel boiler efficiency. This was obtained from published sources.

iv. The ultimate analysis of the wood fuel for wood fuels. This was obtained from published source by Gravalos et al (2016).

3.3 Sampling Techniques and Data Analysis

Purposively and convenience sampling techniques were utilized when choosing the wastewater sample points in the lagoons and the upstream and downstream of the river. The sample techniques were decided based on the fact that, the sampling areas were already predetermined, i.e. the entry to the lagoons, the lagoons, river upstream and downstream.

27 samples of wastewater were collected from the entry point of the lagoons to the downstream of the river. For each wastewater parameter (BOD, COD, EC and pH), three different sample of wastewater was analysed for each point of sample collected. 4 sample of wood was also collected to analyse the Gross calorific value of the wood fuel used.

The analysed wastewater data were subjected to statistical analysis by use of ANOVA single factor tool. This model helped in determining whether there is a statistical difference in waste quality as they moved through various waste management systems before being discharged to the environment.

3.4 Characterization of the waste generated during tea production at the Maramba Tea Factory.

To achieve the above specific objective; classification of the types and sources of wastes generated during tea production process at Maramba Tea Factory was done mainly through observations.

The following procedure was carried out: Observations and characterization of wastes generated was made at different stages of tea production process. The stages included; tea collection, withering, leaf maceration (CTC), fermentation/oxidation, drying, sorting and packaging.

The wastes were classified as either organic waste or inorganic waste i.e. plastic, paper and cardboards, glass, metals, wood, or textile as, liquid wastes and thermal wastes summarized in Table 3.1.

Table 3-1**:** Waste characterization

Main material wastes	**material category**
Organic waste	• Green leaf
Inorganic waste	• Polythene papers and other sacks
Detailed wastes classification	
I. Solid Wastes	
Paper	Newspaper, magazines, writing paper, packaging paper
Cardboard	Folding boxes, corrugated cartons
Carton container	Drink cartons
Plastics	• Polyethylene Terephthalate (PET)
Glass	Glass: Bottles and jars
Metal	• Aluminium cans
Yard waste	Leaves, grass, chopped trimmings
Textile	Pieces of cloth
Wood	Small pieces
Rest	Rubber, leather, medical waste, rock, dust, composite,

Main material wastes	material category
II. Liquid wastes	Due to the major and minor cleaning in the factory
III. Thermal wastes (Gaseous)	Generated from heat losses from the boiler and steam pipes

At the end of waste characterization at Maramba Tea Factory as illustrated in Table 3.1, the major categories of wastes considered were:

I. Solid wastes

II. Liquid Wastes

III. Thermal Wastes

3.5 To Analyse Waste Management in the Maramba Tea Factory

In order to effectively analyse the waste management in Maramba Tea Factory, the quantities of the solids waste and quality of wastewater generated were determined. The data were collected for a study period of five (5) Months. The time period was based on the available resources to collect the data. This also enabled the collection of enough data to give reasonable view of the waste generated at the factory since they vary depending on the amount of clean tea processed as shown in Appendix 1 section 1.9 of this study report.

3.5.1. To determine the quantities of solid wastes, wastewater and thermal wastes at the factory

I. Solid Wastes

Equipment and Material: They include: Weighing scale: to weigh the waste, Plastic bags, Gloves: to handle the waste, Dust masks, Disinfectant to clean sheet and equipment, Paper towel, Pencils, Labels, Knife, Scissor, Safety boots and dustcoat

The solid wastes were collected at the different stages and as classified earlier, their weight was taken and recorded separately.

II. Liquid Waste

The amount of wastewater generated during the tea production process was approximated from the amount of water used. According to Metcalf et al, (2003), 80% of the water usage in paved industrial place is wastewater.

The readings of water consumed were obtained from the water meter readings for water used in minor daily cleaning and major weekly cleaning respectively. The values were recorded for the period of project study.

III. Thermal waste

The following apparatus were used: Analogue balance, Ceramic crucible, stop watch, Ammeter, Stirrer, Oxygen and Oxygen cylinder, Digital thermometer, firing switch, Fuse wire, Cotton wool, measuring beaker 3000ml and measuring cylinder 100ml

Procedures

The calorimeter was dismantled, cleaned and the crucible dried. It was emptied, weighed and then with approximately 1gm of furnace oil, the fuse wire was then installed in the form of coil and a piece of cotton wool was attached to assist in ignition. 10ml of water was added in the bomb to saturate the space inside the bomb and reassembled carefully not to spill the fuel. The bomb was charged with 25 atmospheres of oxygen and the leaks was checked before immersing it to the water and then drying it. 1750ml of water was added of water in the calorimeter and the bomb. The thermometer and the stirrer were installed and the stirrer started for 3 minutes in order to equalize the temperature in the bucket. The first 5 readings were taken at an interval of 1 minute which was used to determine the heat exchange in the jacket. The firing switch was then closed for an instant and then released as soon as the indicator ammeter went back. The temperatures were recorded in 30 seconds until the maximum temperature reached. The falling temperature was read for 5 minutes and the procedure was repeated for three (3) other samples.

The data from above procedure was used in determining the calorific value of the fuel used in tea processing.

The composition of firewood fuel was adopted from study done by Gravalos *et al* (2016).

3.5.2. To determine the quality parameters of wastewater generated during the tea production process

The following parameters were determined to give the indicative quality of wastewater generated: PH, Electrical Conductivity (EC), Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD_5^{20})

I. PH

Apparatus

The following apparatus were used during the study; PH meter, Reference electrode and Glass electrode.

Procedures

The PH Meter was used to determine the PH of the waste water in a laboratory as shown in plate 3.1below.

Plate 3.1: Pictorial showing process in determination of PH

The pH meter probe was used to determine the pH value of the wastewater collected.

II. Electrical Conductivity (EC)

Apparatus

The following apparatus were used during the study; Conductivity meter, Conductivity cell, Pt electrode type and Platinising solution.

The EC was determined by use of conductivity meter in a laboratory as shown in plate 3.2 below.

Plate 3.2: Pictorial showing process in determination of EC

III. Chemical Oxygen Demand (COD)

Apparatus

The following apparatus were used during the study; Reflux flasks, Condensers, jacket Liebig

The COD of the wastewater was determined in a laboratory as shown plate 3.3 below:

Plate 3.3: Pictorial showing process in determination of COD of wastewater

Procedure:

The procedures was as follows: 50 ml of sample or an aliquot will be diluted to 50ml, distilled water was added in 500ml refluxing flask, 1 g HgSO4, few glass beads and 5 ml sulphuric acid reagent was added, mixed and cooled. 25 ml of 0.0417M K2Cr2O7 solution was added and mixed. The flask was connected to the condenser and cooling water turned on, additional 70 ml of sulphuric acid reagent was added through open end of condenser, with swirling and mixing, Reflux was done for 2 hours, cooled, condenser washed down with distilled water to double the volume of contents and cool, 2 drops of Ferroin indicator was added until a colour change from bluish green to reddish brown. Also reflux and titrate was done to distilled water blank with reagents, Standard 0.00417M K2Cr2O7, and 0.025M FAS , when analysing very low COD samples was to be used, The technique and reagents was evaluated by conducting the test on potassium hydrogen phthalate solution, Water was used at the Liebig jacket to prevent jamming.

IV. Biochemical Oxygen Demand (BOD_5^{20})

Apparatus

The following apparatus were used during the study; BOD bottles, 300ml, narrow mouth, flared lip, with tapered and pointed ground glass stoppers, Air incubator, thermostatically controlled at 20°C ± 1

The BOD was determined in a laboratory as shown in Plate 3.4 below;

Plate 3.4: Pictorial showing process in determination of BOD of wastewater**:**

3.6 Evaluating the effectiveness of the wastes management systems in Maramba Tea Factory

3.6.1. Identification of the Existing Waste Management System at Maramba Tea Factory.

The existing waste management systems for various wastes generated (solid organic and inorganic wastes, Liquid wastes and thermal wastes) at Maramba Tea Factory were identified by observation.

3.6.2. Evaluation and Assessment Method of Waste Management Systems

Since the study focused on the effectiveness of the already existing waste management system at the Maramba Tea factory, benchmarking method was adopted. This method enabled the comparison of the standard values of the wastes after they have been processed through the waste management system and the standard values set out internationally and locally by various bodies. Effectiveness of the waste management systems was then established by comparing the waste management systems practices and established values for solid wastes management, liquid waste management and thermal wastes management to the standards agreed practices and set values for an effective system. The detailed evaluation for each system of the solid, liquid and thermal wastes management are outlined in sections 3.6.3, 3.6.4 and 3.6.5 of this report respectively.

The standards set out for various waste parameters which includes, pH, EC, BOD_5, and COD are set out in Table 3.2 below.

Table 3-2: NEMA Standards for Effluent Discharge into the Environment

Institution	**Parameter**	**NEMA Standard level**
NEMA	pH	6.5 - 8.5
	EC	Marginal River Water 80-160
	BOD_5	Max 30 mg/L
	COD	Max 50 (mg/L)

The standards values presented in Table 3.2 was obtained from NEMA Kenya, water quality department. The departed stated the above values are set out in Third Schedule of water quality and regulations for insurance of permits and carrying out audit and monitoring.

Boiler Effectiveness:

Two types of trees i.e. Eucalyptus globulus and Grevillea robusta were used as source of wood fuel at the Maramba tea factory, Gravalos et al (2016) Ultimate Analysis of Wood Fuel were adopted as indicated in Table 4.5 of this study report. In addition, according to Patro (2015) and the Council of Industrial Boiler Owners (CIBO) recommends wood fuel based boiler (similar to the one used at Maramba Tea Factory) efficiency of 75.01% and 75% respectively. The boiler efficiency at Maramba Tea factory was compared to these recommended values of wood fuel energy based boiler.

3.6.3. Solid waste system

Disposal methods at the factory were observed and compared with the standard recommended disposal methods nationally as per NEMA regulations outlined in the Kenya Gazette 7th December, 2007 which requires that for a suitable solid disposal container, a contract with licensed solid waste transporter and a management plan be provided.

The mass balance for the Tea Factory was compared with the existing literature. The data collected from the factory on green leaf per month, manufactured tea per month and Solid waste generated per month were analysed and compared with the available literature.

Available literature estimates that during black tea manufacture, when the system is efficient, 75% is moisture while 24% is the manufactured tea, and 1 % solid waste. These percentage values were used to determine the expected manufactured tea, solid waste and the moisture content in a kilogram of green leaf tea.

To determine the expected amount of solid wastes from black tea production every month in the factory, the following was done:

The values of expected solid wastes compared with the actual measured solid wastes during the study period.

3.6.4. Wastewater systems

Wastewater sample was collected and analysed for BOD_5, pH, COD, and EC. The results were then compared with the effluent discharge maximum limit standards allowed by the NEMA of a BOD of 30mg/L, COD of 50mg/L, EC of 80-160 Siemens per Centimetre (S/CM) and pH of 6.5 - 8.5

ANOVA single factor tool was used to determine whether, there was a statistically change in the wastewater parameters from the source, through treatments systems and to the disposal stage in the stream. Null hypothesis described as $H0\text{: } \mu 1 = \mu 2$ and alternate hypothesis described as

$H1\text{: } \mu 1 \neq \mu 2$

3.6.5. Thermal waste

The following experiment was done to determine the efficiency of the boiler; the reference standards for Boiler Testing at the site using the indirect method was the British Standard, BS 845: 1987 and the USA Standard ASME PTC 4-1 Power Test Code Steam Generating Units.

The Mallick (2015) indirect method also called the heat loss method was applied.

The boiler data and Bomb calorific test data and subsequent calculations are as shown in **appendix 1** section 1.11 of this study report.

