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Dynamic Wet Scrubber System for Residential Waste Incinerator

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Abstract

The small-scale incinerator uses the process of combustion to convert residential solid waste materials into several hazardous gases, ashes, and water. Without a proper filtration system, it will release hazardous combustion gases that can affect human health. Therefore, this study is embarked on an analysis of the composition of gasses obtained after being filtered via a dynamic wet scrubber system from incineration waste. The open burning of municipal solid waste (MSW) could be avoided. The ashes may contain toxic substances or metal that should be safely disposed of. This technology uses the dynamic wet scrubber to filter the gases released from combustion in the garbage tank of the incinerator. The design of the dynamic wet scrubber that has been fabricated was researched to focus on less of the maintenance process in the future. The double swirling water in the scrubber was used to collect the dirt particles and dust in the gases. The suction pump at the outlet of treated gas reduces installation and energy costs. The released emission gasses were monitored using some specific MQ gas sensor modules with Arduino and the data were analyzed using response Microsoft Excel, GraphPad Prism 8, and Design-Expert 13.

Discipline: Mechanical Engineering

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1 Introduction

Household garbage, medical waste, and abattoir waste can be incinerated on a small scale as an alternative to disposal in landfills. The second most popular way to dispose of municipal solid waste (MSW) after landfills are incineration, also referred to as mass burning. When modern emission control technologies and energy recovery are considered, it is one of the most expensive waste treatment facilities.

The primary purpose of adopting incineration technology for municipal solid waste (MSW) treatment is to reduce MSW volume by up to 95 percent. In Malaysia, over 99 percent of municipal solid waste is managed through landfilling, while incinerators have only been employed on a modest scale (Abd Kadir, 2013). The national average is between 0.5 and 0.8 kg/person/day, whereas the urban average is 1.7 kg/person/day. Every day, the city of Kuala Lumpur collects an average of 2,500 tons of MSW, which is then disposed of at the Taman Beringin landfill (Kathirvale, 2004). Before 2006, neither trash incineration nor gas recovery from landfills was utilized, although if implemented, they would effectively lower the pace of unclean landfilling and create energy equivalent to that of fossil fuels (Fazeli, 2016).

It is a common practice to employ wet scrubbers in the process of removing pollutants from the flue gas of a furnace or other gas streams (Husain, 2016). In this project, the use of the Arduino gas sensor module has to run a calibration process. By generating a chemical reaction on their heated electrodes and monitoring the ensuing electric current, these sensors determine the concentration of a particular gas (Abbas, 2020) and the variation in sensor resistance value as a function of gas concentration. When the gas concentration is high, the resistance goes down; when it is low, the resistance goes up (Shi, 2009). In this project, a number of gasses that can harm the environment and people's health due to indoor and outdoor air pollution were measured. Hexane contamination of the air can short-term affect the nervous system and result in headaches, nausea, dizziness, and even unconsciousness (U.S. EPA, 2000). Ground-level ozone is a dangerous air pollutant and a greenhouse gas that causes 1 million premature deaths annually and is primarily formed by methane (Nisbet, 2020). Smoke consists of particles and may contain toxic nitrogen oxides, carbon monoxide, and hydrocarbons. Cigarette smoke can worsen health conditions and cause health problems (Nulsen & Holt, 1974).

Ammonia is a particulate precursor. It combines with nitric and sulphate acids to form harmful ammonium salts (Numbers, 2015). Carbon dioxide emissions are a major source of air pollution due to their greenhouse gas effects (GHG) (Manisalidis, 2020). Toluene is an environmental (volatile organic compound) VOC. Tobacco smoke, traffic exposure, and paint, rubber, and adhesive solvents are sources of it (Mögel, 2011). Under the federal Clean Air Act Amendments of 1990, acetone is not a hazardous air pollutant (HAP) (Ramachandra Rao, 2006). The gas carbon monoxide (CO) is colorless and odorless. Frequently, smoke and exhaust fumes contain carbon monoxide. Carbon monoxide is a common air pollutant (Nielsen, 2011).

The objectives of this project are to assess and analyze a small-scale incinerator with a durable body and structure build quality that undergoes high temperature for a certain duration and to develop a wet scrubber and emission gas analysis system with a low maintenance process and high efficiency of combustion gas treatment. This project mainly uses the Arduino gas sensor module as a gas analyzer for gas emission from the incinerator through a dynamic wet scrubber. The wet scrubber has a significant impact on managing the quality of the air around it.

