*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
*e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 6 Ver. I (Nov. - Dec. 2017), PP 70-78*
*www.iosrjournals.org*

# Process Analysis for Emission Control withinthe Small Scale Coffee Roasting Industries in Kenya.

David M. Njeru[a*],Jean B. Byiringiro[b], Peter. N. Muchiri[a]
[a]*Department of Mechanical Engineering, Dedan Kimathi University of Technology, Kenya*
[b]*Department of Mechatronic Engineering, Dedan Kimathi University of Technology, Kenya*
[*]*Corresponding author: davidmnjeru@gmail.com*

**Abstract**:*Roasting of coffee has been practiced for decades since the beginning of the 20$^{th}$ Century. It is a vital stage in the coffee value chain in which the green coffee beans undergo chemical change giving the characteristic coffee flavor. In the beginning, much of the roasting was home based in small batches for personal consumption but later faded with the rise of the commercial coffee roasting companies. Continuous increase in global consumption of coffee products including beverage, fresheners and coffee flavor additives have seen the industry attract small, medium and large scale coffee roasting firms.Green coffee beans contain many chemical compound like proteins, fats, caffeine and organic acids and during roasting out of these compounds some decompose, oxidize while others volatize thus becoming pollutants. Since the emissions associated with coffee roasting process are inevitable, small scale firms in the industry continue to face emission control challenge thus inhibiting their growth and profitability. The purpose of this research was to develop an emission management plan for treatment, control and disposal of air pollutants for a small scale batch –type coffee roasting firm. Case study methodology was utilized to study the emission problem and data collection. Pareto analysis was done to rate the various emissions risk index. Process improvement techniques towards a clean coffee roasting process are presented for cleaning dust, chaffs and smoke which comprises ofvolatile organic compounds (VOCs) and fuel combustion compounds.It has been found that adopting the proposed designs for cyclones and smoke extract hood for a standard 60kg small batch-type coffee roastercouldclean and control the unwanted emissions.*
***Keywords:***_Roasting, Emission, System Safety and Risk index_
---------------------------------------------------------------------------------------------------------------------------------------
Date of Submission: 07-11-2017 Date of acceptance: 30-11-2017
---------------------------------------------------------------------------------------------------------------------------------------

## I. Introduction

Coffee roasting involves the processing of green coffee beans into roasted coffee products, including whole and ground beans and soluble coffee products. Roaster typically operate at temperature between 370ºC and 540ºC. (Bottazi, October, 2012). The roasting period depends on the intended type of roast ranging from a few minute to 30 minutes. Thus, the beans can be light roasted, brown roasted or dark roasted. Roasting is a vital stage in coffee value-chain because it is the stage at which the characteristic coffee flavor is first smelled (Alexia N Gloess, 2014).

Green coffee beans contain a wide variety of chemical compounds, including proteins, fats, sugars, dextrose, cellulose, caffeine and organic acids (Nicolay, 2006). When heat is applied to these beans during roasting, some of these compounds volatize, oxidize or decompose into toxic by-products of the roast. Thus toxic compounds such as aldehydes (as formaldehydes), organic acids (as acetic acid), volatile organic compounds (VOCs), responsible for much of roast coffee's characteristic odor) and acrolein are then exhausted into the atmosphere (Ostendorf, 1992). Emissions can be subcategorized into two different types: gaseous and particulate matter. Suspended particulate matter is often visible as smoke. The clear bluish white gaseous emissions are caused by distilled oils and the breakdown of organic products (Alexia N Gloess, 2014).The major coffee roasting emissions and the associated process is summarized in the Table 1.

**Table 1:** Coffee roasting emissions and related processes

| PROCESS | Particulate matter | VOCs | Combustion by-products |
|---|---|---|---|
| Unloading | Dusts and chaffs | | |
| Screening | Dusts | | |
| Storage and Handling | Dusts | | |
| Roasting | Chaffs and smoke | Formaldehyde | CO, $NO_x$ and $SO_x$ |
| Cooling | Smoke | | |

In Kenya coffee roasting is done for both domestic and commercial purposes.According to Kenya gazette (Kenya Gazette Supplement No. 136, 2012) on export performance, most dealers and exporters in the coffee auction enjoy less than 1% of the total coffee in the market with the highest buyer, C Dorman Ltd taking up to 18.8%. This study therefore, first categorized these firms and focused on those that trade at less than 1% as the small scale coffee roasting firms in Kenya as shown in Table 2.

