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Development of an Electrostatic High Voltage Air Filter System Used for the Reduction of Emission from Waste Incineration of LPU-Cavite

Engr. Jerny D. Catibayan

Department of Electrical Engineering, College of Engineering, Computer Studies and Architecture

Abstract: **Incineration is waste destruction in a furnace by controlled burning at high temperatures. Waste incinerators are commonly viewed as harmful to the environment because of the pollutants they inevitably emit. Air filtering is one viable way to minimize the harmful gases produced by incineration. Electrostatic high voltage air filter with water filtration is a highly efficient filtration device that is extremely effective oxidant, lethal to all bacteria and viruses. An electrostatic high voltage air filter is suitable in treating the smoke from the incinerator since it can effectively reduce the pollutants present in the smoke. The water filtration is a viable addition in the filtering system since it reduces the smoke coming from the incinerator. The electrostatic high voltage air filter is placed before the water filtration since the former is sensitive in humid air. The incinerator and the filtering system are separated to protect the filtering components from high temperature coming from the incinerator. MQ135 air quality sensor is used to measure the overall quality of air coming out of the exhaust after the filtering system. Industrial-grade suction fans are used to force the smoke from the incinerator to the filtering system. MCU is used to centralize the operation and control of the incineration and filtration. An LCD is used to monitor the current process and display the real-time data indicated by air quality sensor. A keypad is used to provide selection in the process of incineration and filtration. Three trials in each type of non-recyclable garbage (plastics, papers, dry leaves, and assorted) were conducted to determine the average result in four different conditions (both filters are off, filters are on, only electrostatic filter is on, and only water filtration is on). The evaluation of the performance of the filtering system was observed and therefore concluded that it is capable to reduce the pollutants emitted by the incinerator significantly.**

Keywords: **The author gives 4 – 10 keywords which are related to the major part of their research work.**

1. INTRODUCTION

Background of the Study:

Air is the invisible mixture of gases such as nitrogen (79%), oxygen (20%), and other gasses mostly Carbon Dioxide (1%) that surrounds the Earth's atmosphere. Air is important because it contains oxygen which humans and animals need for breathing and other gases that supports any other living things on Earth including plants and other organisms. Also, the air keeps the Earth at a habitable temperature.

Here in the Philippines, especially in rural areas fresh and clean air is almost unavailable because of air pollution. According to The World Health Organization, air pollution is defined as the alteration of the natural characteristics of the atmosphere caused by biological and chemical contaminants. It is known to pose a major health risk as it can lead to the development of respiratory conditions, heart problems, and even cancer. Air pollution may result from both human and nature activities. Human activities which cause air pollution includes burning coals and fossil fuels, exhaust from combustion engines, mining operations, household and farming chemicals and emissions from industries and manufacturing activities. The most common is waste incineration, although it is one way of minimizing the volume of waste, waste incineration emits high level of carbon dioxide, organic compounds, and chemicals into the air.

Air filtering is one way to minimize the harmful gases produced by the said activities. Electrostatic High Voltage Air

Filter with Water Filtration is a highly efficient filtration device that is extremely effective oxidant, lethal to all bacteria and viruses. It can be used to disinfect and sanitize a room or area. Air filtering system in a waste incinerator will decrease the amount of pollutants emitted by the waste and at the same time, this system will decrease volume of the waste. Air filtering system is composed of parallel plates with a high voltage DC (5kV – 9kV) supply. Those parallel plates when supplied by high voltage DC will cause corona discharge which disinfects the air that passes through it. The water filtration is composed of a water pump that serves to circulate the water. The water flows in a layer of abaca in which solid particles are be filtered.

Objectives of the Study:

The general objective of the study was to reduce the amount of pollutants filtered from the emission of waste incineration by an electrostatic high voltage air filter system.

Specifically, the study aimed to:

1. design a waste incinerator with electrostatic high voltage air filter system
2. develop a prototype for the electrostatic high voltage air filter system; and
3. To evaluate the performance of the system.

- determine the amount of pollutants emitted by burning different types of materials without the air filtering system;
- determine the amount of pollutants emitted by burning different types of materials with electrostatic air filter running only;
- determine the amount of pollutants emitted by burning different types of materials with water filtration running only;
- determine the amount of pollutants emitted by burning different types of materials with the whole air filtering system; and
- Compare and analyze the output and calculate the reduction of pollutants.