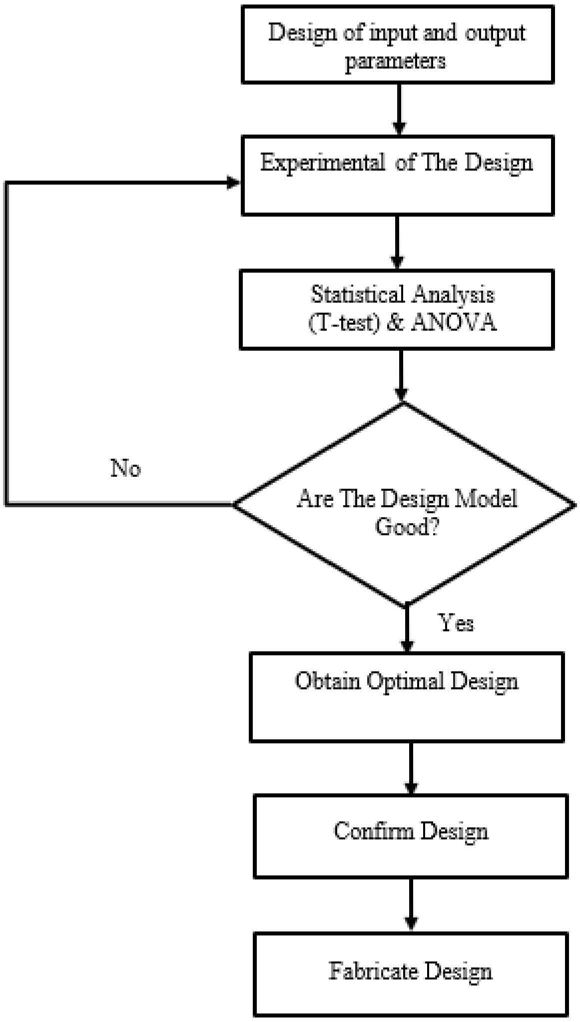


Figure 1: Response Surface Method (RSM) design flowchart.

2 Literature Review

2.1 Parallel-Plate Wet Scrubber

A parallel-plate wet scrubber (PPWS) was built and tested to control low-concentration, soluble acid gases by substituting traditional tower packings with a multi-parallel-plate module (MPPM). The parallel polypropylene plates of the MPPM were coated with nano-TiO_2 particles to increase hydrophilicity and provide a homogenous liquid coating. The gap between the plates was maintained at 3 mm so that the liquid downward scrubbing layer on the plates could capture soluble gas contaminants in the upper gas stream. This study aimed to improve the performance of current wet scrubbers in high-tech businesses by developing a high-efficiency wet scrubber.

2.2 Wet Packed Bed Scrubbers

Ceramic saddles or rings are used as packing material in loosely packed bed scrubbers to increase the wetted surface area for PM and gas collection. They operate well in crossflow, concurrent-flow, and counter-current-flow settings. The creation of a wet-packed bed scrubber-based system, since it is easy to manufacture and run, has a low-pressure drop, a cheap cost, and offers the potential of accomplishing both the gas cooling and purification in a vertically compressed unit tower. The sand bed filter is appealing because it provides excellent collection efficiency for both particles and heavy tars at low running costs.

2.3 Spray Scrubbers

Spray scrubbers use nozzles to spray very small droplets into a chamber where liquid and air interact. Finer droplets increase the surface area of contact between air and liquid, but they might be more difficult to remove from the airstream before the liquid evaporates. The air exits the scrubber. Spray scrubbers are efficient in all three flow arrangements. Cross-current, concurrent, and counter-current. Spray scrubbers possess the lowest airflow pressure a decline among scrubbers. Spray scrubbers working in crossflow and concurrent flow operations are least likely to get plugged

3 Materials and Methods

The methodology is a set of steps or processes for gathering, acquiring, processing, and analyzing the data needed to execute a project. The Response Surface Method (RSM) is the most effective optimization tool available within the statistical design of experiments (DOE). In order to complete this project, the RSM was utilized, and its fundamental flowchart design is shown in Figure 1. In the later development phases, RSM demonstrates the three-dimensional graph of the standard error of design, which is based on the data that was entered in the earlier stages. When the reaction to two separate elements produces different results in various contexts, this is known as an interaction.

3.1 Material Preparation and Experimental Setup

This research was conducted at a residential area at Kota Bharu, Kelantan which is domestic neighboring. The collection of solid waste used in this experiment was paper, plastic, rubber, and wood from random dustbins taken in the neighborhood. The wastes collected were dried for three days, chopped into small pieces, and packed separately into waterproof containers in preparation for experimental processes. The reduction of solid waste sizes into small pieces was necessary for forming homogeneous materials leading to increased surface area and allowing faster heat penetration. The waste samples loaded into incinerators were neither pre-treated nor specific ingredients selected.

The experiment started with the combustion in waste storage in the incinerator and the top exhaust gas outlet connected with an aluminum duct tube directly to the wet scrubber. The waste gas gets through the dynamic wet scrubber assisted with a 450W centrifugal pump by suction from the outer gas of the dynamic wet scrubber. The Gas Analyzer was put inside the PVC pipe at the end of the exhaust and released gas from the centrifugal pump to read the gas and smoke concentration. Two samples of concentration gas were taken using waste oil as a burner and another one without an oil burner. The experiment setup for this project was done as illustrated in the schematic diagram in Figure 2. The red arrows demonstrate the flow of the gas through all the parts in the incineration process.

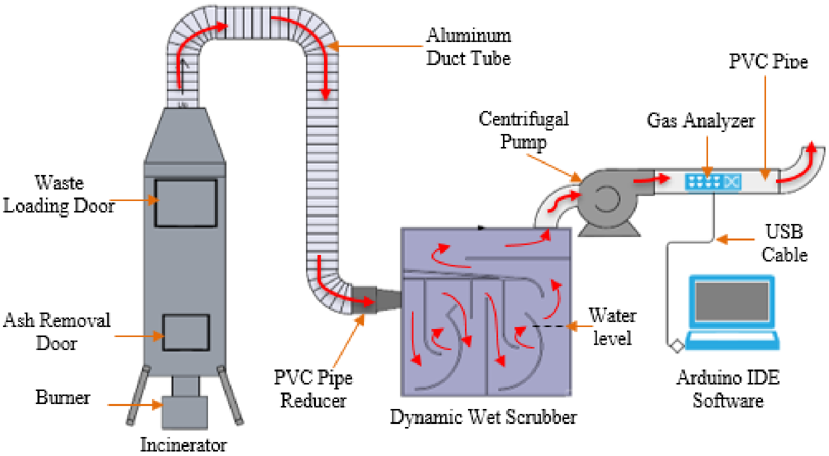


Figure 2: Schematic of experiment setup and gas flow.

