EVALUATION OF WASTE MANAGEMENT SYSTEMS IN A KENYAN TEA FACTORY: A CASE STUDY OF MARAMBA TEA FACTORY IN KIAMBU COUNTY

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ABSTRACT

This paper evaluates the effectiveness of waste management systems in Maramba Tea Factory in Kiambu County, Kenya. Performance of the already existing systems is therefore critical in sustaining our environment. Tea processing generates different types of wastes. A waste management system design should at least begin from a clear characterization of these wastes, the quantities and qualities of the wastes and identification of sources. This study attempted to bring these challenges to the fore. It evaluated the waste management systems for Maramba Tea factory in Kiambu County, Kenya.

Primary data and secondary data, Purposively and Convenience sampling techniques, Benchmarking evaluation technique were utilised.

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 was 486.47 kilograms per month and inorganic solid wastes (sacks and polythene bags) was 15.38 kilograms per month. The amount of liquid wastes generated for the study period were estimated. The highest with major cleaning done weekly averaged of 139.4m³ and least with minor cleaning done daily averaged at 52.8m³.

The thermal wastes generated was due to heat loss from the wood fuel used as a source of energy. The total amount of heat loss was 1145.51kcal/kg representing 37.45% of the Gross Calorific Value (GCV) of wood fuel. The highest heat loss was due to dry flue gas with a 22.09% of GCV of wood fuel representing 675.85kcal/kg and the least 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 BOD₅, COD, pH and Electrical conductivity and comparing the values to the standards recommended by National Environment Management Authority (NEMA). The BOD₅ at 83.7mg/L and COD at 106.63mg/L exceeded the NEMA limits of 30mg/L and 50mg/L respectively.

The thermal waste systems were evaluated by determining the boiler efficiency. Boiler efficiency at Maramba Tea Factory was 62.55%. The boiler efficiency of 62.55% is lower compared to the set values of 75.01% and 75%.

The analysis with ANOVA showed significant differences in the water parameter values from source through the lagoon to the river. The coefficient of determination (R²) for most of the parameter analysed were above 97%.
It was concluded that the waste management systems are only partially effective at Maramba Tea Factory. More targeted studies need to be carried out in other food industries to make a general conclusion on the state of waste management systems in Kenya.

**Keywords:** Evaluation, waste, management systems, standards, tea production

1.0 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 regulatory entities have vested interest and there is too much reliance on obsolete technologies while some wastes are too toxic to handles with the current systems.

Amount of waste generated is on the rise due to the increasing human population and urbanization. Waste materials are generated from manufacturing processes, industries and municipal solid wastes [1]. Poor waste treatment and disposal strategies in Kenya are prevalent in the smallholder tea factories [2]. The increase of these wastes will lead to adverse effects such as pollution of water sources, the environment and human health and supports economic development and improved quality of life is adversely impacted. Often, these wastes are managed and regulated differently depending on the characteristics of the waste and the process of producing them and regulations by laws. 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 [2].

Agro-industries which tea factories fall under generates large quantities of solids, liquids and gaseous wastes arising from processing, treatment and disposal operations. Agro-industrial wastes are organic matter which can be recycled either by integrated waste utilization or simply returned to the place of their origin; nature. The main pollution categories include; solid wastes, wastewater, and air pollution [3]

The common type of wastes management systems in tea factories especially in Kenya includes: natural aerated lagoon for managing liquid wastes, landfilling to handle solid wastes (the systems has long been overtaken by new technologies likes incineration and others modern technologies, landfill is also open to air pollution and if not well designed can spill over) and the thermal wastes are management by ensuring usage of a boiler with high efficiency and also lagging the pipes that deliver steam).