Significance of the Study:

This study is significant in helping the environment by reducing impurities, solid particles, chemicals, bacteria and viruses emitted by an incinerator as it filters the smoke coming out from the system. In a more specific manner, this study benefited the following:

1. the LPU-C community and the nearby barangays;
2. Municipality of General Trias, Cavite; and
3. Future researchers, as the study may serve as a reference for the further development about air filtering system.

Conceptual Framework:

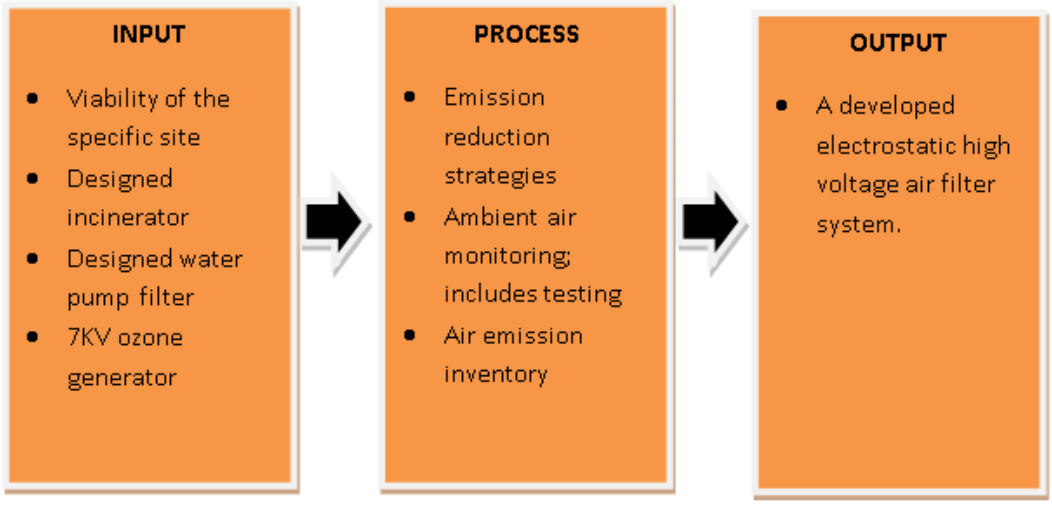

Figure 1. Conceptual Framework

Scope and Delimitation:

The general scope of this study was the development and construction of the prototype and the evaluation of the whole system. The prototype is designed to accumulate a small amount of waste (small scale) enough to measure the reduction of the pollutants emitted by the incinerator. The type of waste that can be incinerated is limited to non-recyclable materials (specified on chapter 4, Tabulated Data of Evaluation). Evaluation and testing was conducted at one of the researcher's place. The parameter of testing was limited to Overall Air Quality with the help of FIGARO TGS 2602 (MQ135) which detects air contaminants.

However, this study did not cover the program and internal circuit design of the microcontroller unit, the production of materials and fabrication of the body of the incinerator and other parameters that were not mentioned in the scope of this study.

Definition of Terms:

To correctly use this manual, the reader must interpret the meaning of the following terms as herein defined:

Air filter is a device composed of fibrous materials which removes solid particulates such as dust, pollen, mold, and bacteria from the air.

Alternating Current (AC) is the flow of electric charge periodically reverses direction.

Bottom ash is part of the non-combustible residue of combustion in a furnace or incinerator.

Corona discharge is an electrical discharge brought on by the ionization of a fluid or gas surrounding a conductor that is electrically charged.

De-energized is the term used for the loss of electrical power.

Direct Current (DC) is the flow of electric charge in only one direction.

Electrostatic is the study of electromagnetic phenomena that occurs when there are no moving charges.

Energized is the term used for electrically connected load to a source of voltage.

Fly ash is one of the residues generated by coal combustion, and is composed of the fine particles that are driven out of the boiler with the flue gases.

Frequency is the number of occurrences of a repeating event per unit time.

Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials.

Incinerator is an apparatus for burning waste.

Insulator is a material whose internal electric charges do not flow freely, and therefore make it impossible to conduct an electric current under the influence of an electric field.