3.1.1 Hardware (Incinerator Setup)

An incineration system, Figure 3 (a) for this project is set up properly before running the test. This incinerator used a nozzle spray by boiling water to blow the fire into the waste storage. The smoke was able to be thoroughly filtered due to the fact that the top of the incinerator, through which it exited, was connected through aluminum duct tubing directly to the dynamic wet scrubber. The solid wastes eliminated in this incinerator were plastic, paper, rubber and wood which were put through the loading door as in Figure 3 (b). After the process of incineration was completed, the incinerator must be allowed to cool down before any residue, such as ash or non-combustible materials, can be removed by pulling the ash removal door.

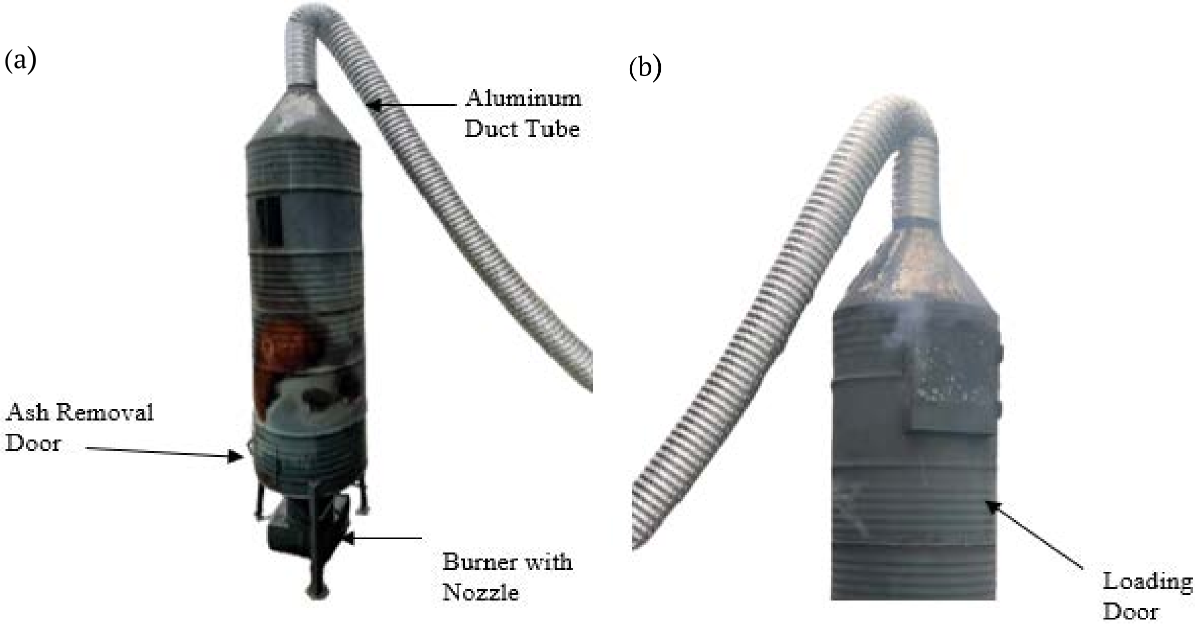


Figure 3: (a) Incinerator and aluminum duct tube; (b) Loading door for the input of solid waste.

3.1.2 Dynamic Wet Scrubber System

The existing model of dynamic wet scrubber design requires a piping system to easily fill and remove water from the scrubber model, with a 4-stop cord which includes 2 for inlet water and 2 for outlet water and ash handling as demonstrated in Figure 4. The two PVC tank connectors are added for the 2 at inlet and 2 at outlet gas of the wet scrubber. The gas outlet pipe is connected to the centrifugal pump by suction. The acrylic sheet of the wet scrubber needs to be drilled before putting it in the piping system. The red arrow in the figure shows the flow of the gas in the wet scrubber.

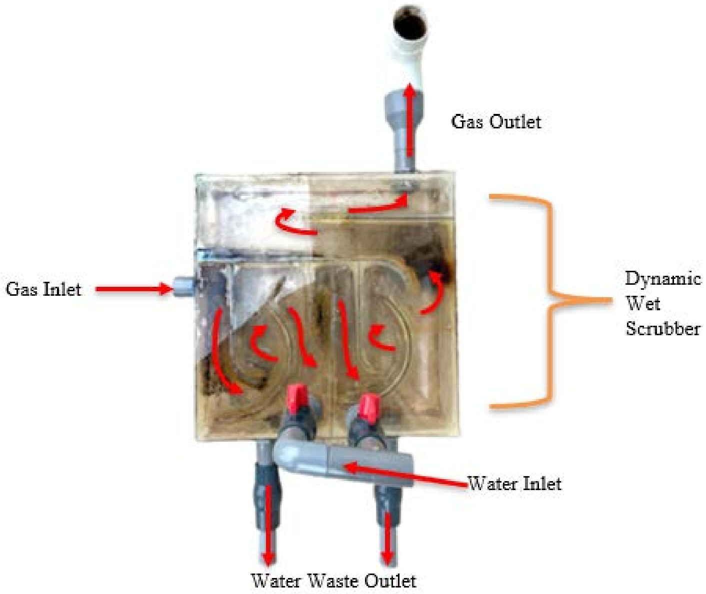
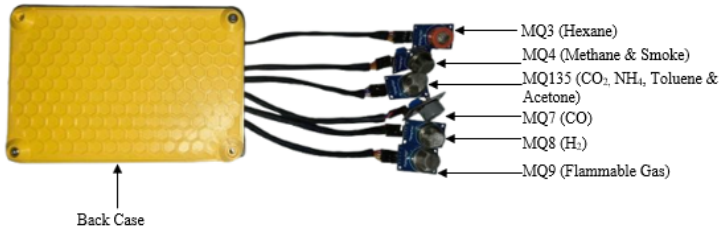