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 better alternative systems in managing the wastes. A study on evaluating the wastes disposal systems in Japan focused on the environmental impacts resulting from the wastes after passing through the disposal systems and the cost of the existing systems visa vis the proposed new technologies systems with the cost of disposal of 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 [4]. A study to evaluate waste management alternatives by Chung and Poon used a multiple criteria approach [5]. Different wastes waste management methods were analyzed by use of Multiple Criteria Approach (MCA). The methods included: landfilling, waste to energy, composting, and source separation [5]. The advantage of multiple criteria approaches is that it accommodates both quantitative and
qualitative data, which gives a more subjective and implicit data for decision making.

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. However, the characterization of wastes in Maramba tea factory has not been done, the quantities and qualities are not known before they are discharged to the environment, and hence the efficiency of the waste management systems is also not known. Furthermore, the state of the general waste management systems of tea factories in Kenya is unknown because of lack of or few documented researches on various factories.

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 waste management system 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 upon which managerial decisions can be made.

1.2 Objective of the study

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

i. To characterize the waste generated during tea production at Maramba Tea Factory
ii. To characterize waste management in the Maramba Tea Factory
iii. To evaluate the effectiveness of the waste management systems in Maramba Tea Factory

1.3 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.

2.0 LITERATURE REVIEW

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 by the provisions of national law.

2.1 Waste Management System

2.1.1 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 [6]. 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. [7], defines a solid waste management system as a systematic administration of activities that facilitates the collection, source separation, storage, transportation, transfer, processing, treatment and disposal of solid waste.

Solid wastes Disposal Methods includes: (a). Reduce, Recycle and Reuse, (b). Thermal treatment (Incineration, Pyrolysis and Gasification, Open Burning) and (c). Dumps/Compositing and Landfills.

2.1.2. Liquid Waste Management Systems/Wastewater Management Systems

These involves procedures and practices / actions whose objective is to prevent discharging of pollutants to stormwater or any water courses as a result of source generation, storage, collection, transportation or transfer and disposal of liquid wastes.
Liquid waste treatment process is grouped into three stages namely: (a). Preliminary and Primary which is physical treatment, (b). secondary which is basically involves biological treatment and (c). Tertiary which is basically chemical treatment.

2.1.3 Gaseous Waste Management System
This are systems whose objective is to prevent causing hazardous impact to the environment from the generation and disposal of gaseous wastes. These gaseous wastes are as a result of anthropogenic activities.

2.1.4 Waste Heat Management Systems
These are systematic procedures and activities 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.

2.2 Waste Generation and Management in Tea Factories

2.2.1 Tea Waste Generation
Waste is generated in tea factories during tea processing from the fiber portion of leaves which is removed and discarded [8]. The waste also contains some tea leaves and dust. This is mostly solid waste. However, in studies done by Jackson on waste management approaches in tea processing factories, and Oirere, on state of waste management systems for tea factory in Nyamira County, they observed that wastes are not only generated from tea processing fibers [9] [10].

2.2.2 Tea Waste Management
A study by Anurag-et al., indicated that tea factory wastes (discarded tea fibres, dust and left-over tea leaves) can be disposed of through various methods. They stated wastes can be sold or exported as poultry and fish feeds, used to separate bioactive chemical components, used as biofertilizer and bio nutrients and by burning [8]. However, 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, she found that, wastewater in a tea factory in Nyamira County is treated through aerated lagoons before discharging them to the water course. Her study also indicated that, solid wastes are management through landfilling and thermal waste is management by lagging the steam pipes to reduce the loss of heat [10].

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.

2.3 Waste Characterization Approaches
Wastes characterization is simply a process in which different waste stream are analyzed by composition. Characterisation of wastes helps to decide which treatment and or disposal methods is to be employed. The characterization process involves collecting, sorting and categorizing waste in order to obtain a statistical portrait of the quantities of waste and their disposal methods.

There are three methods in which the composition of wastes can be determined; 1). Waste Product Analysis: this approach involves, analyzing 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 [11].