Land fill is a site for the disposal of waste materials by burial.

Microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals.

Ozone is an inorganic molecule with the chemical formula O_3.

Parts per million (ppm) is a way of expressing very dilute concentrations of substances.

Voltage is an electromotive force or potential difference expressed in volts.

2. REVIEW OF RELATED LITERATURE

This chapter focuses on the related components needed on the electrostatic high voltage air filter. This also explains how incineration helps garbage reduction and how the high voltage air filter works.

Garbage disposal has been a long-standing problem and will continue to be a problem in the future. As the population of the world continues to increase, so will the garbage produced. It is therefore important to seek out the ways that can best be employed to minimize the amount of garbage. This is not a problem of the future but a problem of today (Maraba Al-

Iraq Al Khadra [M.I.K. Co.], 2013). One example of a garbage problem is in the city of Islip, Long Island. As the landfills began to fill up to capacity, another solution was desperately needed. The answer was to ship the garbage elsewhere. The method was to ship the garbage to another state and pay them to landfill the garbage. So the city loaded 3,186 tons of garbage onto a barge known as the Mobro 4000 which was then transported by a tugboat called Break of Dawn. This seemed like a solution at the time, but it soon became evident that this was not as easy a process as it seemed. The barge came into several ports where it was promptly dismissed by the city officials and sent back to sea. Its stops included North Carolina, Louisiana, Florida, Mexico, Belize, and the Bahamas. The journey lasted a total of 186 days and was unsuccessful as the city still had 3,186 tons of garbage and nowhere to put it. One of the methods for garbage disposal is the method of incineration. In the case of Islip, Long Island, this became the method of choice. Incineration is a method that has become more widely used as the garbage problem has worsened. It has many advantages and disadvantages but the reason it was the method of choice for Islip was because it didn't take up as much landfill space. The volume reduction of garbage disposal is the main advantage of incineration.

Waste Disposal:

According to the Student Records Management Department (SRMD) the Lycean community continues to grow in number as it reached its 7K mark in its fifth year of operation dated 2012-2013 based on annual statistic report released. In relation, as the population continually grows, the waste it produces will be growing also and Lyceum of the Philippines University – Cavite can not recycle all the waste it produces.

The following five waste disposal systems are available to just about anyone given the right tools and space (5 Different Types of Waste Disposal Systems Explained, para. 1).

1. Simply Throwing Garbage Away:

As common as throwing garbage away is, it is also highly problematic when it is taken as a whole. The U.S. commonly throws away 250 million tons or more of garbage annually, consuming more than 3,500 acres of land in the process. There is something very passive about throwing garbage away: put it in the basket and watch the truck hauls it away. It is the don't ask, don't tell' solution to waste disposal.

2. Garbage Disposal Installation:

Having a home garbage disposal reduces landfill waste by pulverizing food waste and washing it down the drain. The food waste does not become liquid, but it is altered enough not to ruin sewer pipes. A garbage disposal is a step in the right direction, but it solves less than half of the problem. Plenty of waste gets thrown away even with a disposal. Not only that, the material that can be put down to a garbage disposal would be better used in a compost pile.

3. Composting:

Taking all organic food scraps, including coffee grounds and eggshells (excluding meat, bones, skin and lard) and throwing it in layers on compost pile eventually breaks it down and becomes nutrient-rich fertilizer. The amounts must be kept in proportion and add grass clippings and other yard debris as well. When done right, is a way in helping to complete the cycle of life. This is one of the best ways to dispose waste.

4. Recycling:

Instead of simply throwing everything away in trash, get in the habit of recycling what can be reused or remade. Metal, paper products, certain plastics, motor oil, electronics, appliances, mattresses, woods, rubber, glasses and other things can all be recycled. In some cases people have to pay to have it hauled away. Other things people will gladly remove from your recycling pile on the street. If everything that could be recycled was recycled across the board, the aggregate trash amount would be drastically reduced every year.

5. Incineration:

While this method is mainly used at the industrial level, residential incinerators are available to dispose of waste. There is the danger of releasing toxins from certain materials, though, so be sure to know the potential hazards.