The efficiency was to be calculated by subtracting the heat loss fractions from 100 as shown in Equation 3-1 below:

$Efficiency\ of\ Boiler\ (\eta) = 100 - (a + b + c + d + e + f)$ ………. Equation 3-1

Whereby the principle losses that occur in a boiler are losses of heat due to:

a. Dry flue gas

b. Evaporation of water formed due to H_2 in fuel

c. Evaporation of moisture in fuel

d. Moisture present in combustion air

e. Radiation and other unaccounted losses

f. Losses due to moisture in fuel and due to combustion of hydrogen are dependent on the fuel, and cannot be controlled by design

The data required for the calculation of the boiler efficiency using indirect method was: Ultimate analysis of fuel (H_2, O_2, S, C, moisture content, ash content), Percentage of oxygen or CO_2 in the flue gas, Flue gas temperature in °C (T_f), Ambient temperature in °C (Ta) and humidity of air in kg/kg of dry air, and GCV of fuel in kcal/kg

The following steps were used in determining the boiler efficiency:

I. Determine theoretical air requirement for combustion of fuel using equation 3.2 below:

$Weight\ of\ kg\ of air\ per\ kg of\ fuel = 1.521C + 34.56H + 4.32(S - O)/100.$

……………………………………………………………………………………………..Equation 3-2

Where C, H, O and S are proportional parts by weight of carbon, hydrogen, oxygen and Sulphur by ultimate analysis

II. Determine Percent of Excess Air Supplied by applying equation 3.3 below:

$\text{EA} = 100 \text{ x} \frac{O_2}{(21-O_2)}$ …………………………………… Equation 3-3

Where:

EA= is Excess air supplied

O_2 is the weight of Oxygen by Ultimate analysis

III. Determine the Actual mass of air supplied (AAS) per kilogram of fuel by using equation 3.4 below:

$$\text{AAS} = \left(1 + \frac{\text{EA}}{100}\right) \text{x theoritical air requirment for combustion of fuel}$$

……………………………………………………………………………………………. Equation 3-4

where:

AAS= Actual mass of air supplied

EA = Excess Air supplied

IV. Determine heat losses as follows:

a. Heat Losses due to dry flue gas:

$$\frac{m\ X\ C_P(T_f - T_a)}{GCV\ of\ fuel}\ \text{x}\ 100$$ …………….. Equation 3-5

where:

m = mass of dry flue gas in kg/kg of fuel

Cp = Specific heat of flue gas (0.23 kcal/kg)

T_f = Flue gas temperature

T_a = Ambient Temperature

GCV= Gross calorific value of fuel

Mass of dry flue gas = Mass of actual air supplied + mass of fuel supplied

b. Heat loss due evaporation of water formed due to hydrogen present in the fuel:

$$9\ \text{x}\ H_2 \left[\frac{584 + C_P(T_f - T_a)}{GCV\ of\ Fuel}\right]$$ …………….. Equation 3-6

Where:

H_2 = percentage of hydrogen in 1 kg of fuel

C_P = Specific heat of superheated steam (0.45kcal/kg)

T_f = Flue gas temperature

T_a = Ambient Temperature

GCV= Gross calorific value of fuel.

c. Heat loss due to evaporation of moisture present in the fuel:

$$M\left[\frac{584 + C_P(T_f - T_a)}{GCV\ of\ Fuel}\right]$$ …………….. Equation 3-7

Where:

M= percentage of moisture in 1 kg of fuel

C_P = Specific heat of superheated steam (0.45kcal/kg)

T_f = Flue gas temperature

T_a = Ambient Temperature

GCV= Gross calorific value of fuel

d. Heat loss due to moisture present in the combustion air:

$$\left[\text{AAS x Humidity ratio of air x}\frac{C_P(T_f - T_a)}{\text{GCV of fuel}}\right]$$ ……….Equation 3-8

where:

AAS = Actual mass of air supplied

C_P = Specific heat of superheated steam (0.45kcal/kg)

T_f = Flue gas temperature

T_a = Ambient Temperature

GCV= Gross calorific value of fuel

e. Heat loss due to radiation and other unaccounted losses:

Heat losses due to radiation and other unaccounted losses are estimated at 1%-2% for smaller boiler and at 0.2% - 1% for larger boiler

4. RESULTS AND DISCUSION

4.1 Results

4.1.1. Characterization of the waste generated during tea production at the factory

The types of wastes generated were identified through observations and measurement. These were done at different stages of the tea production and other sections of the factory.

The types of waste identified were solid wastes, liquid wastes and thermal wastes. These categories of wastes agree with what was established in the literature.

The solid wastes were classified as shown in the Table 4-1 below.

Table 4-1: Type of solid wastes identified at different tea production stages

Tea production stage	**Type of waste**	**Nature of waste**
Leaf reception	Green leaf	Organic
Withering	Green leaf	Organic
Maceration	Green leaf	Organic
Drying	Pekoe dust	Organic
Sorting	Fanning	Organic
Packing	Papers	Organic
	Polythene papers and sacks	Inorganic

The liquid wastes were generated from the cleaning processes in the factory. The two main type of cleaning are major and minor cleaning. Major cleaning is done weekly while minor cleaning was done daily.

The thermal wastes are generated from the heat losses that occur in the factory at the boiler and steam pipelines which were determined as shown in section 4.1.2 part III of this study report. They include losses due to: dry flue gas, moisture in the fuel and air; hydrogen and due to radiation.

4.1.2. Analysis of waste management in the Maramba Tea Factory

4.1.2.1. Quantities of the solid wastes, wastewater and thermal wastes of generated at the factory

I. The Quantities of Solid Wastes generated at Maramba Tea Factor

The quantities of solid wastes generated were collected for study period of Five (5) months which were considered adequate enough for data analysis. The study period of data collection was decided based on the available resources. The quantities of solid wastes were weighted and the results were summarized in Table 4.2 and Table 4.3.

The solid data were collected on a daily basis as shown in appendix 1, section 1.1 to 1.6 of this study report.

Table 4-2: Quantities of Solid Wastes in kilograms (kgs) Generated At Different Stages Of Tea Production

Section	Jul-2016	Aug-2016	Sep-2016	Oct-2016	Nov-2016	Total	Mean	Standard Deviation
Offloading	54	53	60	73	76	316	63.2	10.71
Withering	298.5	327	358	385.5	412.5	1781.5	356.3	45.31
Maceration	19.55	19.2	20.5	24.8	28.6	112.65	22.53	155.92
Drying	23.5	25.5	26.5	27.1	27.5	130.1	26.02	1.60
Sorting	10.7	10.1	11	11.2	11.8	54.8	10.96	0.63
Packing (organic)	6.8	7.6	7.7	7.3	7.9	37.3	7.46	0.43
	14.9	15.0	15.3	15.9	15.8	76.9	15.38	0.45

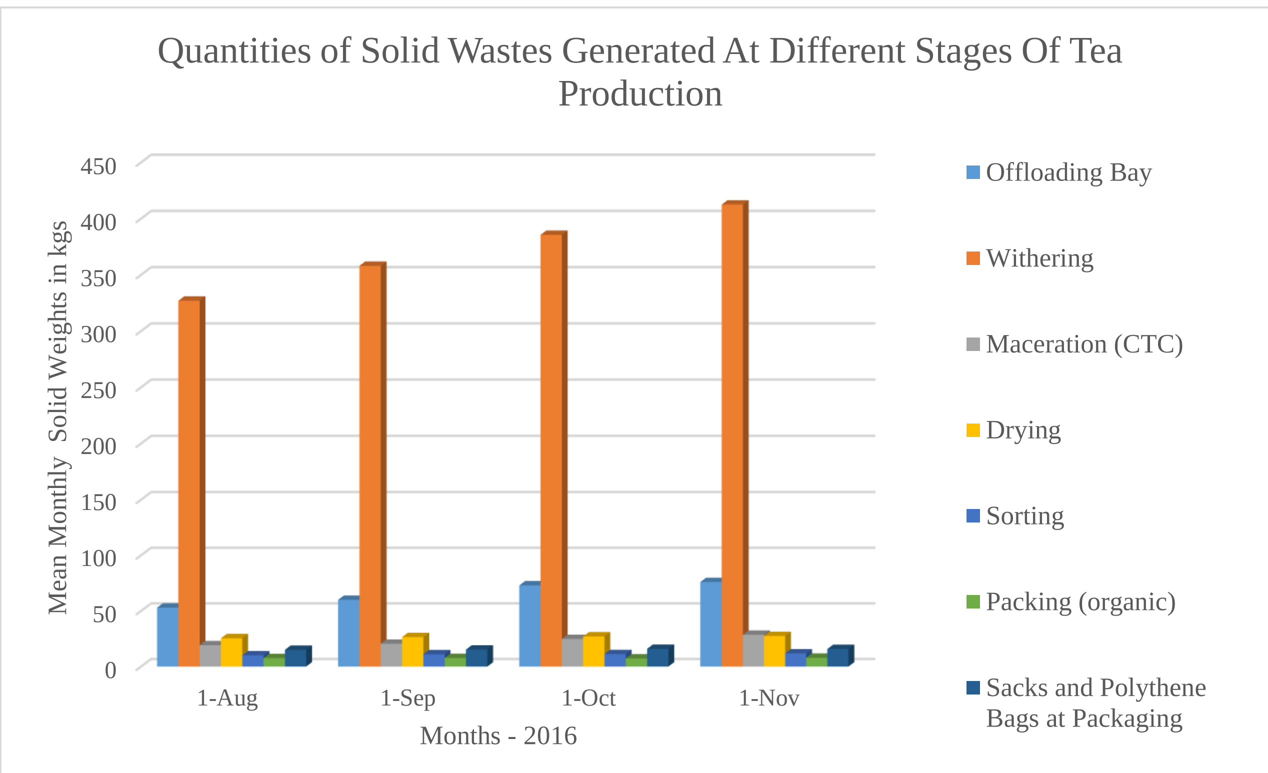

Figure 4-1: Solid Wastes Generated At Different Stages of Tea Production

Table 4-3: Average Quantities of Solid Wastes Generated At Different Stages of Tea Production

Type of waste	**Tea production stage**	**Nature of waste**	**Average Amount (kgs)**	**Proportional Percentage of the solid wastes (%)**
Green leaf	Leaf reception	Organic	63.2	12.59
Green leaf	Withering	Organic	356.3	71
Green leaf	Maceration	Organic	22.53	4.49
Pekoe dust	Drying	Organic	26.02	5.18
Fanning	Sorting	Organic	10.96	2.18
Papers	Packing	Organic	7.46	1.49
Polythene papers and sacks		Inorganic	15.38	3.06
		Total	**501.85**	**99.99**

From Table 4.2 and 4.3 and Figure 4.1 the amount of solid wastes generated is highest at Withering stage of tea production process at 356.3 kilograms per month representing 71% of solid wastes generated at the factory, followed by offloading at 63. 2 kilograms per month representing 12.59% of solid wastes, then followed by drying at 26.02 kilograms per month representing 5.18% of solid wastes. The least amount of solid wastes generated is at sorting stage at 10.96 kilograms per month representing 1.49% of the total solid wastes generated at the tea factory.

II. The Quantities of Liquid Wastes Generated at the Maramba Tea Factory

The amount of wastewater generated during the tea production process was estimated to be at 80% amount of water used. The readings were obtained from the water meter readings for water used in minor daily cleaning and major weekly cleaning respectively as shown in appendix 1, section 1.7 of this study report. The values recorded for the period of project study are represented in Table 4.4 below.

Table 4-4: Amount of Wastewater generated monthly from July 2016 – November 2016

Months	Wastewater Generated from Major cleaning (m^3)	Wastewater Generated from Minor cleaning (m^3)
July 2016	102.4	38.4
August 2016	104	40
September 2016	111.2	41.6
October 2016	118.4	44.8
November 2016	121.6	46.4
Total (m^3)	**557.6**	**211.2**

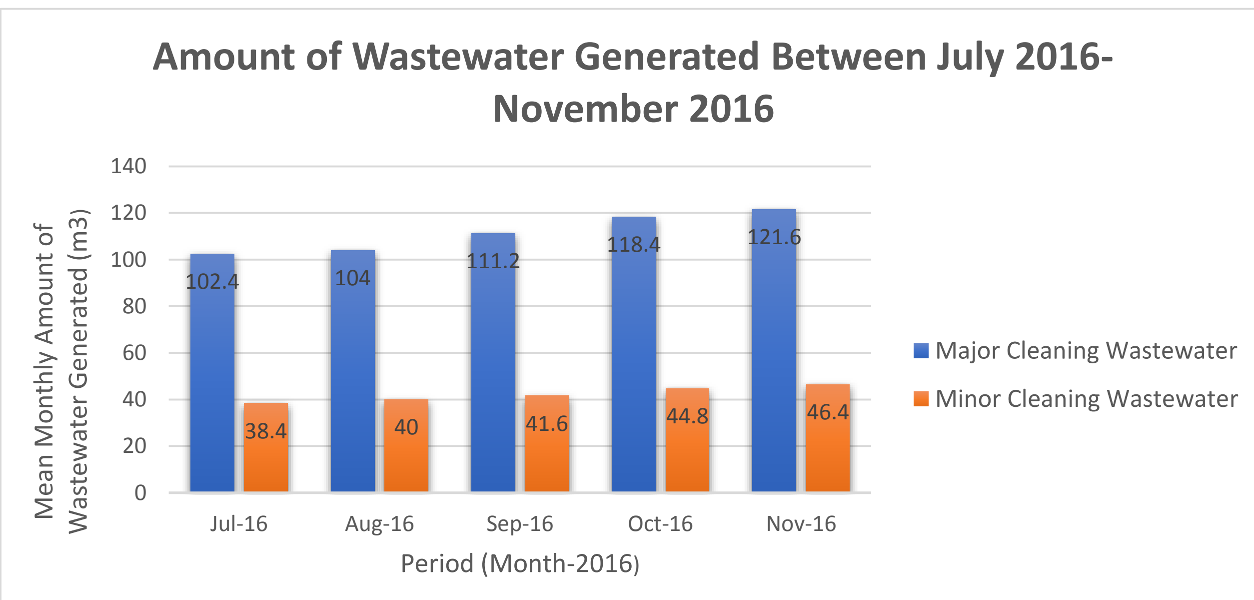

Figure 4-2: Mean Monthly Waste of Major and Minor Cleaning

From the Table 4.4 and Figure 4.2, the amount of liquid waste generated for major cleaning at the Maramba Tea Factory ranged between an average of 102.4 $m^3$and 121.6m^3 respectively per month for the period of study. The highest amount of wastewater generated was in November 2016 at 121.6m^3 and least amount in July 2016 at 102.4 m^3.