2.4 Evaluation of Waste Management Systems
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 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.
Benchmarking which is an evaluation/assessment tool as a continual comparison of products, services, methods, or processes to identify performance gaps, with the goals to learn from the best and to note out possible improvements [12]. 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 [4], in their studies to evaluate the wastes disposal systems in Japan. The study evaluating waste management alternatives. The multiple criteria approaches in their evaluation. Different wastes management methods were analyzed by use of Multiple Criteria Approach (MCA) [5].

2.4.1. Evaluations of Waste Management Systems in Tea Factories

a. Evaluation of Wastewater Management Systems

The wastewater management systems for most of Kenya Tea factories are natural aerated lagoons. In order to evaluate the effectiveness of the wastewater management systems for tea factories, the various parameters which gives an indication of the quality of water are analysed. These parameters include: BOD₅, COD, EC and pH. The values of these parameters are compared to guidelines the standard for allowable limits by NEMA in Kenya.

Table 2.1. NEMA Standard Level for various parameters

| Institution | Parameter | NEMA Standard level |
|-------------|-----------|---------------------|
| NEMA        | pH        | 6.5 - 8.5           |
|             | EC        | Marginal River Water 80-160 (S/CM) |
|             | BOD₅      | Max 30 mg/L         |
|             | COD       | Max 50 (mg/L)       |

Source: NEMA

b. Evaluation of Solid Wastes Management Systems

The solid wastes management in most of the tea factories in Kenya is done by landfilling and composting. 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. However, alternative methods of solid wastes can be evaluated in terms of life cost and lifecycle of each systems [5].

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 either conduction, convection and radiation. To evaluate the thermal wastes systems, the boiler efficiency is analyzed and compared to the standard recommended efficiency.

According to Mallick, 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 (H₂, O₂, S, C, moisture content, ash content), Percentage of oxygen or CO₂ 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 [13].

3.0 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 14th 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 1°8’0”S 36°42’17”E 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. Its annual production capacity is around 4,320,000 kilograms of black tea. The factory receives green leaf from Maramba Company Tea Estates farms. 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 rainfall of approximately 904.2 mm with a mean temperature of 21.6ºC, wind 7.8 mph, average Annual Relative humidity 62.2%

![Study Area Map](image)

**Figure 3-1 Study Area Map**
The study 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 type 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 in the field, i.e. from Maramba Tea Factory.

3.2.2. Sampling Techniques and Data Analysis

Purposive 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, the river upstream and downstream.

The data collected was subjected to statistical analysis by use of ANOVA single factor tool. This model helped in determining whether there is any statistical difference in waste quality as the wastewater move through various waste management stages.

3.3. Characterisation of Waste Generated during Tea Production at the Maramba Tea Factory

To achieve the above specific objective; the classification of the types and sources of wastes generated during tea production process at different stages (tea collection, withering, leaf maceration (CTC), fermentation/oxidation, drying, sorting and packaging) of Maramba Tea Factory was done mainly through observations due to inadequate characterization tools for waste generation.

3.4. Characterisation of waste management in the Maramba Tea Factory

In order to effectively characterize the waste management in Maramba Tea Factory, the quantities of the solids waste and quality of wastewater generated were determined. The data was collected for a study period of five (5) Months. The time period was based on the available resources and also to collect enough data that would give reasonable view of the waste generation at the factory.

3.4.1. Determination of the quantities of solid wastes, wastewater and thermal wastes at the factory

a. Solid Wastes: The Amount of solid wastes generated at various stages (tea collection, withering, leaf maceration (CTC), fermentation/oxidation, drying, sorting and packaging) was determined by weighing.

b. Liquid Wastes/Wastewater: This was approximated using the amount of water consumed. The readings 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.

c. Thermal Wastes: The amount was found by carrying out a Bomb calorific test in a laboratory to determine the Gross Calorific Value of the wood fuel used in tea processing in a laboratory. The composition of firewood fuel was adopted from study done by Ioannis Gravalos [14]

3.4.2. Determination of the quality parameters of wastewater generated during the tea production process

The following parameters were determined in the laboratory to give the indicative quality of the generated wastewater: PH, Electrical Conductivity (EC), Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD₅).
3.5 Evaluating effectiveness of the wastes management systems in Maramba Tea Factory

3.5.1 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.