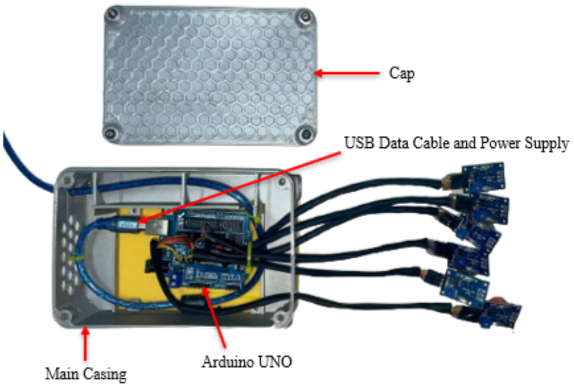
Figure 4: Dynamic Wet Scrubber with the piping system with gas flow.

3.1.3 Arduino UNO and Gas Sensor Module Setup

The gas released from the incinerator through the dynamic wet scrubber during the combustion process is measured using the Gas Sensors Module with Arduino UNO. The Gas Sensors Module being used in this Gas Analyzer are MQ3, MQ4, MQ7, MQ8, MQ9 and MQ135 as illustrated in Figure 5 in which every sensor needs to calibrate before using it. The calibration of the gas sensor module is required. In order to get the correct and accurate data, the gas sensor needs 24 to 48 hours of preheating time. The power supply is connected to all gas sensors and left for the required time until it gets ready for the calibration process. The casing of Arduino UNO with gas sensor (Gas Analyzer) in Figure 5 (a) and (b) is 3D printed using Biqu B1 model. The coding of the Gas Analyzer is done using Arduino IDE software (Azmi Patar,2015). Figure 5 (b) illustrates the Arduino setup inside the case.



(a) Shows the 6 type of Gas Sensor from back case.



(b) Arduino Setup from in front.

Figure 5: 6 Types of a gas sensor module with gas type detector (b) Arduino setup with 3D printed casing.

3.2 Software

The coding for the Arduino UNO and gas sensor module was written using the Arduino IDE (1.8.16) for this project. The data for the result were gathered in the Arduino IDE's serial monitor and converted to a CSV file using Arduspreadsheet tools so that it could be easily opened in Microsoft Excel. The data were tabulated in Excel. GraphPad Prism 8 was used to analyze the data using a t-test table and graph. The analysis of standard error applied Response Surface Methods (RSM) for every gas emission by using Design-Expert 13. A flow chart for this Arduino Gas Analyzer process is illustrated in Figure 6.

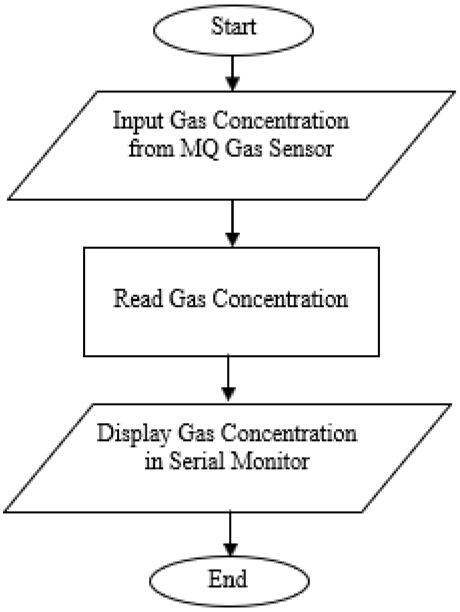


Figure 6: Flow chart of gas sensor concentration in the serial monitor.

3.3 Data and Calibration

Data were gathered using a Gas Analyzer that was USB-connected to a laptop. The Gas Sensor comes in various gas detector types with different specifications. Figure 9 shows the type of MQ Sensor with their function. The data were subsequently examined using t-test analysis. To determine whether there is a significant difference between the means of two groups that may be related in some ways, a t-test of inferential statistics was used. For data sets, the recorded data set was used. The t-test establishes the problem statement mathematically by taking a sample from each of the two sets and presuming that the two means are equal. Certain values are calculated and compared to the standard values using the appropriate formulas, and the assumed null hypothesis is accepted or rejected as a result.

Table 1: MQ sensor module type.

MQ Sensor Type	Gas Measured
MQ3	Hexane
MQ4	Methane & Smoke
MQ135	CO2, NH4, Toluene & Acetone
MQ7	CO
MQ8	H2
MQ9	Flammable Gas

3.3.1 Calibration

For this project, the calibration procedure was carried out before completing the gas sensor module. Every gas sensor's datasheet stated that the graph displays the gas concentration in parts per million (ppm) in relation to the sensor's resistance ratio (R_S/R_0). R_0 is the sensor's resistance at a known concentration in the absence of other gasses or in the fresh air, and R_S is the sensor's resistance that varies with gas concentration. To find R_S, the formula being used in this case is Ohm's Law, as in equation (1).

$$V = I \times R \tag{1}$$

Where V is voltage, I is current, and R is resistance. From equation (1), it can be derived as equation (2) which is the combination of R_S and R_L for R in which R_L is reading resistance. V is equal to V_C.