The Incineration Process:

The incinerator process is relatively simple to understand. Garbage is brought to the site where it is then fed into the incinerator. Inside the incinerator chambers are flames that are usually around 2400 degrees Fahrenheit that burn the

waste in either one stage or in multiple stages. As the waste is burned, ash is produced which is collected for later disposal in a landfill. There are different types of municipal solid waste incinerators. Mass burn incinerators take the waste directly without any preprocessing and can usually burn 50-1000 tons per day of garbage. Modular incinerators do not pre-process the waste either but the waste comes from factories that usually package the garbage in units to ship to the site. Modular incinerators burn from 50-100 tons of waste per day a third type of incinerator is the RDF. RDF stands for refuse-derived-fuel. The waste stream is prepared in such a manner as to improve the combustibility of the garbage. This is done by sorting, shredding, and separating the waste before incinerating it. Although the incineration process is simple, maintenance of the facility is not always as simple and is thought to be one of the main disadvantages of incineration. (The Effectiveness of Incineration, CE540 Research Paper, Perry Holland, April 5, 1999)

July 18, 2015, According to The Philippine Star, The Metropolitan Manila Development Authority (MMDA) is seriously batting for the use of incineration technology as a possible solution to the garbage and flooding woes of the metropolis.

MMDA Chairman Francis Tolentino said that he believes that through the use of incinerators, tons of garbage that are being blamed by the agency for clogging the metropolis' drainage system, could even serve as fuel for generating electricity.

Incinerators, also known as waste-to-energy (WTE) plants, can produce electricity by using heat from the burning of trash to drive generators.

"My ultimate dream is for Metro Manila to adopt incineration plants that will convert waste to energy," he said.

Tolentino said garbage remains a major problem in Metro Manila especially during rainy season as it clogs up the drainage system, causing flash flooding.

Tolentino gave Singapore as an example wherein its six incinerator plants help control flooding.

Tolentino, however admits that the use of incinerators in the country would not be possible at the present due to the Clean Air Act which bans the use of incinerators.

According to REPUBLICT ACT no. 8749 (Philippine Clean Air Act of 1999) Section 20 Ban on Incineration states that - Incineration, hereby defined as the burning of municipal, bio-medical and hazardous wastes, which process emits poisonous and toxic fumes, is hereby prohibited: Provided, however, That the prohibition shall not apply to traditional small-scale method of community/neighborhood sanitation "siga", traditional, agricultural, cultural, health, and food preparation and crematoria: Provided, further, existing incinerators dealing with bio-medical wastes shall be phased out within three (3) years after the effectivity of this Act: Provided, finally, That in the interim, such units shall be limited to the burning of pathological and infectious wastes, and subject to close monitoring by the Department. Local government units are hereby mandated to promote, encourage and implement in their respective jurisdiction a comprehensive ecological waste management that includes waste segregation, recycling and composting. With due concern on the effects of climate change, the Department shall promote the use of state-of-the-art, environmentally-sound and safe non-burn technologies for the handling, treatment, thermal destruction, utilization, and disposal of sorted, unrecycled, uncomposted municipal, bio-medical and hazardous wastes.

Ozone:

Ozone is a form of oxygen, consisting of three oxygen molecules (O3). Unlike diatomic oxygen (O2; the breathable oxygen present in the atmosphere), ozone is very unstable, and decays to O2 within about 30 minutes under normal atmospheric conditions. Ozone is a powerful oxidizing agent. It is able to oxidize a number of molecules including metals (with the exception of gold, platinum, and iridium), nitrogen oxides, carbon, ammonia, and sulfides to name a few. Ozone is of particular value as a disinfectant, as it is able to promote the oxidation of carbon-carbon double bonds (C=C). This type of bond is found in many biological molecules, and in other types of organic compounds, most notably pharmaceuticals. As a result, ozone is effective to kill essentially all pathogens including bacteria, fungi, viruses, as well as prions. Ozone is also effective to promote the degradation of a large number of drug compounds.