3.5.2 Evaluation and Assessment Method of Waste Management Systems

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.

a. Solid Waste System

Disposal methods at the factory were observed and compared with the standard recommended disposal methods nationally as per NEMA solid waste management regulations as outlined in the Legal notice 121, 2006 that requires for a suitable solid disposal container, a contract with licensed solid waste transporter and a management plan to be provided.

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 [8]. These percentage values were used to determine the expected manufactured tea, solid waste and the moisture content in a kilogram of green leaf tea.

The values of expected manufactured tea was compared with the actual manufactured tea while those of expected solid waste was compared against the actual solid waste collected during the study period.

b. Wastewater Systems

The analysed wastewater parameters for BOD, pH, COD, and EC. (Seimens per, S/cm) were compared with the effluent discharge maximum limit standards set by the National Environmental Management Authority (NEMA) Water Quality Regulations, legal notice 120, 2006 of a BOD of 30mg/L, COD of 50mg/L, and pH of 6-9

ANOVA single factor tool was used to determine whether, there were statistically significant changes in the wastewater parameters from the source, through treatments systems and to the
null hypothesis described as $H_0: \mu_1 = \mu_2$ and an alternate hypothesis described as $H_1: \mu_1 \neq \mu_2$.

c. Thermal Waste

The boiler data and Bomb calorific test data were used to determine the boiler efficiency at Maramba Tea Factory. The Mallick, Amiya Ranjan (2015) indirect method (heat loss method) was applied. The efficiency was calculated by subtracting the heat loss percentages from 100 as shown in Equation 3-1 below:

\[ \text{Efficiency of Boiler} (\eta) = 100 - (a + b + c + d + e + f) \] ......... 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

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 ($T_a$) 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:

\[ \text{Weight of kg of air per kg of fuel} = 1.521C + 34.56H + 4.32(S - O)/100 \] .........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:

\[ EA = 100 \times \frac{O_2}{(21-O_2)} \] .................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:

\[ \text{AAS} = \left(1 + \frac{EA}{100}\right) \] theoretical air requirement for combustion of fuel

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:

\[ m \times \frac{C_P(T_f-T_a)}{GCV \ of \ fuel} \times 100 \] ..........Equation 3-5

where:
$m$ = mass of dry flue gas in kg/kg of fuel
$C_P$ = 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:

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

Where:
$H_2$ = percentage of hydrogen in 1 kg of fuel
$C_P$ = Specific heat of superheated steam (0.45 kcal/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\text{P} = \text{Specific heat of superheated steam (0.45 kcal/kg)}

T_f = \text{Flue gas temperature}

T_a = \text{Ambient Temperature}

GCV = \text{Gross calorific value of fuel}

d. \text{Heat loss due to moisture present in the combustion air:}

\[
\text{Heat loss} = \text{AAS} \times \text{Humidity ratio of air} \times \frac{C_P(T_f - T_a)}{GCV}\text{of fuel}
\]

\text{Equation 3-8}

where:

AAS = \text{Actual mass of air supplied}

C_P = \text{Specific heat of superheated steam (0.45 kcal/kg)}

T_f = \text{Flue gas temperature (°C)}

T_a = \text{Ambient Temperature (°C)}

GCV = \text{Gross calorific value of fuel (kcal/kg)}

e. \text{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

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Characterization of the Waste Generated During Tea Production at The Factory

The type of waste identified through observation at the Factory 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 are generated from the cleaning processes in the factory. The two type of cleaning are major and minor cleaning. 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 at the boiler and steam pipelines which were determined as shown in section 4.1.2 part III of this study. They include losses due to: dry flue gas, moisture in the fuel and air; hydrogen and due to radiation.
4.1.2. Characterization of waste management in the Maramba Tea Factory