**Table 2:** Classification of coffee dealers in Kenya

| **Category and Example** | **%-Age share** | **Count** |
|---|---|---|
| Large scale (C Dorman Ltd) | Above 10 | 4 |
| Medium scale (Jowam Coffee Traders Ltd.) | Between 1 and 10 | 12 |
| Small scale (Fair to Good Co. Ltd) | Below 1 | 25 |

## II. Materials And Method

### 2.1 Materials and equipment used

This research was conducted at*Fair to Good Company Ltd*.The firm was chosen as the case study firm of this research because it is a privately owned coffee roasting firm with a share of 0.02% in theKenya coffee auction market and had already experienced social-economic conflicts within the neighborhood as a result ofuncontrolled coffee roasting emissions released from the industry. There was great interest in theset up utilized for smoke control in the firm with view that it is situated in Ruai town,Nairobi an area with fast growth in residential settlement and a newly constructed secondaryschool.Fig.1shows the images of the small scale firm (Fair to Good Company Ltd Ruai, Nairobi**)**.The duct system was installed after the emission problem was evident following long roasting hours as the demand for roast coffee increased. However this system failed to address the problem effectively and with time the firm was on focus as the point source of the emission in the surroundings.


**Fig.1.**Roaster exhaust ducts joined to one main exhaust duct extending outside the roof

In small scale coffee roasting, typical batch-type coffee roasters are utilized as opposed to continuous roasters in large industrial set up. At the place of study a 60kg coffee roaster shown in the Fig.2was identified for study. The roaster is a stand-alone machine, diesel fueled and was efficient with good quality coffee roast.

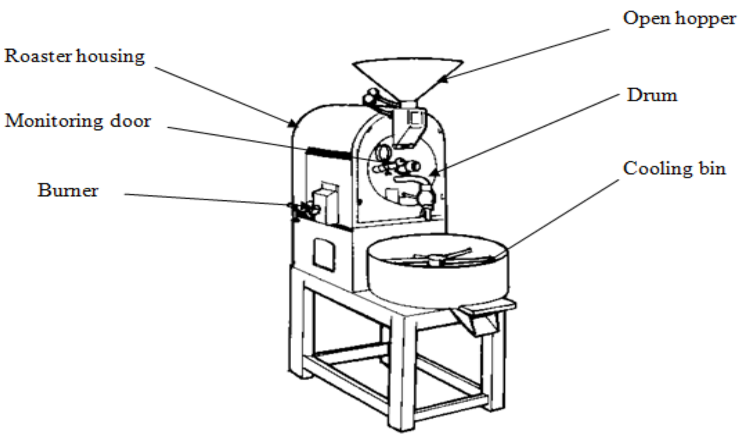


**Fig. 2:**A typical 60kg batch-type coffee roaster

**2.2 Laboratory analysis for particulate matter emission samples**

The purpose of this analysis was to determine the percentage distribution of different grain sizescontained within the stack emission from the coffee roaster. Determining the smallest particle size to be separated was the sure way to design an effective system that would work for all other larger particles. The samples collected at the firm weresent to Dedan Kimathi University of Technology Chemistry lab for particle size distribution anddensity analysis. Size distribution of the dust particles was determined through sieve analysis (Fig.3).

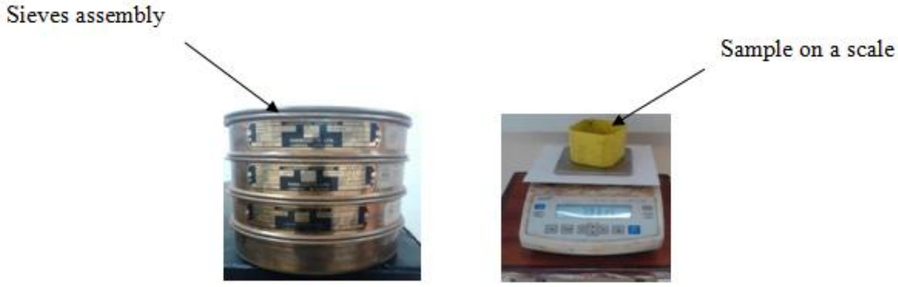


**Fig.3:**Sieve stack and a weigh balance at DeKUT Chemistry lab

Sieve analysis test procedure

- The weight of each sieve was taken and recorded as well as that of the bottom pan.
- Each sample weight was also recorded.
- The sieves were cleaned and assembled in the ascending order of sieve mesh size (Fig. 3)
- The pan was placed below the finest sieve and carefully the emission sample was poured into the top sieve and the cap placed over it.
- The sieve stack was placed in the mechanical shaker and shaken for 10minutes.
- The sieve stack was removed from the shaker and carefully each sieve was weighed with its retained emission.
- The bottom pan was also weighed with is retained fine emission dust.