The minor cleaning which was done daily had the highest amount of wastewater in November 2016 at 46.8m^3 and least amount generated in July 2016 at 38.4m^3

III. The Quantities of Thermal Waste Generated at the Maramba Tea Factory

The quantities of thermal wastes at Maramba Tea factory was estimated determining the calorific value of wood fuel used as source of energy and the heat losses resulting in burning of the fuel. The various heated losses determined includes; loss of heat due to dry flue gas, loss of heat due to hydrogen, heat loss due to moisture in air, heat loss due to moisture in fuel and losses due to radiation. The ultimate analysis of the wood fuel as shown in Table 4.5 was adopted from study done by Gravalos et al (2016)

Table 4-5: Ultimate Analysis of Wood Fuel (Eucalyptus globulus and Grevillea robusta

Type of Tree	**C (%)**	**O (%)**	**H (%)**	**N (%)**	**S(%)**	**Ash (%)**	**Moisture (%)**	**Total (%)**
Eucalyptus Globulus Blue gum)	49.7	39.2	5.7	0.02	0.07	0.5	4.8	99.99
Grivillea Robusta	49	39.38	6	0.05	0.07	1.3	4.2	100
Average	**49.35**	**39.29**	**5.85**	**0.035**	**0.07**	**0.9**	**4.5**	**99.995**

Source: Ioannis Gravalos et al (2016): *An Experimental Determination of Gross Calorific Value of Different Agroforestry Species and Bio-Based Industry Residues*

Fuel Calorific Value = 3,059.52 kcal/kg

Percentage of CO2 in flue gas = 10.7 %

Percentage of O2 in flue gas = 9.0 %

Flue gas temperature, T_f = 280 °C

Ambient temperature T_a= 25.5 °C

Moisture content in air = 0.0205 kg / kg of air from table of moisture – content – air

Theoretical amount Air requirement for combustion of 1 kg of fuel calculated:

Weight of kg air per kg of fuel $= 11.521\ \mathrm{C} + 34.56\ \mathrm{H} + 4.32(\mathrm{S\text{-}O})/100$

Where C, H, O and S are proportional parts by weight of carbon, hydrogen, Oxygen and Sulphur by ultimate analysis

$$\text{Theoritical air requirements} = 11.52 \text{ x } 49.50 + 34.56 \text{ x } 5.85 + 4.32\ (0.07 - 39.29)/100$$

= 6.03 kg of air / kg of fuel

Excess Air Supplied (EA)

$$\mathrm{EA} = 100 \text{ x} \frac{O_2}{(21 - O_2)}$$

Where:

EA= is Excess air supplied

O_2 is the weight of Oxygen by Ultimate analysis

$$\mathrm{EA} = 100\ x\ \frac{9.0}{21 - 9.0}$$

= 75 %

Actual mass of air supplied (AAS)

$$\mathrm{AAS} = \left(1 + \frac{\mathrm{EA}}{100}\right) \text{x theoritical air requirment for combustion of fuel}$$

where:

AAS= Actual mass of air supplied

EA = Excess Air supplied

$$\text{AAS} = \left(1 + \frac{75}{100}\right) \text{x } 6.03$$

= 10.55 kg of air/ kg of fuel

Estimation of Heat losses

a. Heat Losses due to dry flue gas:

$$\frac{m\ X\ C_P(T_f - T_a)}{GCV\ of\ fuel}\ \text{x } 100$$

Where:

m = mass of dry flue gas in kg/kg of fuel

Cp = Specific heat of flue gas (0.23 kcal/kg)

T_f = Flue gas temperature

T_a = Ambient Temperature

GCV= Gross calorific value of fuel

Mass of dry flue gas = Mass of actual air supplied + mass of fuel supplied

$\text{m} = 10.55 + 1 = 11.55$ kg

$$\%\ \text{heat loss due to dry flue gas} = 11.55\ \text{X}\ 0.23(280 - 25.5)\text{X}\frac{100}{3059.52}$$

= 22.09 %, this represents 675.84 kcal/kg

b. Heat loss due evaporation of water formed due to hydrogen present in the fuel:

$$9\ \text{x}\ H_2\left[\frac{584 + C_P(T_f - T_a)}{GCV\ of\ Fuel}\right]$$

Where:

H_2 = percentage of hydrogen in 1 kg of fuel

C_P = Specific heat of superheated steam (0.45kcal/kg)

T_f = Flue gas temperature

T_a = Ambient Temperature

GCV= Gross calorific value of fuel

% Heat loss due evaporation of water formed due to hydrogen present in fuel

$$= 9 \text{ x } 5.85 \left[\frac{584 + \ 0.45(280 - 25.5)}{3059.52}\right]$$

= 12.021 %, which represents, 367.78 kcal/kg?

c. Heat loss due to evaporation of moisture present in the fuel:

$$M \left[\frac{584 + C_P(T_f - T_a)}{\text{GCV of Fuel}}\right]$$

Where:

M= percentage of moisture in 1 kg of fuel

C_P = Specific heat of superheated steam (0.45kcal/kg)

T_f = Flue gas temperature

T_a = Ambient Temperature

GCV= Gross calorific value of fuel

$\% \, Heat \ loss \ due \ to \ evaporation \ of \ moisture \ in \ the \ fuel$

$$= \quad 4.5 \left[\frac{584 + \ 0.45(280 - 25.5)}{3059.52}\right]$$

= 1.03 % This represents 31.51 kcal/kg

d. Heat loss due to moisture present in the combustion air:

$$\left[\text{AAS x Humidity ratio of air x} \frac{C_P(T_f - T_a)}{\text{GCV of fuel}}\right] \text{ x } 100$$

where:

AAS = Actual mass of air supplied

C_P = Specific heat of superheated steam (0.45kcal/kg)

T_f = Flue gas temperature

T_a = Ambient Temperature

GCV= Gross calorific value of fuel

% heat loss due to moisture in the combustion air

$$= \left[\frac{10.55 \ \text{x}\ 0.0205\text{x}\ 0.45(280 - 25.5)}{3059.52} \text{x}\ 100\right]$$

= 0.810 %

This represents 24.78 kcal/kg

e.Heat loss due to radiation and other unaccounted losses:

Since the Maramba tea factory boiler is a smaller one, Heat losses due to radiation and other unaccounted losses were estimated at 1.5% which represents 45.89 kcal/kg

Total heat losses

Total heat input 3059.52 kcal/kg which is equivalent to 100%

Total heat loss = a + b + c + d + e

= (675.84 + 367.78 + 31.51 + 24.78 + 45.89) kcal/kg

= 1,145.51 kcal/kg

Table 4-6: Summary of heat loss in different types

Heat Loss Types	**Amount of Heat Loss (kcal/kg)**
Dry flue gas	675.84
Evaporation of water formed due to hydrogen present in the fuel	367.78
Evaporation of moisture present in the fuel	31.51
Moisture present in the combustion air	24.78
Radiation and other unaccounted losses	45.89
Total Heat Loss	**1,145.51**

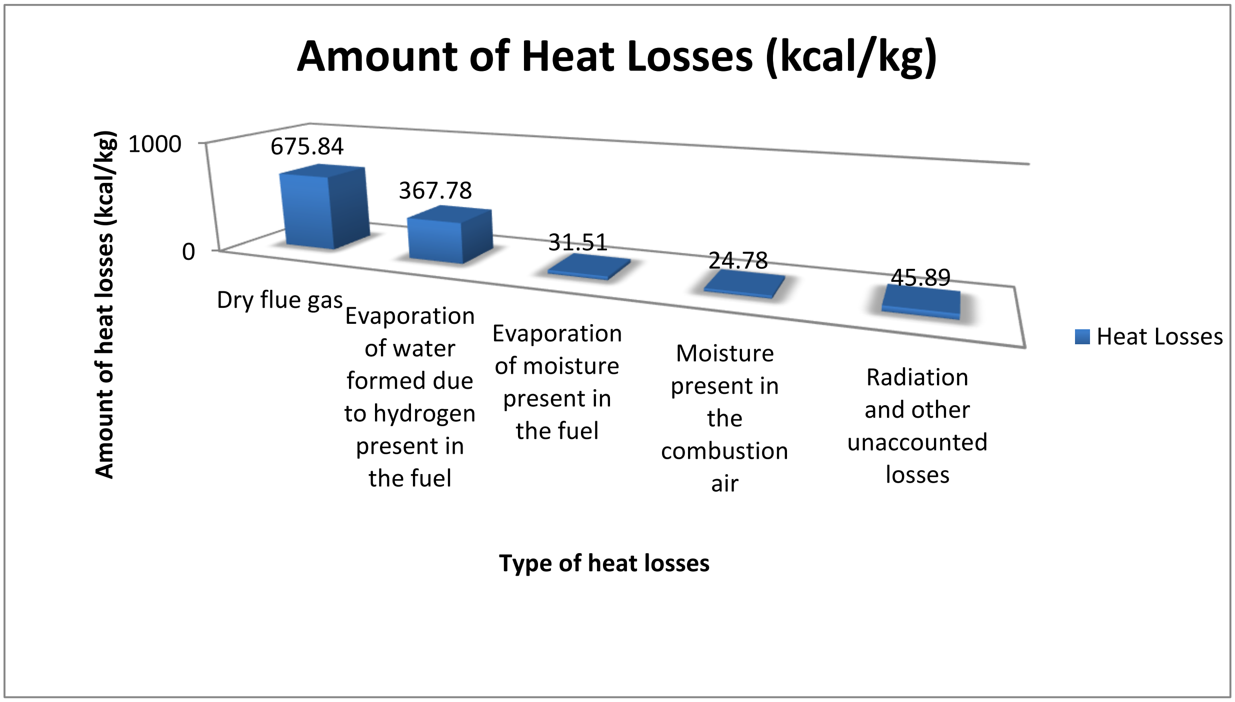

Figure 4-3: Amount of heat loss (kcal/kg)

The total amount of heat loss is 1145.51kcal/kg which represents 37.45% of the GCV of wood fuel. The highest heat loss being due to dry flue gas with a 22.09% of GCV of wood fuel representing 675.85kcal/kg and the least being due to moisture present in the combustion air at 24.78kcal/kg representing 0.810 % of the total GCV of wood fuel

4.1.2.2. Quality parameters of wastewater generated during the tea production process at the factory

To determine, the quality parameters of wastewater generated at the factory, the following parameters were measured:

i. Biochemical Oxygen Demand (BOD_5) in mg/L

ii. Chemical Oxygen Demand (COD) in mg/L

iii. Electrical conductivity (EC) in Siemens per centimetre

iv. pH level.

The results are as shown in Tables 4.7 below:

Table 4-7: Quality Parameters of wastewater generated at the Maramba Tea Factory

LOCATION	**BOD_5**	**COD**	**pH**	**EC (S/cm)**
Min lagoon 1 (ML1)	240.38	810.53	6.49	433.87
Min lagoon 2 (ML 2)	228.58	792.83	6.59	408.31
Min lagoon 3 (ML3)	211.73	604.78	6.64	391.7
Sub lagoon 1 (SL 1)	202.30	555.8	6.58	330.47
Sub lagoon 2 (SL2)	184.68	513.55	6.64	243.55
Man hole (exit to stream)	128.59	223.03	6.91	150.40
At point of entry to stream	111.2	110.12	6.97	45.75
Upstream	83.7	105.1	7.25	32.48
Downstream	81.87	106.63	7.1	31.87
NEMA Limit Standards	**30**	**50**	**6.5-8.5**	**80-160**

4.1.3. Evaluating the effectiveness of the wastes management systems in Maramba Tea Factory

In order to determine the effectiveness of the waste management's systems at Maramba Tea Factory, the solid wastes, liquid wastes systems and Thermal wastes systems were evaluated differently.

4.1.3.1. Existing Waste Management Systems at Maramba Tea Factory

The existing waste management systems identified at Maramba Tea Factory was as shown in Table 4.8 below:

Table 4-8: Existing Waste Management Systems at Maramba Tea Factory.

Types of Wastes	Management Systems
1. Solid Wastes (organic wastes)	• Solid wastes are not segregated hence segregating procedures not in place. • There were no clear solid waste disposal systems; however, most of the organic wastes are disposed of in the banana garden.
2. Solid waste (metals)	They are disposed of by selling to metal scrapper dealers.
3. Liquid wastes	• They are channelled to the lagoons through a paved open canal. • They are treated through naturally aerated lagoons before discharging to the river.
4. Thermal wastes	• There was chimney fitted at the boiler. • There was no pipe lagging that would reduce heat loss.

4.1.3.2. Evaluation Method

The study aimed at establishing the effectiveness of the already existing waste management system that entails waste collection, handling, transportation and disposal at the Maramba Tea factory.

Benchmarking method was adopted. This method enabled the comparison of the standard values of the wastes after they have been processed through the waste management system and compared to the standard values set out internationally and locally by various bodies. The solid, liquid and thermal waste management systems performances are outlined in sections 4.1.3.3, 4.1.3.4 and 4.1.3.4 below.

4.1.3.3.Solid Waste Management Systems at the factory

Solid wastes are not segregated at the factory. The solid wastes generated at factory are both organic and inorganic wastes. Currently there was clear disposal method (no landfills or composting) used to dispose of organic wastes, rather they are just disposed of in garden that has banana plantation next to the factory premises. The amount of organic solid waste collected averaged of 486.47 kilograms per month. The inorganic solid wastes averaged 15.38 kilograms per month which included polythene bags and sacks.