$$I = \frac{V_C}{(R_S + R_L)} \tag{2}$$

For equation (3), V_{RL} is output voltage which means V_{RL} is equal to V as inserted into equation (1). From equation (3), it was derived to get the value of R_S as shown in equation (4).

$$V_{RL} = \left[\frac{V_C}{(R_S + R_L)}\right] \times R_L \tag{3}$$

$$R_S = \left[\frac{(V_C \times R_L)}{(V_{RL})}\right] \qquad (4),$$

The R_S/R_0 in the fresh air was calculated using the graph in the datasheet. The value of the R_S in fresh air must be determined in order to calculate the R_0. This was accomplished by converting the analogue average readings from the sensor to voltage. The scale of the graph in the datasheet was log-log. This indicates that the behaviour of the gas concentration in relation to the resistance ratio is exponential on a linear scale. For a log-log scale, the formula was used instead of the equation for a line. A formula line (5) is calculated as follows:

$$y = mx + b \qquad (5),$$

Where y is the vertical axis value, x is the horizontal axis value, m is the slope of the line and b is the vertical axis intercept. For the log-log scale, the formula was derived as in equation (6). Equation (6) was derived to find the gas concentration for any ratio with equation (7). However, to get the real value of the gas concentration according to the log-log plot, the formula needs to be derived into the inverse log of x as equation (8).

$$\log(y) = m \times \log(x) + b \qquad (6),$$

$$\log(x) = \frac{(\log(y) - b)}{m} \qquad (7),$$

$$x = 10^{\left[\frac{(\log(y)-b)}{m}\right]} \qquad (8),$$

The sensor of the gas Arduino was preheated for 24 hours to start the calibration process. After the preheating process, the sensor runs the calibration process to get the R_0 value of each MQ sensor module as in Table 2. The value was put in the coding in Arduino IDE to start reuploading the programming to the Gas Analyzer.

Table 2: MQ Sensor Module Type with R_0 value for calibration.

MQ Sensor Type	Gas Measured	R0 value (Ω)
MQ3	Hexane	0.88
MQ4	Methane & Smoke	12.39
MQ135	CO2, NH4, Toluene & Acetone	12.69
MQ7	CO	3.86
MQ8	H2	0.30
MQ9	Flammable Gas	5.82

3.3.2 Repeatability Analysis

The repeatability analysis is one method to evaluate the precision of measurements that can be normally or non-normally distributed, and it permits the identification of an explanation for the observed variances. The procedure was carried out with a total of ten samples so that the repeatability of the system can be evaluated. During each of these runs, the concentration of gas that was ousted during either of the two trials is meticulously noted. Using equations (9) through (11), we were able to calculate the mean values, $\overline{x}$ (9), standard deviation (SD) (10), and variance (SD2) (11), where *x* is the value of concentration and n is the total number of samples taken.

$$\overline{x} = \frac{\sum x}{n} \qquad (9),$$

$$SD = \sqrt{\frac{\sum (x - \overline{x})}{n}} \qquad (10),$$

$$SD^2 = \frac{\sum (x - x^2)}{n} \qquad (11),$$

4 Result and Discussion

4.1 Comparative Analysis Between Two Sample Gas With and Without Waste Oil Burner

The mean, Standard Deviation (SD) and Variances were calculated using equations (9), (10) and (11) as tabulated in Table 3 for the experiment (a) which did not use waste oil, while Table 4 depicts experiment (b) which used waste oil burner. From both tables, the highest mean was smoke 24400.93 ppm for case (a) which did not use the waste oil burner but used the waste oil burner with 20379.70 ppm. It is the same as the *SD* and *SD*^{2} in which the highest value goes to smoke emission of the experiment (a) which was 21648.33 ppm and 6408621.47 ppm while exp (b) had 237.10 ppm and 56214.46 ppm.

Table 3: Basic statistic of Exp (a) incineration without using burner.

	Gas (ppm)								
	Hexane	Methane	Smoke	CO_2	NH_4	Acetone	CO	H_2	FG
Sample 1	0.95	88.25	20740.44	2.00	3.20	0.31	0.91	61.00	5.45
Sample 2	0.97	89.53	21648.33	2.00	3.20	0.31	0.90	61.00	5.45
Sample 3	0.98	90.17	22116.15	2.02	3.21	0.31	0.90	61.00	5.40
Sample 4	0.99	92.12	23577.40	2.00	3.20	0.31	0.91	61.09	5.40
Sample 5	1.00	92.78	24084.36	2.03	3.23	0.31	0.90	61.00	5.42
Sample 6	1.02	92.78	24084.36	2.04	3.25	0.32	0.89	61.19	5.40
Sample 7	1.03	94.79	25667.51	2.03	3.23	0.31	0.89	61.09	5.40
Sample 8	1.04	95.46	26216.62	2.03	3.23	0.31	0.89	61.09	5.40
Sample 9	1.04	96.82	27348.30	2.03	3.23	0.31	0.89	61.09	5.37
Sample 10	1.07	98.20	28525.83	2.04	3.25	0.32	0.88	61.00	5.37
Mean	1.01	93.09	24400.93	2.02	3.22	0.31	0.90	61.06	5.41
SD	0.04	3.24	2531.53	0.02	0.02	0.00	0.01	0.07	0.03
SD2	0.00	10.48	6408621.47	0.00	0.00	0.00	0.00	0.00	0.00

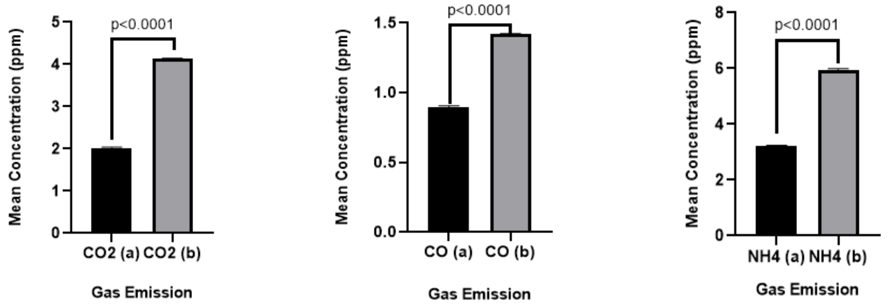
Table 4: Basic statistic of Exp (b) incineration using waste oil burner refine table.