**2.3 Fuel combustion by-products emissions analysis**

Presence of fuel combustion by-products emissions was investigated. This was based on the knowledge that incomplete combustion results to formation of CO, $NO_x$ and $SO_x$.Engineering calculations were applied in estimating the quantities of combustion by-products through prediction based on the application of conservation laws. The technique predicts presence of certain element in the emission streams based on their composition rated in the fuel. Sulphur, for instance, which is converted into compounds of Sulphur during combustion process was estimated by this technique. The equation (Eq.1) used in fuel analysis emission calculation is given below:

$$E_{kpy,\, i} = Q_j * \text{Pollutant Concentration in fuel} * (MW_p / FW_f) * OpHrs \ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

Where:

$E_{kpy,\, i}$ = Emission of pollutant in Kg/yr
$Q_f$= Fuel use, Kg/hr
$MW_p$= Molecular weight of pollutant emitted, Kg/Kg-mole
$EW_f$ = Elemental weight of substance in fuel, Kg/Kg-mole
***OpHrs***= Operating hours, hr/yr

This approach assumed complete conversion of Sulphur to $SO_2$. Various literature revealed that there are volatile organic compounds (VOCs) formed during coffee roasting. This research considered the application of the documented technical reports that guides in the estimation of quantities of VOCs using emission factors.An emission factor is a tool that is used to estimate emission to environment. It relates the quantity of substances emitted from a source to some common activity associated with those emission.

## III. Results And Discussion

**3.1 Particulate matter distribution results**

After collecting samples for mass distribution, the Table 3 below was prepared to show the percentage distribution by size. In summary, it was observed that the smallest particles of 125µm was about 20% of the collected sample and was thus used as the basic collection unit for dust cleaning.

**Table 3:** Laboratory results for roaster stack emissions at Fair to Good Co. Ltd

| DATE | SAMPLE SIZE(gms) | DUST PROPERTIES OBSERVED | | | |
|---|---|---|---|---|---|
| | | PARTICLE SIZE (µm) | MASS(gms) | % BYMASS | % MASS(INT) |
| Jul-15 | 72.05 | >500 | 28.08 | 38.97293546 | 38 |
| | | 250-500 | 18.99 | 26.35669674 | 26 |
| | | 125-250 | 11.54 | 16.0166551 | 16 |
| | | <125 | 13.44 | 18.6537127 | 18 |
| Aug-15 | 94.85 | >500 | 33.85 | 35.68792831 | 35 |
| | | 250-500 | 24.62 | 25.95677385 | 25 |
| | | 125-250 | 15.72 | 16.57353716 | 16 |
| | | <125 | 20.66 | 21.78176067 | 21 |
| Sep-15 | 111.24 | >500 | 37.82 | 33.99856167 | 33 |
| | | 250-500 | 27.97 | 25.14383315 | 25 |
| | | 125-250 | 20.04 | 18.01510248 | 18 |
| | | <125 | 25.41 | 22.8425027 | 22 |
| Oct-15 | 110 | >500 | 36.58 | 33.25454545 | 33 |
| | | 250-500 | 27.97 | 25.42727273 | 25 |
| | | 125-250 | 20.04 | 18.21818182 | 18 |
| | | <125 | 25.41 | 23.1 | 23 |

## 3.2 System and process failure analysis results

The problem presented in the case study requireda system safety analysis in order to establish the faults in various elements of the system design. The analysis focused on establishing the current operating procedures and then develop a comparative relationship table with the standard operating procedures for coffee roasters.
Three principal elements that were analyzed included the roaster machine, factory layout and design and the personnel operations. All emissions cause factors in the design, functioning or human induced in the coffee roasting process were analyzed. This singled out which element was associated with the main cause of system failure and therefore made the base for proactive action in the process improvement. The Table 4 shows the assessment results.