The other type of inorganic solid wastes were scrap metals which were well segregated as aluminium foils and metals and mild steels metals which were placed at designated place. It was noted by the factory management that the scrap metals are disposed of by selling to metal dealers for recycling.

The solid wastes are not managed as per the requirement of NEMA regulations through gazette notice of 7th December 2007.

The solid wastes management system is therefore only partially effective.

The amount of Green Tea and the Blacked Tea Measured compared to the Black tea Expected is presented in Table 4.9 below. It was observed that the amount of Measured Black Tea was slightly higher than the Expected Black Tea at Maramba Tea Factory as illustrated in Figure 4.5. The purpose is to compare the measured solid wastes and the expected solid wastes from literature.

Table 4-9: Tea Production Mass at Maramba Tea Factory for the study period

Month (I)	Green Tea (II)	Black Tea (Measured) (III)	% Black Tea (IV)	Solid waste (measured) (V)	% Solid waste (VI)	Moisture (VII)	% moisture (VIII)	Expected Black Tea (IX)	Expected Solid waste (X)	Expected Moisture (XI)
			(III/II)x100		(V/II)x100	((II-(III+V))	(VII/II)x100	(IIx0.25.06)	(II x 0.01)	(II x 0.74.9)
Nov,2016	1,757,977	455,651.0	25.92	564.3	0.030	1301761.7	74.05	421,914.50	17,579.7	1,318,482.8
Oct,2016	1,711,755	435,016.0	25.41	528.9	0.031	1276210.1	74.56	410,821.20	17,117.5	1,283,816.3
Sept,2016	1,357,540	346,819.00	25.55	483.7	0.036	1010237.3	74.41	325,809.60	13,575.4	1,018,155
Aug,2016	1,248,005	303,062.50	24.28	442.4	0.035	944500.1	75.69	299,512.20	12,489	936,003.8
July,2016	1,197,850	288,903.00	24.12	413.1	0.035	908533.9	75.85	287,484.50	11,978	898,387.5
Average per Month	1,454625.4	365890.3	25.06	486.48	0.033	1088248.6	74.9	349,108.40	14,547.9	1090969.08

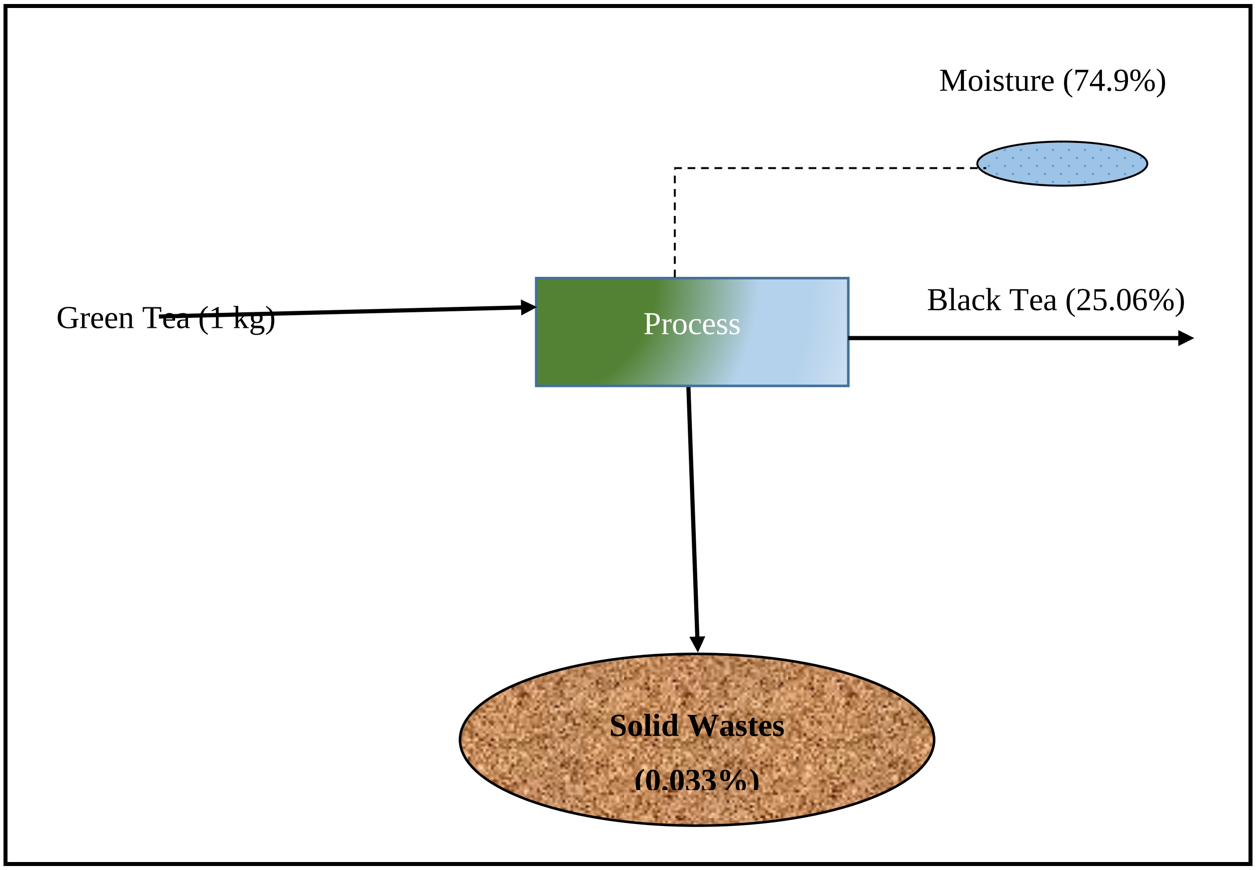

Figure 4-4**:** Tea Production at Maramba Tea Factory (July 2016-November 2016)

From analysis of data collected, it indicates that if 1kilogram of green tea is processed, it will yield 25.06% Black Tea, 74.9 kilograms of moisture and 0.033% of solid wastes as shown in Figure 4.4

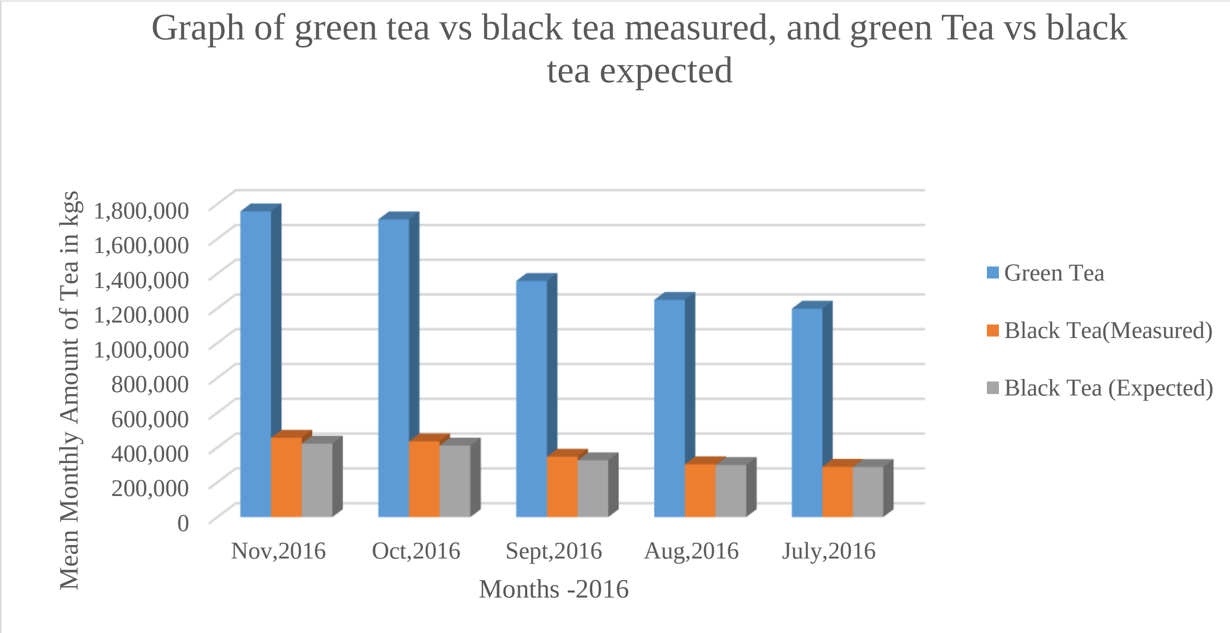

Figure 4-5: Amount of Green Tea comparable to Amount of Measured and Expected Tea in Maramba Tea Factory.

It was noted that the measured solid wastes are only 3% of the expected solid wastes.

4.1.3.4.Wastewater Management Systems at the Factory

In order to evaluate the effectiveness of the wastewater management systems, the following parameters were determined to give the indication of the quality of wastewater generated: Biological Oxygen Demand (BOD_5^{20}), Chemical Oxygen Demand (COD), PH and Electrical Conductivity (EC). The measured results were compared with the established NEMA standards. The results are as shown in Tables 4.10, 4.11, 4.12 and 4.13 respectively.

Furthermore, in analysing the effectiveness of the waste management systems, ANOVA single factor tool was used to determine statistically if the was a change in wastewater parameters; Biological Oxygen Demand (BOD520), Chemical Oxygen Demand (COD), PH and Electrical Conductivity (EC) along the source stage to disposal stage at the stream.

Table 4-10: Wastewater Biological Oxygen Demand (BOD_5) Parameter.

LOCATION	**BOD_5 (mg/L)[1]**	**NEMA standards level [2]**
Min lagoon 1 (ML1)-at the entry of raw wastewater	240.38	At maximum of 30 mg/L
Min lagoon 2 (ML 2)	228.58	
Min lagoon 3 (ML3)	211.73	
Sub lagoon 1 (SL 1)	202.30	
Sub lagoon 2 (SL 2)	184.68	
Man hole (exit to stream)	128.59	
At point of entry to stream	111.2	
Upstream	83.7	
Downstream	81.87	

Source: Author[1,] NEMA[2]

Table 4-11: Wastewater Chemical Oxygen Demand (COD) Parameter

LOCATION	**COD**	**NEMA standards level [2]**
Min lagoon 1 (ML1)	810.53	At Max 50 (mg/L)
Min lagoon 2 (ML 2)	792.83	
Min lagoon 3 (ML3)	604.78	
Sub lagoon 1 (SL 1)	555.8	
Sub lagoon 2 (SL 2)	513.55	
Man hole (exit to stream)	223.03	
At point of entry to stream	110.12	
Upstream	105.1	
Downstream	106.63	

Source: Author[1,] NEMA[2]

Table 4-12: Wastewater pH level Parameter

LOCATION	pH_1	NEMA standards level 2
Min lagoon 1 (ML1)	6.49	6.5 - 8.5
Min lagoon 2 (ML 2)	6.59	
Min lagoon 3 (ML3)	6.64	
Sub lagoon 1 (SL 1)	6.58	
Sub lagoon 2 (SL 2)	6.64	
Man hole (exit to stream)	6.91	
At point of entry to stream	6.97	
Upstream	7.25	
Downstream	7.1	

Source: Author[1,] NEMA[2]

Table 4-13: Wastewater Electrical Conductivity (EC) Parameter

LOCATION	EC (S/cm)1	NEMA standards level 2
Min lagoon 1 (ML1)	433.87	For Marginal River Water 80-160 (S/CM)
Min lagoon 2 (ML 2)	408.31	
Min lagoon 3 (ML3)	391.7	
Sub lagoon 1 (SL 1)	330.47	
Sub lagoon 2 (SL 2)	243.55	
Man hole (exit to stream)	150.40	
At point of entry to stream	45.75	
Upstream	32.48	
Downstream	31.87	

Source: Author[1,] NEMA[2]

Table 4-14 to Table 4-21, shows ANOVA analysis of determined wastewater between two successful points of sampling. This was done from the point of entry up to the downstream of the river. Single factor ANOVA was employed to determine if the was any statistical changes in the values of this measured parameter as wastewater move through the treatment systems designed by the factory.

The result of the analysis showed significant difference as Probability Value (P Value) was less than 0.05 and F< Fcrit.

From the values obtained, the BOD and COD values are higher than the maximum allowable limit by NEMA, pH and EC values were within the maximum allowable limits as shown in Tables 4.10, 4.11, 4.12 and 4.13 respectively. Hence the wastewater management is on partially effective since the values of the wastewater parameters were reduced as analysed by ANOVA as shown in Table 4-14 to Table 4-21.