	Gas (ppm)								
	Hexane	Methane	Smoke	CO_2	NH_4	Acetone	CO	H_2	FG
Sample 1	0.16	87.30	20080.91	4.14	5.98	0.73	1.42	58.80	10.61
Sample 2	0.16	87.30	20080.91	4.11	5.94	0.72	1.41	58.88	7.10
Sample 3	0.16	87.84	20453.57	4.11	5.94	0.72	1.42	58.80	10.04
Sample 4	0.16	87.30	20080.91	4.17	6.02	0.73	1.41	58.80	8.19
Sample 5	0.16	87.84	20453.57	4.11	5.94	0.72	1.42	58.96	10.70
Sample 6	0.16	88.38	20832.87	4.11	5.94	0.72	1.42	58.88	7.66
Sample 7	0.16	87.84	20453.57	4.11	5.94	0.72	1.42	58.96	10.72
Sample 8	0.16	87.84	20453.57	4.14	5.98	0.73	1.43	58.96	7.17
Sample 9	0.16	87.84	20453.57	4.11	5.94	0.72	1.42	58.96	9.37
Sample 10	0.16	87.84	20453.57	4.14	5.98	0.73	1.42	58.96	9.63
Mean	0.16	87.73	20379.70	4.13	5.96	0.72	1.42	58.90	9.12
SD	0.00	0.34	237.10	0.02	0.03	0.01	0.01	0.07	1.47
SD2	0.00	0.12	56214.46	0.00	0.00	0.00	0.00	0.01	2.15

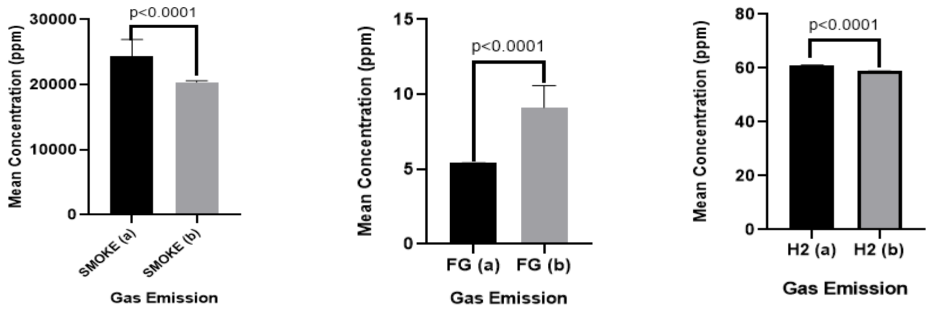
After this project, the concentration of gas Carbon Dioxide CO_2, Carbon Monoxide, Ammonium Ion NH_4, Smoke, flammable gas FG, Hydrogen H_2, Methane, Acetone and Hexane was taken by using a Gas Analyzer for both experiments that used waste oil burner and without oil burner. In the comparative analysis between two sample gasses with and without waste oil burner in Table 5, the results showed that the mean of CO_2 was 2.022 ppm and 4.125 ppm, while the standard of error of the mean (SEM) was 0.005 ppm and 0.007 ppm, respectively. The t-test shows a significant difference in CO_2 gas emissions. The mean of CO was 0.896 ppm when not using a burner and 1.419 ppm when using a waste oil burner with SEM 0.005 ppm and 0.007 ppm respectively. Significant variation occurred when not using burners and when using waste oil burners as demonstrated in Table 5.

Table 5: T-test analysis between without burner and with waste oil burner.

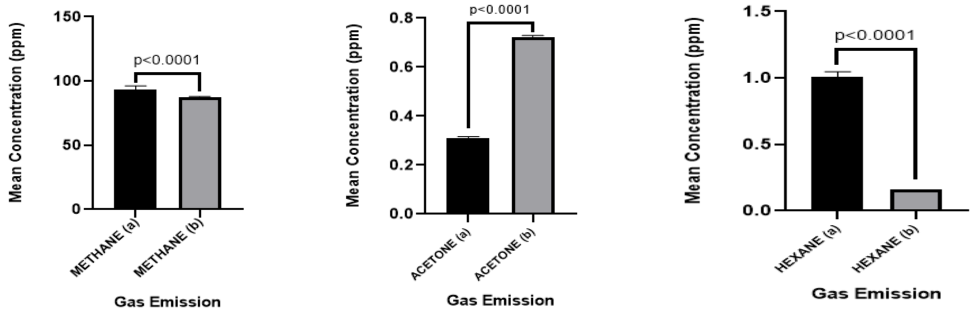
Gas Emission	(a) Without burner (ppm)	(b) With waste oil burner (ppm)	T-test (Pairwise) Significance (p-value) (ppm)
CO_2	2.022 ± 0.005	4.125 ± 0.007	< 0.0001
CO	0.896 ± 0.003	1.419 ± 0.002	< 0.0001
NH_4	3.223 ± 0.006	5.960 ± 0.009	< 0.0001
Smoke	24400.930 ± 800.539	20379.702 ± 74.976	< 0.0001
Flammable Gas	5.406 ± 0.009	9.119 ± 0.463	< 0.0001
H_2	61.055 ± 0.021	58.896 ± 0.023	< 0.0001
Methane	93.090 ± 1.024	87.732 ± 0.108	< 0.0001
Acetone	0.312 ± 0.001	0.724 ± 0.002	< 0.0001
Hexane	1.009 ± 0.012	0.160 ± 0.000	< 0.0001