**Table 4:**Coffee roasting emissions and related cause modes

| Emission | Cause mode | Related system element | Likelihood |
|---|---|---|---|
| ***Chaffs*** | Roaster exhaust gas | Roaster | Frequent |
| ***Smoke*** | Roaster fuel combustion | Roaster/plant design | Frequent |
| ***VOCs*** | Roasting temperatures ($250^0$C) | Roaster | Probable |
| ***CO, $NO_x$, $SO_x$*** | Fuel combustion products | Roaster fuel (Diesel) | Probable |
| ***Odor*** | Quenching | Roaster/operator/plant design | Frequent |

### 3.2.1 Severity and probability index

A severity index was assigned to each emission and a factor to likelihood of occurrence. The severity values were rated at 1.0 for the lowest severity and 3.0 for the highest while likelihood values were assigned between 1.0 and 5.0 for improbable and frequent respectively as shown in the Table 5.

**Table 5:** Severity and probability index

| Emission | Consequence | Losses | Severity index (S) | Probability (P) |
|---|---|---|---|---|
| **Chaffs and dusts** | Clogging in the ductwork thereby causing fire outbreaks | Plant downtime to put out fire leading to low throughput | 3.0 | 5.0 |
| **Smoke** | Poor visibility in the surrounding. | Settled smoke in the neighborhood degrades environment and brings health nuisance. | 3.0 | 3.0 |
| **VOCs** | Are invisible and carcinogenic to human health | Health related problems and smell nuisance. | 3.0 | 2.0 |
| **CO, $NO_x$ and $SO_x$** | Acidic compounds that form acid precipitation | Accelerates roof rusts and health respiratory problems | 3.0 | 4.0 |
| **Odor** | Strong characteristic smell of coffee roasting within the premises | Health nuisance | 2.0 | 2.0 |

### 3.2.2 Risk index matrix

Hazard risk assessment matrix was employed to compute the risk index as a measure of undesirability of the various emissions. The risk index is a function of the likelihood and severity of the hazardous emissions. The matrix used to compute risk index is given in the Table 6.

**Table 6:** Risk index matrix

| Reducing Severity Index | Reducing likelihood factor → 5 Frequent | 4 Probable | 3 Occasional | 2 Remote | 1 Improbable |
|---|---|---|---|---|---|
| 3 High | **15** | **12** | **9** | **6** | **3** |
| 2 Moderate | **10** | **8** | **6** | **4** | **2** |
| 1 Low | **5** | **4** | **3** | **2** | **1** |

### 3.3 Emissions risk assessment results

Results of the various emissions risk indices were derived and tabulated as shown in the Table 7.A simplified Pareto analysis was done as shown in Figure 4. The Pareto chart represent the emissions category on the x-axis and a risk index on the y-axis given by a product of likelihood factor and severity index.

**Table 7:**Risk indices for various emissions identified at Fair to Good Co. Ltd

| Emission | Likelihood factor (P) | Severity index (S) | Risk index (S*P) |
|---|---|---|---|
| **Chaffs and dusts** | 5.0 | 3.0 | 15.0 |
| **Smoke** | 3.0 | 3.0 | 9.0 |
| **VOCs** | 2.0 | 3.0 | 6.0 |
| **CO, $NO_x$ and $SO_x$** | 4.0 | 3.0 | 12.0 |
| **Odor** | 2.0 | 2.0 | 4.0 |