ANOVA Analysis

Table 4-14: pH ANOVA Analysis_1 (between ML1 and ML2)

Water Quality Parameter	**pH**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	19.48	6.493333	0.008133
Row 2	3	20.72	6.906667	0.000433

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.25627	1	0.256267	59.82879	0.001505	7.708647
Within Groups	0.01713	4	0.004283			
Total	0.2734	5				

Remarks

$H_1: \mu_1 \neq \mu_2$

P<0.05, 0.001505< 0.05

F>F crit, 59.82879 > 7.708647

Table 4-15: pH ANOVA Analysis_2 (between Manhole - Point of entry to river)

Water Quality Parameter	pH
Analysis	**SUMMARY**

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	19.91	6.636667	0.001233
Row 2	3	21.3	7.1	0.0025

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.322017	1	0.322017	172.5089	0.000194	7.708647
Within Groups	0.007467	4	0.001867			
Total	0.329483	5				

Remarks

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 \neq \mu_2$

$P<0.05$, $0.00019 < 0.05$

There is statistically significant difference

Table 4-16: EC (S/cm) ANOVA Analysis_1 (ML1-ML2)

Water Quality Parameter	EC (S/cm)						
Analysis	**SUMMARY**						
	Groups	*Count*	*Sum*	*Average*	*Variance*		
	Row 1	3	137.25	45.75	23.5225		
	Row 2	3	95.6	31.86667	11.64333		
	ANOVA						
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
	Between Groups	289.1204	1	289.1204	16.44326	0.015412	7.708647
	Within Groups	70.33167	4	17.58292			
	Total	359.4521	5				
Remarks	$H_0: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ P<0.05, 0.015412< 0.05 F>F crit, 16.44326 > 7.708647 **There is statistically significant difference**						

Table 4-17: EC (S/cm) ANOVA Analysis_2 (between Manhole - Point of entry to river)

Water Quality Parameter	**EC (S/cm)**
Analysis	See SUMMARY and ANOVA below

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	1301.6	433.8667	232.0033
Row 2	3	991.4	330.4667	104.2033

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16037.34	1	16037.34	95.40168	0.000616	7.708647
Within Groups	672.4133	4	168.1033			
Total	16709.75	5				

Remarks

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 \neq \mu_2$

P<0.05, 0.000616 < 0.05

F>F crit, 95.40168> 7.708647

There is statistically significant difference

Table 4-18: BOD_5 ANOVA Analysis_1 (between ML1-ML2)

Water Quality Parameter	**BOD_5**

Analysis

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	721.15	240.3833	97.52583
Row 2	3	606.91	202.3033	7.441033

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2175.13	1	2175.13	41.44412	0.002995	7.708647
Within Groups	209.9337	4	52.48343			
Total	2385.063	5				

Remarks

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 \neq \mu_2$

P<0.05,   0.002995< 0.05

F>F crit,   41.44412 > 7.70864

There is statistically significant difference

Table 4-19: BOD_5 ANOVA Analysis_2(between Manhole - Point of entry to river)

Water Quality Parameter	**BOD_5**
Analysis	see below
Remarks	see below

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	333.6	111.2	43.33
Row 2	3	245.6	81.86667	1.453333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1290.667	1	1290.667	57.64049	0.001615	7.708647
Within Groups	89.56667	4	22.39167			
Total	1380.233	5				

Remarks

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

P<0.05, 0.001615< 0.05

F>F crit, 57.64049 > 7.708647

There is statistically significant difference

Table 4-20: COD ANOVA Analysis_1 (Between ML1-ML2)

Water Quality Parameter	**COD**						
	SUMMARY						
	Groups	*Count*	*Sum*	*Average*	*Variance*		
	Row 1	3	2431.6	810.5333	0.563333		
	Row 2	3	1540.66	513.5533	38.53653		
	ANOVA						
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
	Between Groups	132295.7	1	132295.7	6767.066	1.31E-07	7.708647
	Within Groups	78.19973	4	19.54993			
	Total	132373.9	5				
	$H_0: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$ P<0.05, 1.31E-07 < 0.05 F>F crit, 6767.066 > 7.70864 **There is statistically significant difference**						

Table 4-21: COD ANOVA Analysis_2(between Manhole - Point of entry to river)

Water Quality Parameter	COD
Analysis	**SUMMARY**

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	3	330.35	110.1167	0.385833
Row 2	3	319.9	106.6333	3.943333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.20042	1	18.20042	8.408277	0.044131	7.708647
Within Groups	8.658333	4	2.164583			
Total	26.85875	5				

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

P<0.05, 0.044131 < 0.05

F>F crit, 8.4087 > 7.708647

There is statistically significant difference

4.1.3.5. Thermal Management Systems at the Factory

In order to determine the effectiveness of the thermal waste management systems at the factory, the boiler efficiency was determined. Mallick (2015) indirect method also called the heat loss method was applied. The efficiency was calculated by subtracting the heat loss fractions from 100. The heat losses from the boiler were:

i. Dry flue gas

ii. Evaporation of water formed due to H_2 in fuel

iii. Evaporation of moisture in fuel

iv. Moisture present in combustion air

v. Radiation and other unaccounted losses

vi. Losses due to moisture in fuel and due to combustion of hydrogen are dependent on the fuel, and cannot be controlled by design

These losses were determined as shown in section 3.6.5.

$$\text{Efficiency of Boiler } (\eta) = 100 - (\text{i} + \text{ii} + \text{iii} + \text{iv} + \text{v} + \text{vi})$$

$$= 100 - (22.09 + 12.021 + 1.03 + 0.810 + 1.5) = (100 - 37.45)\%$$

$$= \mathbf{62.55}\%$$

The Boiler efficiency at Maramba Tea Factory is 62.55%. Patro (2015) and the Council of Industrial Boiler Owners (CIBO) recommends wood fuel energy-based boiler efficiency of 75.01% and 75% respectively. Consequently, the boiler efficiency of 62.55% is still lower compared to the set values of 75.01% and 75%. Hence the thermal management system is only partially effective.

4.2 Discussion

4.2.1. Characterization of the waste generated during tea production at the factory

The types of wastes generated during tea production in Maramba Tea Factory were identified through observations and measurements. The wastes identified were solid waste, liquid wastes and thermal wastes. Most studies done in India on Tea Factory wastes only focused on the tea leaves fibres as the tea wastes. However, this fell short of recognizing other type of wastes generated in the factory. This study, attempted to characterise all type of wastes generated in Tea Factory in Kenya. The studies done in Kenya are few and cannot be used to generalize the type of wastes generated for all tea factories in Kenya, hence the need for more studies and this study was aimed at providing more documented data on which policies can be made.

The solid wastes identified in the tea production process were both organic and inorganic wastes as classified in Table 4.1.

The liquid wastes are generated from two cleaning processes, i.e. major and minor cleaning in the factory. Major cleaning is done weekly while minor cleaning is done daily.

The thermal wastes are generated from the heat losses that occur in the factory. They include losses due to: dry flue gas; moisture in the fuel and air; hydrogen and due to radiation.

Linkage of the India Study with the Current Study

The current study is similar to the India one in the following aspects:

i. Both studies focus on black tea production, hence same production stages.

ii. Both studies identify solid waste as the type of waste generated from tea production.

iii. Both India and Kenya have a body mandated to regulate pollution emanating from wastes to the environment: Kenya has National Environment Management Authority (NEMA) and India has Central Pollution Control Board (of government of India).

However, the study done in India differ with the current study to the point that; this study identifies liquid and thermal wastes are the other type of wastes generated from tea factories apart from solid wastes. India study only identify solid fibre wastes as the only waste that results in black tea production

4.2.2. Analysis of waste management in the Maramba Tea Factory

In order to analyse the waste management systems at Maramba Tea Factory, the amount of solid, liquid and thermal wastes generated were determined. The quality of wastewater generated was also determined respectively.

I. The Quantities of Solid Wastes generated at Maramba Tea Factory

The data collected and analysed shows that highest amount of solid waste was generated at the withering stage at an average weight of 356.3 kilograms per month representing 71% of total Solid waste generated. This was as a result of spillages caused by overloading of some of the troughs. Solid wastes at offloading bay was second highest at 63.2 kilograms representing 12.59% total solid waste generated, due to spillages resulting from the manner of handling during offloading. Sorting stage generated the least amount of solid wastes at an average of 10.96 kilograms per month representing 2.18% of solid wastes generated as indicated in Table 4.2 and 4.3 and Figure 4.1 and 4.2. The result also shows a variation of solid waste generated between the periods of the study. This was due to variation in amount of green leaves supplied through the study period. The results agree with the study done by Oirere (2015), which showed that more solid wastes is generated at withering stage of tea production process.

II. The Quantities of Liquid Wastes Generated at the Maramba Tea Factory

The amount of liquid waste generated at Maramba Tea Factory was estimated from water used during the tea production process. According to Metcalf et al, (2003), 80% of this water consumed is estimated to be wastewater. The readings were obtained from the water meter readings for water used in minor daily cleaning and major weekly cleaning respectively.

The data collected represented in Table 4.4 and analysed in Figure 4.3, shows that the amount of liquid waste generated for major cleaning at the Maramba Tea Factory ranged between 102.4 $m^3$and 121.6 m^3 respectively per month for the period of study. The highest amount of wastewater generated was in November 2016 at 121.6 m^3 and least amount in July 2016 at 102.4 m^3. The minor cleaning which was done daily had the highest amount of wastewater in November 2016 at

46.8 m^3 and least amount generated in July 2016 at 38.4 m^3. High amount of liquid wastes generated at both Major and minor cleaning respectively was a result of wastage by those assigned to that the cleaning. They sometime left the water taps not tightly closed and others using large amount of water for cleaning while they could do same task with less amount of water.

III. The Quantities of Thermal Waste Generated at the Maramba Tea Factory

The wood fuel used at Maramba Tea factory were Eucalyptus Globulus Blue gum) and Grivillea Robusta. In order to determine the quantities of thermal wastes generated at the factory, calorific value of these wood fuels was determined. The various heat losses that were determined include; loss of heat due to dry flue gas, loss of heat due to hydrogen, heat loss due to moisture in air, heat loss due to moisture in fuel and losses due to radiation. The ultimate analysis of the wood fuel as shown in Table 4.5 was adopted from study done by Gravalos et al (2016) "An Experimental Determination of Gross Calorific Value of Different Agroforestry Species and Bio-Based Industry Residues

From the data collected and analysed, the total amount of heat loss is 1145.51kcal/kg which represents 37.45%. of the GCV of wood fuel. The highest heat loss being due to dry flue gas with a 22.09% of GCV of wood fuel representing 675.85kcal/kg and the least being due to moisture present in the combustion air at 24.78kcal/kg representing 0.810 % of the total GCV of wood fuel.

This gives boiler efficiency at Maramba Tea Factory of 62.55%. However, Patro (2015) and the Council of Industrial Boiler Owners (CIBO) recommends wood fuel energy-based boiler efficiency of 75.01% and 75% respectively. Consequently, the boiler efficiency though at above average level of 62.55% it is still below the set values of 75.01% and 75% for wood fuel based boiler efficiencies. This explains the high heat loss experienced at the factory.

IV. Quality parameters of wastewater generated during the tea production process at the factory

From the data collected and analysed, the following wastewater quality parameters were measured:

i. Biochemical Oxygen Demand (BOD_5) in mg/L

ii. Chemical Oxygen Demand (COD) in mg/L

iii. Electrical conductivity (EC) in Seimens per centimetre

iv. pH level.

The result in Table 4.7 shows that values of BOD_5, COD, EC and pH vary from the sample points (from the source at Mini lagoon 1 to entry to the stream respectively). These change in water parameter shows that the wastewater treatment systems have an effect in reducing the values of this water quality parameter. However, as shown in Table 4.7, the downstream values of BOD_5 at 81.87mg/L and COD at 106.63mg/L, are higher than the NEMA recommended maximum values of 30 BOD5 at 30mg.L and COD at 50mg/L respectively.

On the other hand, the value of pH at 7.1 and EC at 31.86S/cm are within the NEMA recommended values of pH at 6.5-8.5 of river water and EC at 80-160 S/cm respectively.

4.2.3. Evaluating the effectiveness of the wastes management systems in Maramba Tea Factory

I. Solid Waste Management Systems at the factory

The solid wastes generated at factory are both organic and inorganic wastes. These wastes are not segregated. Currently there were clear disposal method (no landfills and compositing) used to dispose of organic wastes, rather they are just disposed of in garden that has banana plantation next to the factory premises. The amount of organic solid waste collected averaged of 486.47 kilograms per month. The inorganic solid wastes averaged 15.38 kilograms per month which included polythene bags and sacks. However, these organic wastes and inorganic wastes generated are not segregated at the factory, they are mixed.

The other type of inorganic solid wastes were scrap metals which were well segregated as aluminium foils and metals and Mild steels metals which were placed at designated place. I was informed by the factory management that they dispose of this scrap metals by selling them for recycling.

The amount of measured solid wastes was compared to the amount of expected solid wastes from Green Tea and the measured Blacked Tea Measured respectively as presented in Table 4.9. It was observed that the amount of measured solid wastes was only 3% of the expected solid wastes.

It was observed that the solid wastes generated at the factory had not been segregated in terms of the type and amount apart from scrap metal wastes. All organic wastes generated at the factory were disposed in a banana garden at the factory premises.

The solid wastes are not managed as per the requirement of NEMA regulations through gazette notice of 7th December 2007.

The Solid wastes management at the factory is only partially effective.

II. Wastewater Management Systems at the Factory

In order to evaluate the effectiveness of the wastewater management systems, the following parameters were determined to give the indicative quality of wastewater generated: Biological Oxygen Demand (BOD_5^{20}), Chemical Oxygen Demand (COD), PH, Electrical Conductivity (EC), and. The measured results were compared with the established NEMA standards as shown in Tables 4.10, 4.11, 4.12, 4.13 respectively.