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

Table 4-2: Quantities of Solid Wastes Generated at Different Stages of Tea Production

| Section                                                                 | Jul-2016 | Aug-2016 | Sep-2016 | Oct-2016 | Nov-2016 | Total   | Mean   | % Mean | Standard Deviation |
|-------------------------------------------------------------------------|----------|----------|----------|----------|----------|---------|--------|--------|-------------------|
| Offloading Bay                                                          | 54       | 53       | 60       | 73       | 76       | 316     | 63.2   | 12.59  | 10.71             |
| Withering                                                              | 298.5    | 327      | 358      | 385.5    | 412.5    | 1781.5  | 356.3  | 71     | 45.31             |
| Maceration (CTC)                                                        | 19.55    | 19.2     | 20.5     | 24.8     | 28.6     | 112.65  | 22.53  | 4.49   | 0.46              |
| Drying                                                                 | 23.5     | 25.5     | 26.5     | 27.1     | 27.5     | 130.1   | 26.02  | 5.18   | 1.6               |
| Sorting                                                                 | 10.7     | 10.1     | 11       | 11.2     | 11.8     | 54.8    | 10.96  | 2.18   | 0.63              |
| Packing (organic)                                                       | 6.8      | 7.6      | 7.7      | 7.3      | 7.9      | 37.3    | 7.46   | 1.49   | 0.43              |
| Sacks and Polythene Bags at Packaging                                  | 14.9     | 15.0     | 15.3     | 15.9     | 15.8     | 76.9    | 15.38  | 3.06   | 0.45              |

Figure 4-1: Solid Wastes Generated at Different Stages of Tea Production
From Table 4.2 and Figure 4.1 and 4.2 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 approximated using the 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.

The values recorded for the period of project study are represented in Table 4.3 below.

| Months          | Major cleaning (m³) | Minor cleaning (m³) |
|-----------------|---------------------|---------------------|
| July 2016       | 128                 | 48                  |
| August 2016     | 130                 | 50                  |
| September 2016  | 139                 | 52                  |
| October 2016    | 148                 | 56                  |
| November 2016   | 152                 | 58                  |
| **Total (m³)**  | **697**             | **264**             |
From the Table 4.3 and Figure 4.3, the amount of liquid waste generated for major cleaning at the Maramba Tea Factory ranged between 128 m³ and 152 m³ respectively per month for the period of study. The highest amount of wastewater generated was in November 2016 at 152 m³ and least amount in July 2016 at 128 m³.

The minor cleaning which was done daily had the highest amount of wastewater in November 2016 at 58 m³ and least amount generated in July 2016 at 48 m³.

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

The quantities of thermal wastes at Maramba Tea factory was estimated by 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 was adopted from study done by Ionis Gravels [14]

Table 4-4: 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                | 1,145.51                     |

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

The quality parameters of wastewater generated at the factory were determined and summarised in Table 4-5 below:

| LOCATION                  | BOD (mg/L) | COD (mg/L) | 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

I. Existing Waste Management Systems at Maramba Tea Factory

The existing waste management systems identified at Maramba Tea Factory was as shown in Table 4.6 below:

| Types of Wastes     | Management Systems |
|---------------------|--------------------|
| 1. Solid Wastes (organic wastes) | There were no clear systems, however, most of the organic wastes is disposed in the garden for decomposition |
| 2. Solid waste (metals) | They are disposed by selling them to metal scrapper |
| 3. Liquid wastes     | They are treated through naturally aerated lagoons before discharging to the river |
| 4. Thermal wastes    | • There was chimney at the boiler. |
|                     | • There was no pipe lagging that would reduce heat loss. |

II. Solid Waste Management Systems at the Factory

As earlier indicated from existing wastes management, there was no clear solid wastes management systems at the factory. However, the amount of expected solid wastes emanating from the tea production was determined and compared
to the measured solid wastes. The results are summarized in Table 4-7 below:

**Table 4-7: Expected Solid wastes and Measured Solid Wastes at Maramba Tea Factory for the study period**

| Month  | Green Leaf (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) |
|--------|----------------|---------------------------|------------------|----------------------------|-------------------|---------------|------------------|------------------------|--------------------------|----------------------|
| Nov_16 | 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_16 | 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_16| 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_16 | 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_16| 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 4-6: Measured and Expected Solid Wastes at Maramba Tea Factory

### III. 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$_5$), Chemical Oxygen Demand (COD), PH, Electrical Conductivity (EC), and.
The measured results were compared with the established NEMA standards as shown in Table 4-8 below:

Table 4-8: Wastewater BOD$_5$, COD, pH and EC Parameters.

| LOCATION                     | BOD$_5$ (mg/L)$_i$ | COD (mg/L)$_i$ | pH$_i$ | EC (S/cm)$_i$ |
|------------------------------|--------------------|----------------|--------|---------------|
| 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 (SL 2)          | 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 standards level**     | **Max 30 mg/L**    | **Max 50 (mg/L)** | **6.5 - 8.5** | **For Marginal River Water 80-160 (S/CM)** |

Source: Author$^1$, NEMA$^2$

Furthermore, in analysing the effectiveness of the waste management systems, ANOVA single factor tool was used to determine statistically if there 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 i.e. (1). Between Min Lagoon 1 – Manhole Exit and (2). Between Entry point to river – Downstream of the river.
### Table 4-9: pH ANOVA Analysis_1 (between Min Lagoon 1 - Manhole Exit to stream)

| 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**

H₀: \( \mu_1 = \mu_2 \)  
H₁: \( \mu_1 \neq \mu_2 \)  
P<0.05, 0.001505<0.05  
F>F crit, 59.82879 > 7.708647  
**There is statistically significant difference**

### Table 4-10: pH ANOVA Analysis_2 (Between Point of entry to River – River Downstream)

| Water Quality Parameter | pH |
|-------------------------|----|
| **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**

H₀: \( \mu_1 = \mu_2 \)  
H₁: \( \mu_1 \neq \mu_2 \)  
P<0.05, 0.00019<0.05  
F>F crit, 172.509 > 7.70864  
**There is statistically significant difference**
### Table 4-11: EC (S/cm) ANOVA Analysis_1(between Min Lagoon 1- Manhole Exit to stream)

| Water Quality Parameter | EC (S/cm) | SUMMARY |
|-------------------------|-----------|---------|
|                         |           | Groups  | Count | Sum  | Average | Variance |
|                         |           | Row 1   | 3     | 137.25 | 45.75 | 23.5225 |
|                         |           | Row 2   | 3     | 95.6  | 7       | 3        |

#### ANOVA

| Source of Variation | SS      | df | MS     | F      | P-value | F crit |
|---------------------|---------|----|--------|--------|---------|--------|
| Between Groups      | 289.120 | 4  | 1  | 16.4432 | 0.01541 | 7.70864 |
| Within Groups       | 70.3316 | 7  | 2  | 17.5829 |
| Total               | 359.452 | 5  |

#### Remarks

- $H_0: \mu_1 = \mu_2$
- $H_1: \mu_1 \neq \mu_2$
- $P<0.05, 0.015412<0.05$
- There is statistically significant difference
Table 4-12: EC (S/cm) ANOVA Analysis_2 (Between Point of entry to River – River Downstream)

| Water Quality Parameter Analysis | EC (S/cm) |
|---------------------------------|-----------|
| **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:
- $H_0$: $\mu_1 = \mu_2$
- $H_1$: $\mu_1 \neq \mu_2$
- $P<0.05$, $0.000616 < 0.05$