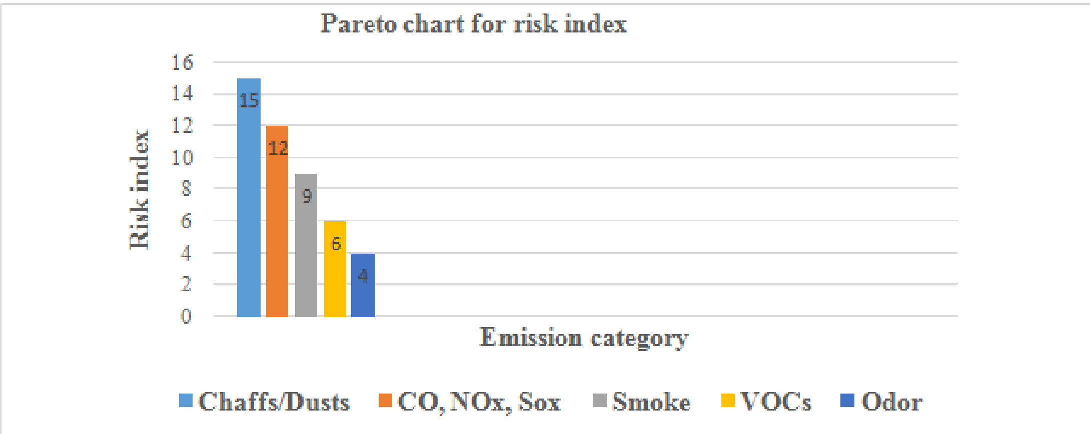


**Fig4.** Pareto Chart for risk index

Thus from the Pareto analysis, the release of chaffs and dusts from the roasting process and the control of combustion compounds were the most critical emission of concern. In the view that these are products of roasting activity the roaster machine was therefore the main element that required detailed assessment and improvement for addressing the identified emission challenge.

### 3.5 Roaster Failure modes and effects analysis (FMEA) results

Developing aFailure Modes and Effects Analysis*(*FMEA*)*for the roaster required assessing each of the roaster part and the associated function and performance standards in the current context at the industry. Each part of the roaster machine was examined through structured interviews and technical reports provided secondary sources of data. Table 8shows a summary of the findings for different components and subsystems of the machine.

After this tabulation, the functional failure, effects and consequences were analyzed based on the information gathered about the case study problem. A form of a modified FMEA in the Table 9was therefore developed focusing on both roaster system design and process improvement.

From the FMEA, the method utilized for treatment of stack emissions and the design of the gas burner were identified as the components responsible for the production of unfriendly emissions from the small scale coffee roasting industry. This opened way for working towards the main objective of this research work of designing a process improvement criteria for the small scale coffee roasting firm.

**Table 8***:* Roaster machine part operating context

| Machine part | Function | Performance | Operating context |
|---|---|---|---|
| *Basket conveyor* | Storage and handling green coffee beans before roasting. | 2kgs per basket | Stand-alone without back up |
| *Hopper* | Feeding green coffee beans to the roasting drum. | Batch of 60kgs | Working in full capacity |
| *Roasting drum* | Burning green coffee beans to brown roasted beans. | Roasting 60kgs in 30min | Closed drum direct fired<br>No sight glass for monitoring |
| *Cooling bin* | Contains a perforated base through which cool air is drawn by blower brown beans | 60kgs batches cooling | Several sieves provided to allow cleaning<br>Cleaning schedule not provided |
| *Auger* | Agitating roasted beans while cooling | Working correctly | Independently driven at low speed |
| *Blower* | Cooling beans and sucking chaffs | Cools but not very efficient | Single blower installed for each roaster |
| *Cyclone* | Particles separator | Not fitted | Not installed |
| *Exhaust chimney* | Releasing stack emissions | Allows backflow of smoke | Designed with one main duct but with smaller ducts from exhaust points of each roaster. |

**Table 9***:* Modified FMEA for the coffee roasting plant

| Roaster subsystem | Process function | Failure | Functional failure mode | Failure effects to system function | Consequence to process function | Proactive tasks |
|---|---|---|---|---|---|---|
| Cyclone | Particles separator | Improper separation | Inefficient cyclone design | Backflow of dust particles clogging in duct | Fire breakouts within ducts | Redesigning the cyclone |
| | | | Unattended cyclone | Clogged dust particles inside the cyclone | Presence of dust in the gaseous emission | Cleaning the system |
| | | | Unfitted cyclone | Heavy particles in stack emission | Untreated dense smoke emitted from exhaust | Design and fitting a cyclone<br>Fit a filtration system |
| Roaster ducts | Carries the roaster emissions to chimney | Blockages | Clogged coffee chaffs | Excess particles fall back to roaster drum | Burnt out chaffs trigger fires within ducts | Fitting non-return valves |
| Cooling blower | Draws cool air through roasted beans in bin | Unable to draw smoke and chaffs | Wrong sizing | Beans over roast due to conduction | Bad product (Black) roasted beans | Redesign and fitting the right blower size |
| Gas burner | Indirect firing | Production of smoky flame | Poor air and fuel mixing<br>Incomplete combustion | Creating unburnt fuel elements in the roaster exhaust emissions | Bad ordour from the roasting process | Fitting a proper burner with regulators |
| De-stoning system | Removes bits of rocks and metals from roasted beans | Ineffective separation | Blocked openings | Presence of debris in the roasted beans | Poor quality of ground coffee and destruction of grinder wheels | Redesign an alternative way of destoning from filtration or sieving. |