Furthermore, in analysing the effectiveness of the waste management systems, ANOVA single factor tool was used to determine statistically if the was a change in wastewater parameters; Biological Oxygen Demand (BOD_5^{20}), Chemical Oxygen Demand (COD), PH, Electrical Conductivity (EC) along the source stage to disposal stage at the stream. The analysis with ANOVA shows significant different in the water parameter values from source through the lagoon to the river. This is evident with the values of $P<0.05$, and $F>F$ critical for all the water quality parameter analysed. This is shown in Tables 4.14 to Table 4.21 respectively.

The results were also compared to the maximum allowable discharge limits to the environment values set by NEMA as shown in Tables 4.10, 4.11, 4.12, 4.13 respectively. The values were higher for BOD_5, and COD. While they were within acceptable range for EC and PH parameters.

The values of biochemical oxygen demand (BOD5) and chemical oxygen demand (COD) exceeds the maximum allowable discharge limits of effluent to the environment by NEMA. This indicates the lagoons are not 100% effective in treating the wastewater to the required limits of 30mg/L and 50mg/L for BOD5 and COD respectively.

III. Thermal Management Systems at the Factory

In order to determine the effectiveness of the thermal waste management systems at the factory, the boiler efficiency was determined. Mallick (2015) indirect method also called the heat loss method was applied.

From the data collected and analysed, the Boiler efficiency at Maramba Tea Factory was 62.55%. However, Patro (2015) and the Council of Industrial Boiler Owners (CIBO) recommends wood fuel energy-based boiler efficiency of 75.01% and 75% respectively. Consequently, the boiler efficiency though at above average level of 62.55% it is still below the set values of 75.01% and 75% for wood fuel-based boiler efficiencies. This shows the boiler is only partially effective to a recommended value and hence there is a lot of energy is lost through heat losses.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

I. From the data collected and analysed, the type of wastes identified were solid (which could be classified as organic and inorganic solid wastes, liquid wastes and thermal wastes). Study showed solid wastes are not classified and segregated into organic and inorganic wastes from the tea processing stages.

However, the scrap metals are segregated into aluminium foils and mild steel which are disposed- off by selling to the scrap metal dealer.

II. On the waste management systems, it was observed that there was no clear solid waste disposal system for both organic solid wastes and inorganic solid wastes at generated at the factory. Some of the solid wastes are thrown in the banana garden at the factory. The quantities of the solid wastes generated at factory were highest at the withering stage with an average weight of 356.3 kilograms per month representing 71% of total Solid waste generated. The least solid wastes were generated at sorting stage at an average of 10.96 kilograms per month representing 2.18% of solid wastes generated.

The amounts of liquid wastes generated for the study period were estimated at 80% of the amount of water used. The highest with major cleaning which happens once a week estimated an average of 111.52m^3 per month and least with minor cleaning which averaged at 42.24m^3 per month

The quantity of thermal wastes determined from heat loss. The total amount of heat loss was found to be 1145.51kcal/kg which represents 37.45%. of the GCV of wood fuel. The highest heat loss being due to dry flue gas with a 22.09% of GCV of wood fuel representing 675.85kcal/kg and the least being due to moisture present in the combustion air at 24.78kcal/kg representing 0.810 % of the total GCV of wood fuel.

III. In evaluating effectiveness of the waste management systems at the factory. It was observed that the solid wastes generated at the factory had not been classified and segregated in terms of the type and amount apart from scrap metal wastes. All organic wastes generated at the factory was disposed in a banana garden at the factory premises. The solid wastes are not managed as per the requirement of NEMA regulations through gazette notice of 7th December 2007. However, the scrap metals were segregated.

The liquid wastes management systems at the factory were the lagoons. The wastewater parameter measured at downstream BOD5 at 83.7mg/L COD at 106.63mg/L, EC at 31.87S/cm and pH at 7.1. when these values are compared to NEMA recommended standard value, the BOD5 and COD are higher than the NEMA standards values of 30mg/L and 50mg/L respectively. This shows that the lagoons are not 100% effective in treating the wastewater. However, the pH values and EC values are within the NEMA recommended values of 6.5-8.5 and 80-160 S/cm respectively.

It can be concluded that, the wastewater treatment system only partially effective.

The thermal waste systems were evaluated by determining the boiler efficiency. Boiler efficiency at Maramba Tea Factory was 62.55%. However, Patro (2015) and the Council of Industrial Boiler Owners (CIBO) recommends wood fuel energy-based boiler efficiency of 75.01% and 75% respectively. Consequently, the boiler efficiency though at above average level of 62.55% it is still below the set values of 75.01% and 75% for wood fuel based boiler efficiencies. This shows the boiler was just partially effective to a recommended value and hence there is a lot of energy is lost through heat losses.

IV. The research hypotheses were tested.

a. There were different types of wastes generated at the factory

b. The quality of wastewater generated at the factory exceeded the maximum NEMA standards value for BOD_5 and COD

c. The waste treatment systems at the factory was not effective

5.2 Recommendations

I. Regular wastewater parameter analysis to be effected to check compliance standards and the effectiveness of the waste treatment systems.

II. Most organic solid wastes should be investigated to determine whether they can be recycled as away managing the waste. For instances greens leaf wastes and cartons wastes used for packing should be reused as a source of energy in the boiler.

III. The wastewater used in major cleaning should be recycled and proper water use practices should be encouraged at the factory to avoid wastages. For instance, closing the water taps tightly when not in use. Cleaning only when it is necessary.

IV. Landfilling and compositing should be adopted as a Solid wastes disposal system. Preferably the organic solid waste should be disposed in a landfill and composite bit to use them later a source of energy.

V. More studies need to be carried out to establish the state of waste management systems in food industries in Kenya. A single or two studies cannot be compressive used to generalize or the factory in Kenya

VI. In order to reduce heat loss at the factory, the boiler efficiency needs to be increased. For instance, pipe lagging should to reduce heat losses

VII. The design parameters of the current wastewater treatment lagoons should be investigated to increase its effectiveness. The lagoons should be protected from inflow of debris that end up filling it. Other wastewater treatment methods should be considered that can recover and treat the wastewater for recycling at the factory.

VIII. The trough beds should not be overloaded to reduce high amount of solid wastes at withering stage. Tea leaves handling during offloading should be done with the aim of reducing green leaves spillages.

6. REFERENCES

ABDULKADIR KAN (2009): *General characteristic of Waste management***.** Science and Technology Part a: Energy Science and Research 01/22009; 23(1): 55-69

AGAMUTHU, P. (2002): *Solid Waste: Principles and Management,* University of Malaya, Kuala Lumpur. Pp.153

AGWU, L (2012). *Waste collection multi objective model with real time traceability data*. Journal of Waste Management 31, 2391–2405

AGNIESZKA GENEROWICZ, AND KRZYSZTOF GASKA,(2015): *The Selection of An Appropriate Waste Management System For The City of Zabrze Using Multi-Criteria Analysis.*

ASAE (2010): *Design of Anaerobic Lagoons for Animal Management***.** AABE standards 2010 pp.814-818

ARCHANA SHIRKE (2009): *Municipal Solid Waste Management*. http://mahenvis.nic.in/Pdf/MSW_.pdf. Accessed on December 2016

ANURAG CHOWDHURY, SATYAJIT SARKAR, AKASH CHOWDHURY, SOUMIK BARDHAN, PALASH MANDAL AND MONORANJAN CHOWDHURY (2017). *Tea Waste Management: A Case Study from West Bengal, India.*

BABCOCK & WILCOX CO (2007): *Steam, Its Generation and Use*

Basel Convention (1989). T*he Control of Transboundary Movements of Hazardous Wastes and Their Disposal*. Retrieved 2018-09-01

BOMA QUEBEC TASK FORCE ON WASTE MANAGEMENT (2016): *The Guide to Efficient Waste Characterization.* Canada

BRUNDABAN PATRO (2015): *Efficiency studies of combination tube boilers*: National Institute of Technology Rourkela, Odisha 769008, India

BRUNNER, PH AND ERNST, WR (1986): *Alternative Methods for the Analysis of MSW, Waste Management & Research*; Vol4, pp 147 160.

CENTRAL POLLUTION CONTROL BOARD (CPCB) (2008**):** *The Environment Protection Act* in India

DAS, S.K., (2006): *Further Increasing the Capacity of Tea Leaf Withering Troughs.* Agricultural Engineering International: The CIGR Journal. Manuscript FP 05 012. Vol. January

DANIEL HOORNWEG AND PERINAZ BHADA-TATA (2012): "*WHAT A WASTE": A Global Review of Solid Waste Management*. *Urban Development Series Knowledge Papers no.15*. Washington, DC 20433 USA

DIVYA C. BORKAR SHRUTI S.ACHARYA, V.P (2014): *Creating a 'Eco City' in India*: vol. 2 (9) 54-61

ESAYAS ALEMAYEHU (2004). *Solid and Liquid Waste Management For Health Extension Workers*. Jimma University n collaboration with the Ethiopia Public Health Training Initiative, The Carter Center, the Ethiopia Ministry of Health, and the Ethiopia Ministry of Education

EUGENE L. KEATING (2007): *Applied Combustion*, Second Edition**,** CRC Press (Taylor and Francis Group), NY

FINLAYS SINCE 1750. *Our Business History*.at http://www.finlays.net/our-business/history/. Retrieved on 19 January 2017

FRANKE M. (1999): **"***The Application of Experience of European Waste Management to Latin American Conditions***"** Seminarionternational. Gestion intergral De ResiduosSolidos Y Peligroso, silgo xxi

GABLER (2014): http://wirtschaftslexikon.gabler.de/Archiv/2297/benchmarking-v7.html. Accessed on 10th September 2018

GEORGE TCHOBANOGLOUS AND FRANK KREITH, (2002)*: Handbook of Solid Waste Management.* New York: McGraw Hill,

GOVERNMENT OF KENYA (2006,): *The Environmental Management and Coordination Act, 200*6. Government of Kenya Press

GOVERNMENT OF KENYA (2011): *The Tea (Amendment) Act NO. 4 of 2011***.** Government of Kenya Press

GOVERNMENT OF KENYA (2002): *Water Act 2002***.** Government of Kenya Press

GOVERNMENT OF KENYA (2006): *Water Resource Management Authority 2006***.** Government of Kenya Press

HEIMLICH, J. E., HUGHES, K.L., CHRISTY, A.D. (2001): *Integrated Solid Waste Management.* Louisiana Cooperative Extension service U.S.A

KREITH, F. (2008). *Handbook of solid waste management (2nd ed).* Europe: McGraw-Hill Professional.

IKIARA, M.M., KARANJA, A.M., AND DAVIES, T.C (2004): **'***Collection , Transportation and Disposal of Urban Solid Waste in Nairobi', in Baud, I., Post, J. and Furedy, C (eds), Solid Waste management and Recycling: Actors, Partnerships and Policies in Hyderabad, India and Nairobi, Kenya, Chapter 4, Kluwer Academic* Publishers, Dordrecht, The Netherlands.

ISO 1928: 2009: *Solid Mineral Fuels. Determination of Gross Calorific Value by the Bomb Calorimetric Method and Calculation of Net Calorific Value*

INSITUTE OF DEVELOPING ECONOMIES-JAPAN EXTERNAL TRADE ORGANIZATION (IDE-JETRO) (2009): *African Growing Enterprise (AGE) File*. Mihama-ku, Chiba-shi, Chiba, 261-8545.Japan

KUMAR, P. (2010): T*raining Manual on Energy Efficiency for Small and Medium Enterprises. Asian Productivity Organisatio*n, ISBN: 92-833-7084-8

MALLICK, AMIYA RANJAN (2015): *Practical Boiler Operation Engineering and Power* Plant, Fourth Edition, Delhli

MACLAREN, Y. (2000). *Improvement and modification of the routing system for the health-care waste collection and transportation in Istanbul*. Journal of Waste Management 28, 1461–1471

METCALF & EDDY INC., G. TCHOBANOGLOUS, F. L. BURTON, AND H. D. STENSEL, (2003). *Wastewater Engineering: Treatment and Reuse*, Fourth Edition. McGraw-Hill, New York.

MILLER, R., MAJOR, J. AND TRINCA, P. (2011): *How a Lagoon Works*. Extension Publications: Cooperative Extension Services. Utah State University

M'RIBU, JACKSON (2006). *A study of waste management approaches in tea processing factories*: Case study of Smallholder tea factories in Kenya.

NIRMAL HALDER (2016): *Characterization of Tea waste and Cooked waste as a potential feedstock for Biogas production*. Department of Mechanical Engineering, Indian Institute of Technology kanpur, Kanpur

OWOUR, P.O., OBANDA, M., NYIRENDA, H.E. AND MANDALA, W.L. (2008): *Influence of Region of Production on Clonal Black Tea Characteristics*. Food Chemistry, 108, pp.262-271

PRASERTSAN, P., PRASERTSAN, S. AND KITTIKUN, A. (2008*): Recycling of Agro-Industrial Wastes through Cleaner Technology*. Prince of Songkla University, Hat Yai, Thailand

RUDRAMOORTHY, R., SUNIL KUMAR, C.P., VELAVAN, R., SIVASUBRAMANIAM, S. (2000): *Innovative Measures for Energy Management in Tea Industry PSG College of Technology*, Coimbatore-641 004

SAMIR SARKAR (2009): *Fuels and Combustion*, ,3rd Edition, University Press, India.