The generation and handling of ozone is relatively simple using a variety of available technologies that make use of oxygen in the ambient atmosphere. As a result, ozone is conveniently generated on site, and does not require specialized containers for transport, as are required with other chemicals. Further, ozone degrades naturally into oxygen in a relatively short period of time (10-30 min); thus, does not leave any toxic residue behind. (Treatment of Biomedical Waste with Ozone, Colin D. Rasmussen, Ph.D., LL.B. – Rasmussen, Rasmussen & Charowsky, PLC, January 2, 2007)

Synthesis:

Incineration with an effective air filtering system can be a great alternative in dumping non-recyclable waste in dumpsites. Without a filtering system, incineration can be rather harmful to the environment. REPUBLIC ACT no. 8749 (Philippine Clean Air Act of 1999) clearly states that small scale incineration should not be prohibited by the law. Because this study used a small volume of waste similar to traditional backyard burning of trash or "*pagsisiga"*, it is not prohibited according to the law.

The construction of the filtering system adopts the concept of an ozone generator and it also has a secondary stage which is water filtration for a better result. Ozone disinfects the air, removes bacteria and viruses, while the water filtration traps solid particles.

3. RESEARCH METHODOLOGY

This section presented the research's methodology and design in attaining the objectives of the study. The design of the system involved an electrostatic high voltage air filter and an additional water filtration as an application for waste incineration.

Time and Place of the Study:

The study was conducted at the Lyceum of the Philippines University – Cavite from June 2014 to September 2015.

The title proposal was done last June 2014; the title defense was conducted on September 2014. The gathering of data, design, construction and evaluation were made from November 2014 to September 2015. Evaluation was conducted at vacant lot at the back of the university.

Project Development:

The prototype is composed of several components. These are the incinerator, high voltage dc power supply, conductor plates (for electrostatic), water pump (for water filter), microcontroller, LCD monitor, keypad and MQ135 air quality sensor. The sizing of the components and proper insulation is important on achieving best results.

Figure 2. Waste Incinerator with Electrostatic High Voltage Air Filter System

The Air filtering system is illustrated in Figure 2. The incinerator burns the waste inserted on it using a high pressure burner with LPG. The smoke and other pollutants emitted by the burned materials will be sucked by the exhaust inserted inside the filtering system. The contaminated air will flow through the electrostatic air filter which removes viruses and toxics and through the water filtration which collects solid particles. The processed air will be released through the pipe and at the top end of the pipe there is an air quality sensor which reads the amount of remaining contaminant in the air. All the process is controlled by the microcontroller, all the processing and data is shown in the LCD moni

Incinerator Design:

The incinerator's body is made up of cast iron (melting point of $1200^{o}C$) with a thickness of about five mm and

is supported by aluminum. It is cylindrical in shape with a diameter of about 350 mm and a height of 760 mm. The pipe between the incinerator and air filter system is made of aluminum while the exhaust pipe is made up of PVC with an inside diameter of 100 mm and is 1700 mm high.

Insulation:

The insulating material used in the incinerator is Hardiflex board which is about five mm thick. It can withstand high temperature and it is also fireproof. It serves as the outer layer of the incinerator. There is a one inch space between the cast iron and Hardiflex board to avoid extreme heat conduction to the outer layer of the incinerator. The electrostatic high voltage air filter is placed and sealed in a box made up of versa board which is great for electric insulation. The air filtering system also has Hardiflex board as its outer layer. There is also space between the versa board and Hardiflex board which is the place for the wirings and controller circuits. The distance between the incinerator and filtering system measures about five inches. The whole system is covered with high temperature resistant paint, inside and out.

Operation and Testing Procedures:

The following procedure must be done before and after any adjustment, modification, maintenance to the air filtering system. Assure that the system is electrically and thermally insulated inside and outside. Make sure that the conductor plates are well placed, firm and sealed inside the filtering system. Make sure that there is no leak in the gas tank. For step by step instructions and troubleshooting guides, refer to the manual. Safety precautions must be implemented because it deals with high voltage.

These rules should be strictly followed:

- Avoid contact with energized electrical circuits.
- Treat all electrical devices as if they are live or energized.
- Disconnect the power source before servicing or repairing electrical equipment.
- Use only tools and equipment with non-conducting handles when working on electrical devices.
- Never use metallic pencils or rulers, or wear rings or metal watchbands when working with electrical equipment. This rule is very easy to forget, especially when you are showing some electrical part pointing with metallic pencil.
- When it is necessary to handle equipment that is plugged in, be sure that hands are dry and, when possible, wear nonconductive gloves, protective clothes and shoes with insulated soles.
- De-energize open experimental circuits and equipment to be left unattended.