### 3.6 Process improvement design alternatives

The industrial coffee roasting done at the firm was found to produce four types of emissions that irritated the neighborhood. These were dust, chaffs, odor and smoke. Dust is generated in the handling of green beans, which are bagged in sisal sacks. Chaffs consist of the outer covering or the skin that bursts when the beans swell during roasting. The odor and smoke are combination of organic constituents volatilized at the roasting temperatures and the steam produced when the roasted beans are quenched with water. Also released in the form of smoke are the NOx from combustion of fuel at high temperatures.

3.6.1 Dust and chaffs control plan

Stack emissions included dust and uncontrolled chaffs found as the exhaust output at the point of discharge to the environment. Also traces of $SO_2$, CO and VOCs were indicated. The state agency, National Environment Management Authority (NEMA), responsible for jurisdiction of air quality regulation in Kenya was consulted to provide guidelines in what aspects of the coffee roasting are subject to permitting and undergoing inspection with regard to stack emissions. The information provided singled out the particulate matter control as the key aspect of inspection associated directly with coffee roasting.

The research proposed two possible methods of cleaning dust and chaffs from the roaster exhausts; filtration and use of cyclone separators. Filtration uses a sieving mechanism that separates all particles from the gas stream through the exhaust. Cyclone on the other hand utilizes the centrifugal force created by spinning gas stream to separate particles from the gas. Cyclones were considered for application to this case based on the fact that they are simple to fabricate, economic and inexpensive giving a collection efficiency of up to 99%.

In this research work, two cyclone separator were designed for adoption at the firm to improve on the existing ducts systems for managing particulate matter contained in the stack emissions of coffee roasting process in the form of dust and chaffs.

One cyclone is to clean all chaffs that form during roasting while the second is the separate any chaffs that might find way to the cooling bin. Figure 5 shows the conceptual layout of the improved roaster for emission control while Figure 6 shows the CAD drawings for the two cyclones and the layout for the cyclones in the place of study.