SUDHAKAR YEDLA (2005): *Modified Landfill Design for Sustainable Waste Management*. International Journal of global Energy issues Vol. 23 (1), 93-105

STOCKHOLM ENVIRONMENT INSTITUTE, (2009): Economics of Climate Change Kenya Project report; http://www.sei-international.org/mediamaanager/document/ Publications/Climate-mitigation-adaptation/Kenya-climatechange.pdf (Accessed on 10th October, 2015)

S.S. CHUNG AND C.S. POON (1996): *Evaluating waste management alternatives by the multiple criteria approach. Journal of Resources, Conservation and Recycling. Volume 7*, page 189-210. Elsevier B.V

TEA BOARD OF KENYA (TBK) (2015): *National Survey on Processing Capacity Needs for Tea Industry. Report*. Unpublished

TIPTON, T.V., YOKOYAMA, K.M., WANITPRAPHA, K. AND NAKAMOTO, S.T (1990): *Tea Economics Fact Sheet No.8.* University of Hawaii, College of Tropical agriculture and Human resources, pp.4

THE COUNCIL OF INDUSTRIAL BOILER OWNERS (CIBO) (1978): *Energy Efficiency and Industrial Boiler Efficiency; An Industry Perspective*

TRFK (2014,): *The tea Growers hand Book.* The Tea Research Foundation of Kenya Printing services.

UNITED NATION- ESCAP (1997). Introduction type of wastes.

UNITED NATION ENVIRONMENTAL PROGRAMME, (2005). *Solid Waste Management: Volume 1*, Calrecover Incorporation.

UNITED STATE ENVIRONMENTAL PROTECTION AGENCY (2017).*Recycling Basics*. At https://www.epa.gov/recycle/recycling-basics. Retrieved on 19 May 2017

USEPA (2004): *Primer for Municipal wastewater treatment systems.* Office of Water; Wastewater management, Washington Dc 20460

YAMAMOTO, T; KIM, M; JUNEJA, L R (1997). Chemistry and Applications of Green Tea. CRC Press. p. 4. ISBN 0-8493-4006-3.

YASUHIKO WADA, TAKUMA OKUMOTO AND NARIAKI WADA (2008): *Evaluating waste disposal systems*. Civil and Environmental Engineering, Faculty of Engineering, Kansai University, Yamate 3-3-35, Suita, Osaka 564-8680, Japan

ZHANG, R. (2001): *Biology and Engineering of Animal Wastewater lagoons.* California Plant and Soil Conference, California Chapter of American Society of Agronomy

APPENDICES

Appendix 1.

1.1. Waste Weight from Off-loading area (cleared)

Table 7.1.: Waste Weight from Off-loading area

Day	July, 2016	August, 2016	Sept, 2016	October, 2016	November, 2016
1	2	2	2	2	2
2	0	3	1	0	4
3	0	2	3	3	3
4	2	2	0	3	2
5	3	2	3	2	2
6	2	2	4	3	0
7	2	0	3	2	3
8	3	3	2	3	4
9	2	3	3	0	2
10	0	2	2	4	3
11	3	2	0	3	3
12	2	2	2	2	4
13	0	0	1	1	0
14	3	0	2	4	4
15	2	1	4	3	2
16	3	2	3	0	3
17	0	2	2	3	3
18	2	2	0	3	4
19	3	2	2	4	3
20	4	2	3	3	0
21	3	0	4	4	3
22	2	4	2	3	3

Day	**July, 2016**	**August, 2016**	**Sept, 2016**	**October, 2016**	**November, 2016**
23	0	2	1	3	3
24	2	1	2	4	4
25	0	2	0	0	3
26	2	1	3	3	2
27	0	2	1	1	0
28	2	0	2	3	2
29	3	1	2	2	2
30	2	2	1	0	3
31	0	2	0	2	0
Count	**31**	**31**	**30**	**31**	**30**
Average	**1.742**	**1.710**	**2.0**	**2.355**	**2.533**
Total	**54**	**53**	**60**	**73**	**76**

1.2. Wastes from beds in kgs

Table 7.2: **Waste from Beds in Kilograms _ Withering Stage**

Period	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**Count**	**Average**	**Total**
Nov. 2016	62	64.5	68	70	72	76	6	68.75	412.5
Oct-16	60.5	59	62	64.5	69	70.5	6	64.25	385.5
Sept. 2016	54	56	58	60	64	66	6	59.667	358
Aug. 2016	50	48.5	50	54.5	61.5	62.5	6	54.5	327
July. 2016	48	46	48.5	50.5	52.5	53	6	49.75	298.5
Count	5	5	5	5	5	5			
Average	54.9	54.8	57.3	59.9	63.8	65.6		**59.3833**	
Total	274.5	274	286.5	299.5	319	328			

1.3. Waste Pekoe (CTC)

Table 7.3: Waste Pekoe Dust (CTC)

Day	July, 2016	Aug, 2016	Sept, 2016	Oct, 2016	Nov, 2016
1	0.5	0.5	1	1	1
2	0.5	1	1	0	1
3	0	0	0.5	1	0.6
4	1	0.5	0	0.5	1
5	0.5	1.5	1.5	1	1.5
6	1	1	1	1.2	0
7	0.5	0	1	1	1.3
8	0	1	0.5	0.5	0.5
9	1	1.2	1	0	1.5
10	0	0	1	1.6	1.6
11	1	1	0	1	1
12	1.5	0.5	0.5	1.5	1.5
13	1	1	0.5	0.5	0
14	1	0	0	1	1
15	0.5	0.5	1.5	1.5	0.5
16	1	1	0.5	0	1
17	0	0.5	1.5	1.5	1.5
18	0.5	1	0	1	1
19	1	1	1	1	0.5
20	1	0.5	1	0.5	0
21	1.5	0	1	1	1
22	0	0	0.5	1	1.6
23	1	1	1	0	1
24	0	1	0.5	1.5	0.5
25	0.55	0.5	1	0.5	1
26	1	1	0	1	1.5
27	1	0.5	1	1	0

Day	July, 2016	Aug, 2016	Sept, 2016	Oct, 2016	Nov, 2016
28	0	0	0	0	1
29	0.5	1	0.5	0.5	1.5
30	0.5	0.5	0	0	1
31	0	0	0	1	0.5
Count	31	31	30	31	30
Average	**0.63**	**0.62**	**0.68**	**0.8**	**0.95**
Total	**19.55**	**19.2**	**20.5**	**24.8**	**28.6**

1.4. Waste Pekoe Dust

Table 7.4: Waste Pekoe Dust (Drying)

Day	July, 2016	Aug, 2016	Sept, 2016	Oct, 2016	Nov, 2016
1	0.5	1.5	1	1	1.5
2	1.5	1	1.5	0	1
3	0	0	0.5	1	0.6
4	1	0.5	0	1.5	1
5	0.5	1.5	1.5	1	1.5
6	1	1	1	1.5	0
7	1.5	0	1	1	1.3
8	0	1	1.5	0.5	1
9	1	1.5	1	0	0.5
10	0	0	1	1.6	1
11	1	1	0	1	1
12	1.5	1.5	0.5	1.5	1.5
13	1	1	1.5	0.5	0
14	1	0	0	1	1
15	0.5	1.5	1.5	1.5	0.5
16	1	1	0.5	0	1
17	0	0.5	1.5	1.5	1.5

Day	July, 2016	Aug, 2016	Sept, 2016	Oct, 2016	Nov, 2016
18	1.5	1	0	1	1
19	1	1	1	1	1.5
20	1	1.5	1	0.5	0
21	1.5	0	1	1	1
22	0	0	1.5	1	1.6
23	1	1	1	0	1
24	0	1	0.5	1.5	0.5
25	1	1.5	1.5	0.5	1
26	1	1	0	1	0.5
27	1	0.5	1	1	0
28	0	0	0	0	1
29	0.5	1	1	1.5	1
30	1	1.5	1.5	0	1
31	0	0	0	1	0.5
Count	31	31	30	31	30
Average	**0.76**	**0.82**	**0.88**	**0.87**	**0.92**
Total	**23.50**	**25.5**	**26.5**	**27.1**	**27.5**

1.5. Waste Pekoe Dust (sorting)

Table 7.5: Waste Pekoe Dust (Sorting)

Day	July,	August , 2016	September,	October,	November, 2016
1	0.5	0.5	0.5	0.5	0.2
2	0.5	0.5	0.4	0	0.5
3	0	0	0.5	0.5	0.4
4	0.5	0.5	0	0.5	0.5
5	0.5	0.2	0.5	0.2	0.5

Day	**July,**	**August , 2016**	**September,**	**October,**	**November, 2016**
6	0.5	0.4	0.4	0.5	0
7	0.5	0	0.5	0.5	0.5
8	0	0.2	0.5	0.5	0.5
9	0.5	0.5	0.5	0	0.5
10	0	0	0.5	0.5	0.5
11	0.5	0.5	0	0.3	0.5
12	0.6	0.5	0	0.4	0.5
13	0.5	0.4	0.5	0.5	0
14	0.4	0	0	0.5	0.5
15	0.5	0.3	0.5	0.5	0.3
16	0.3	0.2	0.5	0	0.5
17	0	0.5	0.5	0.4	0.4
18	0,6	0.8	0	0.5	0.5
19	0.5	0.3	0.5	0.3	0.3
20	0.7	0.5	0.6	0.5	0
21	0.4	0	0.5	0.4	0.5
22	0	0	0.5	0.3	0.2
23	0.5	0.5	0.5	0	0.5
24	0	0.5	0.3	0.5	0.3
25	0.2	0.6	0.5	0.5	0.5
26	0.5	0.5	0	0.5	0.5
27	0.3	0.5	0.4	0.4	0
28	0	0	0	0	0.4
29	0.5	0.2	0.4	0.5	0.5
30	0.8	0.5	0.5	0	0.3
31	0	0	0	0.5	0.5
Count	31	31	30	31	30
Average	**0.35**	**0.33**	**0.37**	**0.36**	**0.39**

Day	July,	August , 2016	September,	October,	November, 2016
Total	**10.70**	**10.1**	**11**	**11.2**	**11.8**

1.6. Waste Pekoe Dust (Packaging)

Table 7.6: Waste Pekoe Dust (packaging)

Day	July, 2016	August, 2016	Sept, 2016	Oct,	Nov, 2016
1	0.3	0.3	0	0.2	0.2
2	0.2	0.2	0.4	0	0.3
3	0	0	0.5	0.5	0
4	0.3	0.5	0	0.5	0.2
5	0.2	0.2	0.2	0	0.5
6	0.2	0.4	0.4	0.5	0
7	0.3	0	0.5	0.2	0.4
8	0	0.2	0	0.5	0.2
9	0.5	0.5	0.4	0	0.3
10	0	0	0.5	0.2	0.4
11	0.5	0.4	0	0.3	0.3
12	0.4	0.3	0	0.4	0.2
13	0.2	0.4	0.5	0	0
14	0.4	0	0	0.5	0.5
15	0.4	0.3	0.5	0.2	0.3
16	0.3	0.2	0	0	0.3
17	0	0.3	0.5	0.4	0.4
18	0.3	0.4	0	0.3	0.5
19	0	0.3	0.5	0	0.3
20	0.3	0.2	0.4	0.5	0
21	0.4	0	0.2	0.4	0

Day	July, 2016	August, 2016	Sept, 2016	Oct,	Nov, 2016
22	0	0	0	0.3	0.2
23	0.4	0.5	0.5	0	0.2
24	0	0.3	0.3	0.3	0.3
25	0.2	0.2	0.4	0.2	0.2
26	0.2	0.3	0	0.3	0.5
27	0.3	0.5	0.4	0.4	0
28	0	0	0	0	0.4
29	0.3	0.2	0.4	0.2	0.3
30	0.2	0.5	0.2	0	0.3
31	0	0	0	0	0.2
Count	31	31	30	31	30
Average	**0.22**	**0.25**	**0.26**	**0.24**	**0.26**
Total	**6.80**	**7.6**	**7.7**	**7.3**	**7.9**

1.7. Solid Waste data

Table 7.7: **Solid waste Data (Weight in Kgs)**

Section	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Total	Mean
Offloading Bay	54	53	60	73	76	316	63.2
Withering	298.5	327	358	385.5	412.5	1781.5	356.3
Maceration (CTC)	19.55	19.2	20.5	24.8	28.6	112.65	22.53
Drying	23.5	25.5	26.5	27.1	27.5	130.1	26.02
Sorting	10.7	10.1	11	11.2	11.8	54.8	10.96
Packing	6.8	7.6	7.7	7.3	7.9	37.3	7.46
Sacks and Polythene Bags at Packaging	14.9	15.0	15.3	15.9	15.8	76.9	15.38

Section	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Total	Mean
Total(exclusive of sacks and polythene bags	**413.1**	**442.4**	**483.7**	**528.9**	**564.3**	**2432.35**	**486.47**