There is statistically significant difference

Table 4-13: BOD$_5$ ANOVA Analysis_1 (between Min Lagoon 1- Manhole Exit to stream)

| Water Quality Parameter Analysis | BOD$_5$ |
|---------------------------------|---------|
| **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 4-14: BOD5 ANOVA Analysis_2 (Between Point of entry to River – River Downstream)

| Water Quality Parameter Analysis | BOD$_5$ Analysis |
|----------------------------------|------------------|
| **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**                        | **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 4-15: COD ANOVA Analysis_1 (between Min Lagoon 1- Manhole Exit to stream)

| Water Quality Parameter | COD Analysis |
|-------------------------|--------------|
| **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**                | **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      |             |            |             |            |

**Remarks**
- $H_0$: $\mu_1 = \mu_2$
- $H_1$: $\mu_1 \neq \mu_2$
- $P<0.05$, 1.31E-07 < 0.05
- There is statistically significant difference
Table 4-16: COD ANOVA Analysis (Between Point of entry to River – River Downstream)

| Water Quality Parameter | COD Analysis SUMMARY |
|-------------------------|----------------------|
| Groups | Count | Sum | Average | Variance |
| Row 1 | 3 | 330.35 | 7 | 3 | 110.116 | 0.38583 |
| Row 2 | 3 | 319.9 | 3 | 3 | 106.633 | 3.94333 |

| ANOVA Source of Variation | SS | df | MS | F | P-value | F crit |
|---------------------------|----|----|----|---|---------|--------|
| Between Groups            | 18.2004 | 2 | 18.2004 | 8.40827 | 0.04413 | 7.70864 |
| Within Groups             | 8.65833 | 3 | 2.16458 |          |         |        |
| Total                     | 26.8587 | 5 |      |       |         |        |

H₀: μ₁ = μ₂  
H₁: μ₁ ≠ μ₂  
P<0.05, 0.044131 < 0.05  
There is statistically significant difference

From the above tables and analysis, it can be deduced that there is statistically significant difference in the wastewater parameters from point of entry in the lagoons to the downstream of the river.

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 by using observation 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 types of wastes generated in the factory. This study, attempted to characterize 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 Tea factories, 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.

4.2.2. Characterization of waste management in the Maramba Tea Factory

In order to characterize 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 analyzed 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 were overloaded. 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. The result also shows a variation of solid waste generated between the period 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 in 2015, which showed that more solid wastes are generated at withering stage of tea production process.

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

Since it was not possible to measure the amount of liquid waste generated at Maramba Tea Factory, it was therefore necessary to obtain the amount of wastewater generated during the tea production process by approximation using the amount of water used. The readings were obtained from the water meter readings for water used in daily minor cleaning and major weekly cleaning respectively.

The amount of liquid waste generated for major cleaning at the Maramba Tea Factory ranged between 128m³ and 152m³ per month for the period of study. The highest amount of wastewater generated was in November 2016 at 152m³ and least amount in July 2016 at 128m³. The minor cleaning which was done daily had the highest amount of wastewater in November 2016 at 58m³ and least amount generated in July 2016 at 48m³. High amount of liquid wastes generated at both major and minor cleaning respectively was a result of wastage by those assigned to do the cleaning. They sometime left the water taps not tightly closed and others using large quantities 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, gross calorific value of these wood fuels was determined. The various heat losses that were 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 was adopted from study done by Ioannis Gravalos in 2016.

From the data collected and analyzed, 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 a boiler efficiency at Maramba Tea Factory of 62.55%. However, Brundaban Patro in 2015 and the Council of Industrial Boiler Owners (CIBO) recommends wood fuel energy-based boiler efficiency of 75.01% and 75% respectively [15] [16]. Consequently, the boiler efficiency of 62.55% is lower compared to the set values of
75.01% and 75%. 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 analyzed, 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 Siemens per centimeter
iv. pH level.

The result in Table 4.8 shows that values of BOD$_5$, COD, EC and pH varies from the sample points, i.e. from the source at Mini lagoon 1 to entry to the stream respectively. These changes in water parameter shows that the wastewater treatment systems have an effect in reducing the values of these water quality parameter. However, as shown in Table 4.8, 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 BOD$_5$ 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.