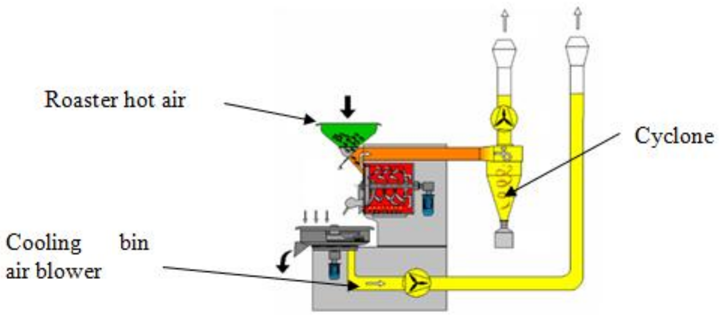


**Fig. 5:** Ideal conceptual model of an improved coffee roaster

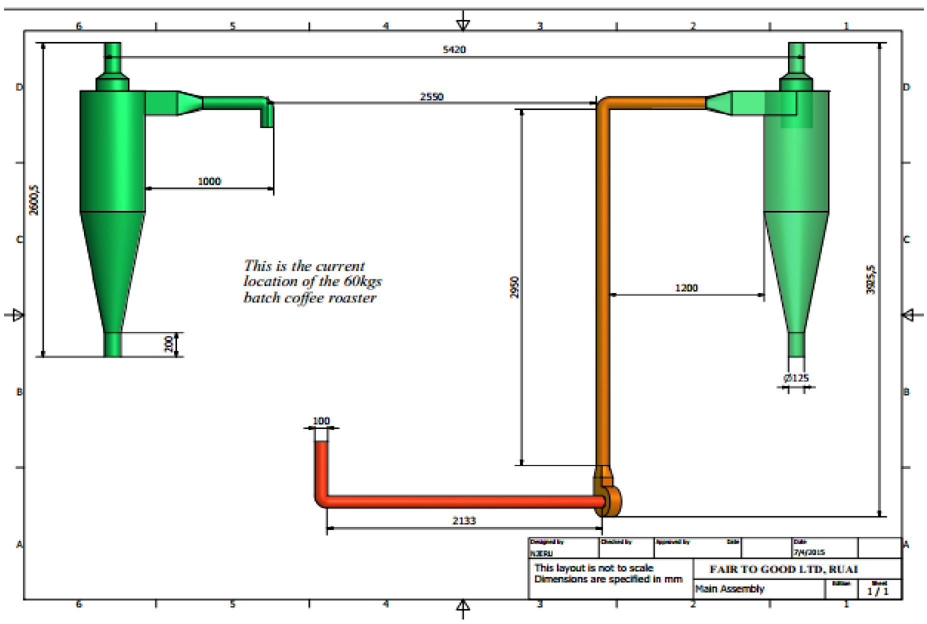


**Fig 6:**Design alternative for cyclones for the 60kg coffee roaster

**3.6.2Smoke extraction plan**

A smoke extract hood was proposed for minimizing smoke, steam and odors produced during coffee roasting. The hood was designed to be mounted above the roasters top with a fan that will pull air through the ductwork and outside the premises. In sizing the hood, proper calculations for total airflow were done. The guidelines required that a good design of a hood is one capable of cycling air in the workplace 15 times per hour.

To determine the total airflow for the hood, the heat output from the roaster, measured in BTU, was to be considered as shown in the Equation 2.

***Airflow (CFM) = Heat output (BTU) ÷ 100……………………………………………………. (2)***

It is important to take to consideration the losses due to duct lengths and bends. Thus, for the duct work 9CFM and 25CFM should be added for every 9" length and each 90º elbow encountered. This computation was adopted for the target value for total airflow high enough to convey all the particulates suspended in the gas stream from the roasters. The same is adopted for blower fan selection.

### 3.6.3VOCs emissions control plan

Volatile organic compounds (VOCs) were found to be formed in two stages. First during the roasting operation when the coffee beans are being heated in the roaster drum and during the quenching in the cooling bin. These VOCs include toxic acrolein, acetaldehyde and formaldehyde. They are air-borne and are emitted as by-product in form of steam or smoke. The research found that their release to atmosphere is a risk to human health because some are carcinogenic. Thus, for the process improvement to eliminate these pollutants, two systems were applicable.

These are;

- Thermal afterburner
- Catalytic incinerator

#### 3.6.3.1Thermal afterburner

Also referred to as thermal oxidizer. Thermal oxidizers or thermal incinerators are combustion systems that control VOC, CO, and volatile HAP emissions by combusting them to carbon dioxide (CO2) and water. This device is designed to eliminate VOCs by elevating the roaster exhaust gas to temperature greater than 1400º F. A dedicated burner is fitted within the ductwork of exhaust emission and in less than a second any VOCs that is contained in the gas stream is burnt out and the pollutants and odor are eliminated.

#### 3.6.3.2Catalytic incinerator

Also known as catalytic oxidizer (Figure 7), this pollution control system incorporate a heating system along with a catalyst. The heater can be gas fire or electric. The roaster exhaust gas is then heated to 750ºF or greater and the catalyst will react with the VOCs in the gas stream to volatize and otherwise destroy the exhaust pollutants.Thermal afterburners were found to be cheaper to purchase and maintain than catalytic incinerators.