(i) Carbon Dioxide, CO2 (ii) Carbon Monoxide, CO (iii) Ammonium



(iv) Smoke (v) Flammable Gas (vi) Hydrogen



(vii) Methane (viii) Acetone (ix) Hexane

Figure 7: Comparative analysis between two sample gas with and without waste oil burner using a bar chart with an error bar. (i) comparison of CO_2; (ii) comparison of CO; (iii) comparison of NH_4; (iv) comparison of smoke; (iv) comparison of FG; (v) comparison of FG; (vi) comparison of H_2; (vii) comparison of Methane; (viii) comparison of Acetone; (ix) comparison of Hexane.

Without using a burner, the mean concentration of NH_4 was 3.223 ppm with an SEM of 0.006 ppm, and when using a burner, it was 5.960 ppm with an SEM of 0.009 ppm. When a waste oil burner was used, the mean levels of smoke and flammable gases were 20379.702 and 9.119 parts per million (ppm) and 24400.930 and 5.406 ppm, respectively. The mean for H_2 was 61.055 ppm and 58.896 ppm for burning waste oil and not using a burner, respectively. Methane levels averaged 93.090 ppm when burning with no oil, and 87.732 ppm when burning with waste oil. Meanwhile, the mean concentrations of acetone and hexane were 0.312 ppm and 1.009 ppm, respectively when no burner was present, and they were 0.724 ppm and 0.160 ppm, respectively, when using a waste oil burner.

Figure 7 demonstrates Mean Concentration against Gas Emission. The bar chart with error bar (a) represents the mean of an experiment that did not use a waste oil burner, while the bar chart with error bar (b) represents an experiment that used the waste oil as the burner. The bar chart also shows the p-value for the significant difference between the two experiments on the top of both bars of each case in Figure 7. The value of p shown was lower than 0.0001 ppm. The bar chart with error bar (iv) shows the mean concentration of smoke emission was the highest which was 24400.930 ppm for (a) while (b) was 20379.702 ppm.

4.2 Response Surface Methods (RSM) For Standard Error

4.2.1 Interaction Plot

Interaction effected between Carbon Dioxide, CO_2 and Carbon Monoxide, CO emission from the wet scrubber using a Gas Analyzer was tested using ANOVA. The standard error of design was plotted using an interaction graph. Figure 8 shows the interaction plot between CO_2 and CO for the experiment (a) which does not use a waste oil burner. Figure 9 illustrates the interaction plot between gas CO_2 and CO with incineration using a waste oil burner.

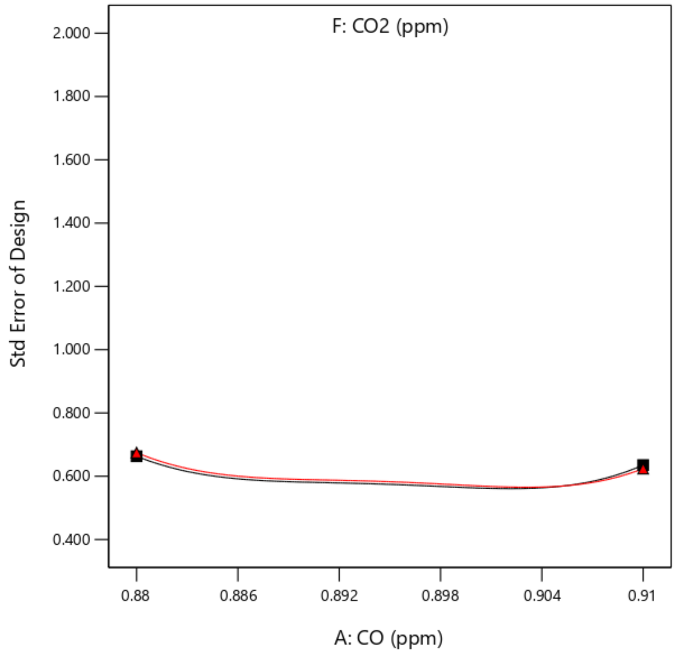


Figure 8: Interaction plot for CO_2 against CO for the experiment (a). ANOVA analysis showed insignificant interactions for both gasses.

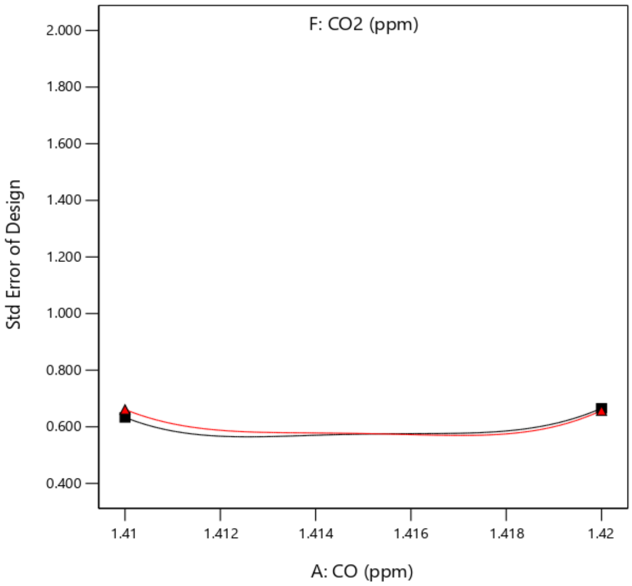


Figure 9: Interaction plot for CO_2 against CO for the experiment (a). ANOVA analysis showed insignificant interactions for both gasses.