It is strongly advised to use the incinerator away from any flammable objects.

Safety Practices:

- Appropriate warning signs will be posted on or near the air filter.
- Safety inspection should be done for maintenance of the equipment.
- The electrostatic high voltage air filter will have an indicator which gives signal that the air filter output is enabled.

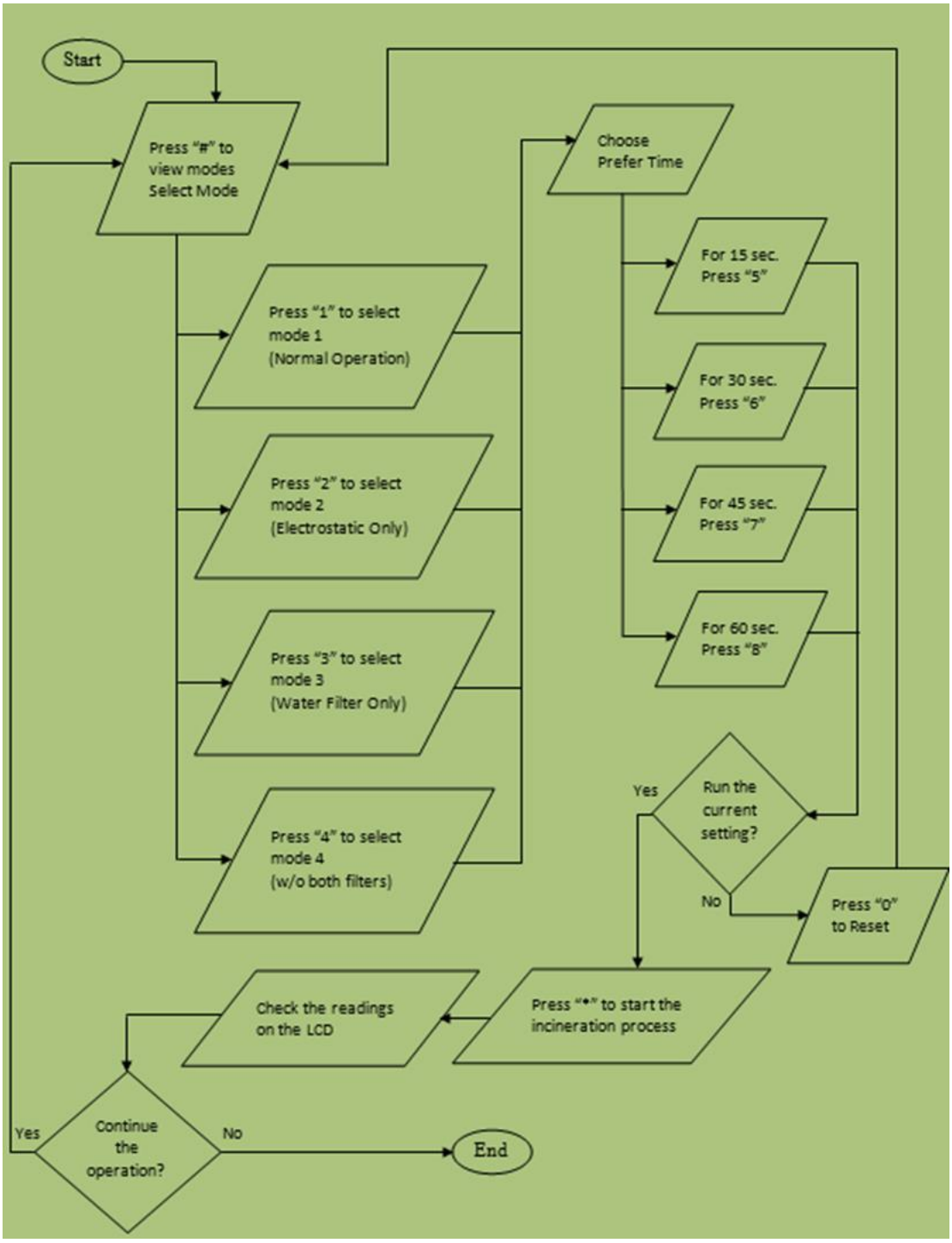

Figure 3. Operational Flow Chart

The operational flowchart above depicts the procedure on how to operate the air filter system. First is by starting the system and then choosing desired mode by selecting from the numbers 1 to 4 in the keypad. Next is to choose the duration of operation by selecting from numbers 5 to 8 in the keypad. Press the start button again and check the result on the LCD. After a complete operation, the machine must rest for at least five minutes before operating again. Its purpose is to lower down the heat in the system.