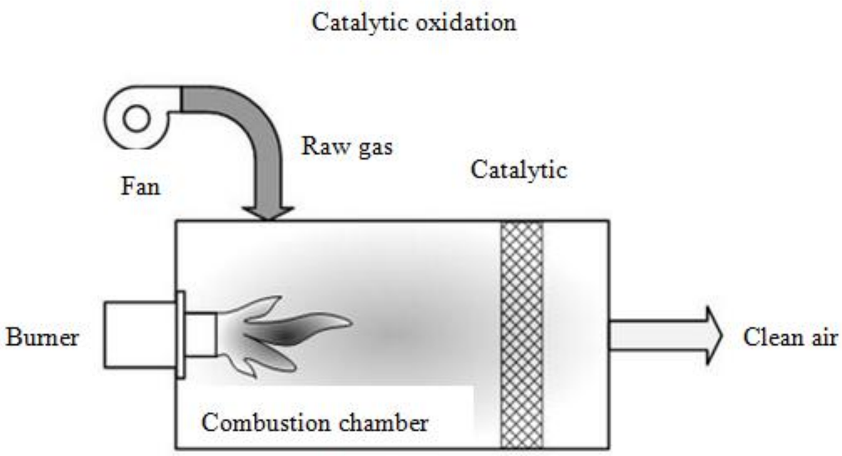


**Fig.7:** Catalytic oxidation

3.6.4Fuel combustion compounds formation control plan

The burners utilized in small scale coffee roasters use combustion to produce fuel emissions. Thermal $NO_x$ are thus probable as by-products of combustion and hence adding to emissions as shown in the Equation 3.

***Combustion: Fuel + Air + Ignition………………………………………………………. (3)***

Oxides of nitrogen (NO, $N_2O$ and $NO_2$) are by-products of incomplete combustion fuel. The higher the burner temperatures, the more these oxides are produced at the burner and through the roaster exhaust ducts they are emitted to atmosphere as pollutants in the gas stream. In order to reduce the composition of these oxides, use of low- $NO_x$ burners were proposed. These are specially designed burners that literature showed that they can reduce the $NO_x$ formation by 50%.

The low-$NO_x$ burners were found to be expensive to purchase and fit to an already existing roaster. It was not well established, through this research work, whether or not there are such burners developed for small shop sized roasters like the one used in the case study.

Improvement on the current burner was proposed to provide for flame regulator at different time intervals during the roasting period. This is to utilize the heat energy from the heated beans to complete the roast process without necessarily consuming more fuel thus less $NO_x$, CO and $SO_2$ formation.

3.6.5Recirculating system for treated roaster exhaust gas plan

Forethought of energy recovery from the hot exhaust gas from the coffee roaster meant reduction in the total amount of fuel to run the plant. This in turn would reduce the formation of $SO_2$, CO and NOx which are associated with fuel combustion. This research established that installing a recirculating system to send back the cleaned exhaust gas to pre-heat the green coffee beans in the hopper prior to roasting was viable. This provision would largely contribute to cleaner environment and boost on the payoffs to the plant owner by a greater profit margin realized as result of less operating cost.

## IV. Conclusion

This research addressed the emission management problem as identified in small scale coffee roasting firms in Kenya. Step by step process analysis was done to identify the various coffee roasting emissions and the related roaster system element. Pareto analysis was utilized to rate the risk index of the emissions for an objective management plan of the most adverse emissions. Particulate matter in form of dusts and chaffs from roasted coffee beans was found to have the highest risk index while odor had the least. Process improvement techniques presented an emission treatment and management plan that required incorporation of a specified cyclone dust separator to the typical 60kg batch type coffee roasterand use of regulators to the burners to lower the fuel emission levels. VOCs were estimated and recorded as within the safe levels. The uniquecontribution of the research was the design of high efficiency cyclones and blowers for a typical 60kg batch-type coffeeroaster which, if added to design, will clean and control the unwanted emissions.

## Acknowledgment

This work was supported by Dedan Kimathi University of Technology (DeKUT). Special acknowledgement goes to Fair to Good Ltd for allowing us to use his firm tocarry out this research.

## References

[1]. Alexia N Gloess, A. V. (2014). Evidence of different flavor formation dynamics by roasting coffee from different regions. International Journal of Mass spectrometry, 324-337.
[2]. Bottazi, D. (October, 2012). Numerical approach for the analysis of coffee roasting process. Jounal of food engineering, 243-252.
[3]. Heumann, M. (1983). Understanding Cyclone dust collectors. Louisville: Fisher Kosterman Inc.
[4]. John Byatt, R. D. (1988). Minimum Particle size for Cyclone dust separator.
[5]. Peter Pckard, K. M. (2013). Understanding thermal oxidisers. Zeeco.
[6]. Webster, T. (2003). BURNER TECHNOLOGY FOR SINGLE DIGIT NOx EMISSIONS IN BOILER APPLICATIONS. CIBO NOx Control XIV Conference (pp. 1-9). San Diego, CA: John Zink Company LLC.

David M. Njeru Process Analysis for Emission Control withinthe Small Scale Coffee Roasting Industries in Kenya." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 14, no. 6, 2017, pp. 70-78