4.2.2 Three-Dimensional Surface Response

Figure 10 illustrates a 3D Surface using the response surface method for the experiment of incineration without using oil as a burner, and it also shows the standard error of design based on data entered. Based on the graph, the range of standard error of design was 0.500 ppm to 1.500 ppm for CO and flammable gas emissions. For 3D Surface utilizing the response surface method, Figure 11 shows the experiment involving incineration with the use of waste oil as a burner which illustrates the standard error of design based on the data entered. According to Figure 11, the standard error of design ranged from 0.500 ppm to 1.500 ppm for CO and flammable gas emissions.

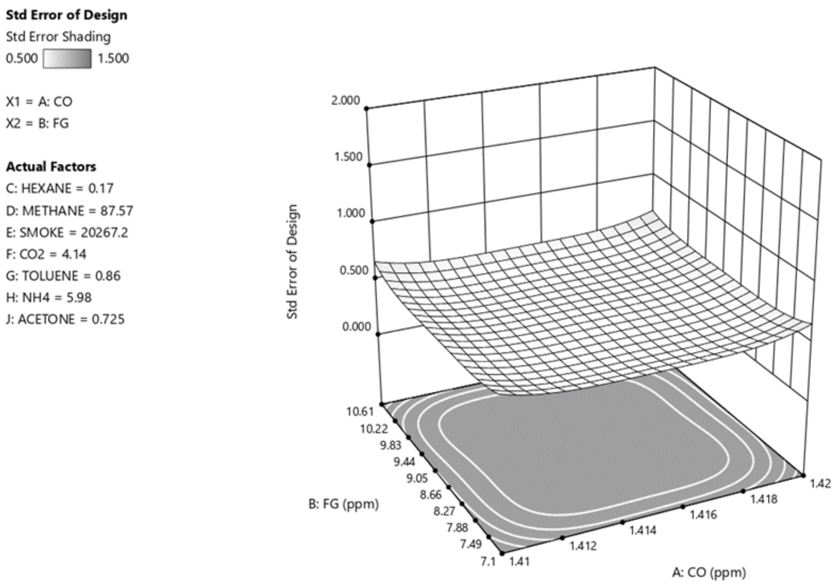


Figure 10: Three–dimensional response surface for CO and flammable gas experiment (a) incineration without using a waste oil burner.

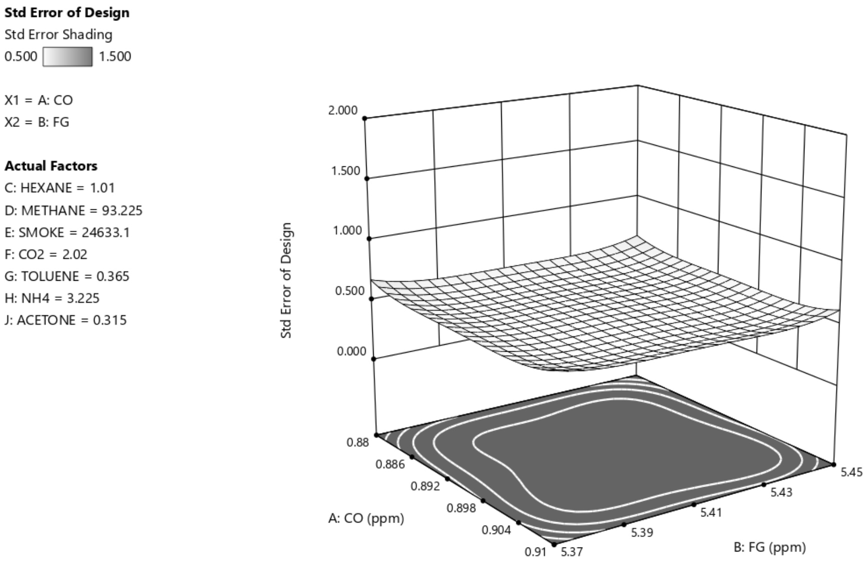


Figure 11: Three–dimensional response surface for CO and flammable gas Experiment (b) using waste oil burner during incineration.

5 Conclusion

The data analysis revealed that the burning of solid waste releases a significant amount of pollution gas, the amount of which is dependent on the type of waste being burned and the kind of burner being used during the process. The primary objective, which was to evaluate and analyze a small-scale incinerator with a durable body and structure build quality that can withstand high temperatures for a certain amount of time, was successfully attained. Additionally, the secondary objective, which was to develop a wet scrubber and emission gas analysis system with a low maintenance process and high efficiency of combustion gas treatment, was also successful. The CO and CO_2 gases released from the incineration through the scrubbing system were below a dangerous level based on Air Quality Index (AQI) in environmental. However, this project still has limitations for gas analysis that may require additional expenses for high efficiency and quality. The recommendation for the subsequent researcher is that they investigate the dynamic wet scrubber design, which has the potential to accommodate a moderate scaling up. The data analysis can also be improved by putting in the threshold line of gas or smoke release from burning that may be set by the Environmental Department or WHO. A threshold line is the level of detection or the point at which a limit of gas released into the environment by waste burning is reached.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

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