**4.3 Evaluating the effectiveness of the wastes management systems in Maramba Tea Factory**

**I. Solid Waste Management Systems at the factory**

Currently there was no landfills used to disposes of organic wastes, rather they are just disposed in garden that has banana plantation next to the factory premises. The organic wastes and inorganic wastes generated are not segregated at the factory, they are mixed.

The scrap metals which were well segregated as aluminum foils and metals and Mild steels metals which were placed at designated place and are disposed of by selling to recycling.

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 was disposed in a banana garden at the factory premises.

**II. Wastewater Management Systems at the Factory**

In order to evaluate the effectiveness of the wastewater management systems, ANOVA single factor tool was used to determine statistically if the was a change in these wastewater parameters as the wastewater moves 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 analyzed. This is shown in tables 4-9 to table 4-16 respectively.

The results were also compared to the maximum allowable discharge limits to the environment values set by NEMA as shown in tables 4-8. The values of biochemical oxygen demand (BOD$_5$) 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 BOD$_5$ 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, Amiya Ranjan in 2015 indirect method also called the heat loss method was applied.

From the data collected and analyzed, the Boiler efficiency at Maramba Tea Factory was 62.55%. However, Brundaban Patro, 2015 and the Council of Industrial Boiler Owners (CIBO), 1978 recommends wood fuel energy-based boiler
efficiency of 75.01% and 75% respectively. Consequently, the boiler efficiency of 62.55% is lower compared to the set values of 75.01% and 75%. This shows the boiler is not so effective to a recommended value and hence there is a lot of energy is lost through heat losses.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

I. The overall objective of this research study was met, since the solid waste management systems, Liquid waste management systems and Thermal Management systems were evaluated respectively.

II. From the data collected and analyzed, the type of wastes identified were solid (which could be classified as organic and inorganic, liquid wastes and thermal wastes). The study showed that the wastes are not classified and segregated into organic and inorganic wastes from the tea processing stages. Some of the solid wastes even find way in the liquid wastes that finds its way into the lagoons. However, the scrap metals are segregated into aluminum foils and mild steel which are disposed-off by selling to the scrap metal dealer.

III. On the wastes management systems, it was observed that there was no a solid waste management 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 amount of liquid wastes generated for the study period were estimated from the amount of water used. The highest with major cleaning which happens once a week estimated an average of 139.4m$^3$ per month and least with minor cleaning which averaged at 52.8m$^3$ 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 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.

The noise wastes were not determined at factory since it was outside the scope of study.

IV. 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. There was no proper solid management system to evaluate. However, the scrap metals were segregated.

The liquid wastes management systems at the factory were the lagoons. The wastewater parameter measured at downstream BOD$_5$ 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 BOD$_5$ 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 is not very effective.

The thermal waste systems were evaluated by determining the boiler efficiency. Boiler efficiency at Maramba Tea Factory was 62.55%. However, Brundaban Patro; 2015 and the Council of Industrial Boiler Owners (CIBO); 1978 recommends wood fuel energy-based boiler efficiency of 75.01% and 75% respectively. Consequently, the boiler efficiency of 62.55% is lower compared to the set values of 75.01% and 75%. This shows the boiler was not effective to a recommended value and hence there is a lot of energy is lost through heat losses.

V. 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 BOD5 and COD
   c. The waste treatment systems at the factory was not effective

5.2. Recommendations

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

II. Most organic solid wastes should be reused 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 waste water used in major cleaning should be recycled and proper water use practices should be encouraged at the factory to avoid wastages

IV. Landfilling and composting Solid wastes treatment system should be put in place. Preferably the organic solid waste should be disposed in a landfill and composite bit to use them later a source of energy.

V. More targeted 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 state of waste management in the Kenyan factory.

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 reviewed 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 which that can recover and treat the wastewater for recycling at the factory.

The high amount of solid wastes at withering and offloading stage of tea production can be avoided by adhering to simple practices. Avoid overloading trough beds, and prober handling during offloading.

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