1.8. Wastewater data

Table 7.8: Amount of Wastewater generated monthly from July 2016 – November 2016

Months	Major cleaning (m^3)	Minor cleaning (m^3)
July 2016	128	48
August 2016	130	50
September 2016	139	52
October 2016	148	56
November 2016	152	58
Total (m^3)	**697**	**264**

1.9. Maramba Tea Factory Green Leaf And Made Tea Recorded From July 2016 To November 2016

Table 7.9: Amount of Green Leaf and Made Tea Recorded From July 2016 to November 2016

MARAMBA TEA FACTORY LTD		
MONTH	**GREEN LEAF(KGS)**	**MADE TEA**
NOVEMBER 2016	1,757,977.00	455,651.00
OCTOBER 2016	1,711,755.00	435,016.00

SEPTEMBER 2016	1,357,540.00	346,819.00
AUGUST 2016	1,248,005.00	303,062.50
JULY 2016	1,197,850.00	288,903.00

Source (Maramba Tea Factory Limited)

1.10. Quality Parameters (PH, EC, BOD5 and COD)

Table 7.10: Quality Parameters

LOCATION	**Samples No.**	**PH**	**EC (S/cm)**	**BOD_5 (mg/L)**	**COD (mg/L)**
MIN LAGOON 1 (ML1)	Sample 1	6.40	450.50	250.20	810.50
	Sample 2	6.50	420.60	240.50	809.80
	Sample 3	6.58	430.50	230.45	811.30
MIN LAGOON 2 (ML 2)	Sample 1	6.59	415.22	230.10	790.30
	Sample 2	6.58	405.50	235.40	795.00
	Sample 3	6.61	407.20	220.25	793.20
MIN LAGOON 3 (ML3)	Sample 1	6.63	388.00	215.20	600.40
	Sample 2	6.65	390.50	210.30	603.40
	Sample 3	6.70	396.60	209.70	610.50
SUB LAGOON 1 (SL 1)	Sample 1	6.50	320.50	203.16	560.30
	Sample 2	6.56	330.00	204.50	550.20
	Sample 3	6.67	340.90	199.25	556.90

LOCATION	**Samples No.**	**PH**	**EC (S/cm)**	**BOD_5 (mg/L)**	**COD (mg/L)**
SUB LAGOON 2 (SL 2)	Sample 1	6. 60	240.45	189.25	520.70
	Sample 2	6.64	280.05	184.20	510.46
	Sample 3	6.67	210.15	180.60	509.50
	Sample 1	6.89	150.00	130.80	230.20
MAN HOLE (EXIT TO STREAM)	Sample 2	6.90	149.99	128.46	220.40
	Sample 3	6.93	151.20	126.50	218.50
AT POINT OF ENTRY TO STREAM	Sample 1	6.95	40.90	118.30	110.45
	Sample 2	6.97	45.75	105.30	110.50
	Sample 3	6.98	50.60	110.00	109.40
UPSTREAM	Sample 1	7.20	30.90	85.20	105.20
	Sample 2	7.30	30.75	84.20	104.80
	Sample 3	7.25	35.80	81.70	105.30
DOWNSTREAM	Sample 1	7.05	29.70	83.00	108.20
	Sample 2	7.10	30.10	82.00	107.30
	Sample 3	7.15	35.80	80.60	104.40

1.11. Boiler Data

II. Flue gas temperature, T_f = 280 °C

III. Ambient temperature T_a= 25.5 °C

1.11. Bomb calorimeter Data and Calculations

Mass of empty crucible 12.5gm

Mass of crucible + fuel 13.5gm

Mass of fuel 1.0gm

Volume of water in calorimeter in 1750gm

Water equivalent of bomb 520gm

Total equivalent of water 2270gm

Table 7.11: Calorific Test Data

Time (Mins)	Test Sample (Diesel)	Sample 1	Sample 2	Sample 3	Sample 4
0	25.4	28.4	21.4	20.6	20.4
1	25.6	28.3	21.4	20.7	20.4
2	25.7	28.4	21.4	20.7	20.4
3	25.7	28.3	21.4	20.7	20.4
4	25.8	28.3	21.5	20.7	20.4
5	25.8	28.3	21.5	20.7	20.4
5.5	25.8	28.2	21.4	20.7	20.3
6	25.8	28.3	21.5	20.7	20.3
6.5	25.8	28.3	21.5	20.7	20.4
7	25.8	28.2	21.4	20.7	20.4
7.5	26.2	28.2	21.4	20.7	20.4
8	26.3	28.2	21.4	20.7	20.4
8.5	26.5	28.4	21.4	20.8	20.4
9	26.6	28.7	21.5	21	20.6

Time (Mins)	Test Sample (Diesel)	Sample 1	Sample 2	Sample 3	Sample 4
9.5	26.7	29	21.6	21.2	20.9
10	26.7	29.1	21.7	21.4	21.1
10.5	26.7	29.2	21.9	21.5	21.2
11	26.7	29.4	22	21.6	21.4
11.5	26.7	29.5	22.1	21.7	21.5
12	27.1	29.5	22.1	21.7	21.6
12.5	27.1	29.6	22.2	21.8	21.6
13	27.1	29.6	22.2	21.8	21.6
13.5	28.3	29.6	22.2	21.9	21.6
14	28.4	29.6	22.3	21.9	21.6
14.5	28.8	29.6	22.3	21.9	21.6
15	28.9	29.7	22.3	21.9	21.7
15.5	30.3	29.7	22.3	21.9	21.7
16	30.3	29.6	22.2	21.9	21.7
16.5	30.4	29.6	22.3	22	21.7
17	30.8	29.7	22.2	22	21.7
18.5	31.0	29.6	22.2	22	21.7
19	31.1	29.6	22.3	22	21.7
19.5	31.1	29.6	22.3	22.1	21.8
20	31.1	29.6	22.3	22.1	21.8
20.5	31.1	29.6	22.3	22.1	21.8
21	31.1	29.6	22.2	22.1	21.7
21.5	31.6	29.5	22.2	22.1	21.7
22	31.7	29.6	22.3	22	21.7
22.5	31.8	29.6	22.3	22.1	21.8
23	31.2	28.8	21.5	22.1	21.2

Time (Mins)	Test Sample (Diesel)	Sample 1	Sample 2	Sample 3	Sample 4
23.5	31.2	28.8	21.5	22.1	21.2
24	31.2	28.7	21.5	22.1	21.2
25	31.2	28.7	21.5	22.1	21.2

Calorific value is energy liberated when a unit mass or volume of fuel is burnt completely in the presence of oxygen

Gross calorific value or higher calorifc value is amount of heat evolved when a unit mass or unit volume of fuel is burnt completely in access supply of oxygen and the biproduct of combustion are allowed to cool at room temperature

Net calorific value or lower calorific value is amount of heat evolved when a unit mass or unit volume of fuel is burnt completely in access supply of oxygen and the biproduct of combustion are allowed to escape in the atmosphere

Gross Calorific value of Diesel is 45600KJ/Kg according to Engineering ToolBox (2003)

(Engineering ToolBox, (2003). Fuels - Higher and Lower Calorific Values. [Online] Available at: https://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html [Accessed 4 April 2018].)

Temperature rise due to diesel oil= 6.4 ^{0}C

Total equivalent weight = 2.27kg

Weight of fuel = 1×10^{-3} kg

If the initial and final temperatures of the water are measured, the energy released can be calculated using the equation

$$H = \Delta T\, mCp$$

Where;

H = heat energy absorbed (in kJ),

ΔT = change in temperature (in °C),

m = mass of water (in kg), and

C_p = specific heat capacity (4.18 J/g °C or 418kJ/kg °C for water)

The resulting energy value divided by grams of fuel burned gives the energy content (in kJ/kg).

$$Energy\ released\ by\ diesel\ fuel\ = H\ =\ \Delta T\ mCp =$$

$$Energy\ released\ by\ dieasel\ fuel =\ 6.4°C\ * \frac{4.18kJ}{kg}°C\ \ * 2.27kg$$

$$Energy\ released\ by\ diesel\ fuel\ = 60.72704\ kJ$$

$$HGV\ of\ diesel\ fuel\ = \frac{60.72704\ kJ}{1\times10^{-3}\ \text{kg}} = 60727kJ/kg$$

Energy liberated due to wood fuel

Average Temperature rise due to wood fuel = $\frac{1.5^{O}C+0.9^{O}C+1.5^{O}C+1.5^{O}C}{4} = 1.35^{0}c$

$$Energy\ released\ by\ diesel\ fuel\ = H\ =\ \Delta T\ mCp =$$

$$Energy\ released\ by\ dieasel\ fuel =\ 1.35°C\ * \frac{4.18kJ}{kg}°C\ \ * 2.27kg$$

$$Energy\ released\ by\ diesel\ fuel\ = 12.80961\ kJ$$

$$HGV\ of\ wood\ fuel\ = \frac{12.80961\ kJ}{1\times10^{-3}\ \text{kg}} = 12809.61kJ/kg$$

But 1 kcal = 4.187 kJ

= **3,059.522786 kcal/kg**

Table 7.12. Some example electrical conductivity values of various water sources

Water type	Electrical conductivity (µS/CM)
Deionised water	0.5-3
Pure rainwater	<15
Town water	200-<800
Freshwater rivers	0-800
Marginal river water	800-1600
Brackish water	1600-4800
Saline water	>4800
Seawater	51500
Industrial water	100-10000

Typical conductivity of waters:

Ultra pure water $5.5 \cdot 10^{-6}$ S/m

Drinking water 0.005 – 0.05 S/m

Sea water 5 S/m

Read more: https://www.lenntech.com/applications/ultrapure/conductivity/water-conductivity.htm#ixzz5JXKLcCw7

Appendix 2.

Plate 2.1: Lagoons

Plate 2.2:collecting Water Samples.

Plate 2.3: Stack of wood

Plate 2.4: Boiler

Plate 2.5: At Maramba Tea Factory

Plate 2.6: Metal Scraps

Plate 2.7: PH and EC Meter

Plate 2.8: Electrical conductivity determination

Plate 2.9: Pictorial showing Determination of COD of wastewater

Plate 2.10: Pictorial showing **Determination of BOD of wastewater**

Appendix 3.

Table 1: Maramba Tea Factory (Coordinates of the Factory Layout)

Point 1.1	**Degree ̊**	**Mins ´**	
S	01	08.063	
E	036	42.230	
Elevation	2040 m		
Point 1.2			
S	01	08.052	
E	036	42.213	
Elevation	2043 m		
Point 1.3			
S	01	07.987	
E	036	42.208	
Elevation	2049 m		
Point 1.4			
S	01	07.955	
E	036	42.260	
Elevation	2051 m		
Point 1.5			
S	01	08.071	
E	036	42.341	
Elevation	2038 m		
Point 1.6			
S	01	08.103	
E	036	42.284	

Point 1.1	**Degree ◌̊**	**Mins ́**	
Elevation	2047m		
Closed to the original starting point 1.1			

Note: the coordinates are taken clockwise from the gate corner

Table 2: Tea Process Coordinate Points

	degrees◌̊	**mins**	**Activities (Duration)**
Leaf collection/ transportation and offloading			
	01	08.023	
	036	42.227	
Elevation (m)	2075		
Process			12-16 hours For moisture reduction
WITHERING	01	08.007	
S	036	42.246	
E	2077		
CFM(FERMENTING)			
S	01	08.006	Blow air, colour changes because of oxidation.
E	036	42.259	

	degrees ̊	mins	Activities (Duration)
Elevation (m)	20757		Approximately 20 minutes
DRIERS			
S	01	07.990	Reduce MC from around 60%-3.5% Hot air from steam used
E	036	42.274	
Elevation (m)	2077		
SORTING/GRADING			
S	01	07.996	PVC rollers charger. Separate, weigh, pack, store, dispatch
E	036	42.284	
Elevation (m)	2077		
QUALITY ASSURANCE (CONTOL/TEA TESTING)			
S	01	08.005	Test done manually Skilled acquired through experience
E	036	42.277	
Elevation (m)	2077		

Table 3**:** Waste Water Sampling Points

POINT	**DEGREES**	**MINS**
MIN LAGOON 1 (ML1)		
S	01	08.048
E	036	42.320
Elevation (m)	2057	
Map	N	
MIN LAGOON 2 (ML2)		
S	01	08.052
E	036	42.325
Elevation (m)	2057	
Map	W	
MIN LAGOON 3 (ML3)		
S	01	08.054
E	036	42.324
Elevation (m)	2056	
Map	W	
SL1		
S	01	08.019
E	036	42.302
Elevation (m)	2065	
Map	N	
SL2		
S	01	08.026

POINT	**DEGREES**	**MINS**
E	036	42.307
Elevation (m)	2064	
Map	N	
MANHOLE (Exit to river)		
S	01	08.057
E	036	42.331
Elevation (m)	2057	
Map	N	
POINT OF ENTRY TO		
S	01	08.100
E	036	42.410
Elevation (m)	2035	
Map	N	
UPSTREAM		
S	01	08.080
E	036	42.390
Elevation(m)	2050	
Map	N	
DOWN STREAM		
S	01	08.197
E	036	42.491
Elevation (m)	2032	
Map	N	