Data Gathering:

The data for this research were collected by conducting series of tests and trials. The reduction was measured by the amount of the contaminants removed from the smoke emitted by the waste incinerator. The process of testing was composed of three trials per condition. The classifications of test materials to be used are important in determining the

burning time needed. After the testing were done, all the acquired data were be recorded and were analyzed by the researchers and a certified statistician evaluated the performance of the electrostatic high voltage air filter system.

Evaluation Procedure:

The electrostatic high voltage air filter in incineration process was evaluated according to the amount of pollutant lost when the air filter is present in the system. The researchers gauged the performance of the system by observation and data acquisition through actual measurement and computation.

4. RESULTS AND DISCUSSION

This chapter deals with the gathering and understanding the data in relation with the specific objectives of the study: 1) site availability; 2) specifications of the high voltage electrostatic generator, air quality sensor, pressure gas burner, submersible water pump; 3) design and development of air filtering system; and 4) evaluation of the system.

Presentation of Project Design:

Site Availability: The air filtering system was placed at the back of LPU Cavite Phase 2 Building (near the Civil Engineering Laboratory). The site was suitable considering the place is outside; therefore, it gave an advantage on diffusing the unfiltered smoke easily. The site was also suited since it is isolated from people.

Figure 4. **High Voltage Electrostatic Generator**

Specifications:

Table 1. Specifications of the High Voltage Electrostatic Generator

Description	**Specification**
Power Source	Electrical
Power Dimension	150mm * 60mm * 42mm
Ceramic piece Size	90mm * 50mm
Input voltage	220vAC (0.4A) 110vAC (0.8A) 12vDC (4A)
Output voltage	7kV
Operating power	85w – 95w
Operating frequency	16Khz
Life Span	7000 hours

The high voltage electrostatic generator provided the power supply needed for the air filtering system. This component gave an output voltage of 7kV in which a corona discharge was created and lead to kill pathogens present near its conducting plates.

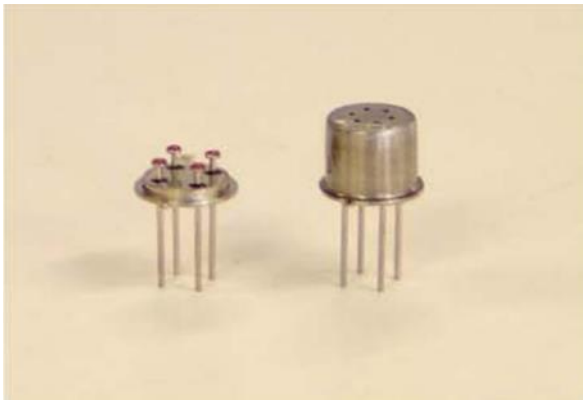

Figure 5.FIGARO TGS 2602

Specifications:

Table 2. Specifications of the FIGARO TGS 2602

Model Number			TGS 2602-B00	
Sensing element type			D1	
Standard package			TO-5 metal can	
Target gasses			Air contaminants	
Typical detection range			1 ~ 30 ppm of EtOH	
Standard circuit conditions	Heater voltage	V_H	5.0±0.2V DC/AC	
	Circuit voltage	V_C	5.0±0.2V DC	PS≤15mW
	Load resistance	R_L	Variable	0.45KΩ min.
Electrical characteristics under standard test condition	Heater resistance	R_H	Approx. 59Ω at room temp.	
	Heater current	I_H	56±5mA	
	Heater power consumption	P_H	280mW (typical)	
	Sensor resistance	R_S	10K ~ 100KΩ in air	
	Sensitivity (change ratio of R_s)		0.15 ~ 0.5	R_S (10ppm of EtOH) / R_S (air)
Standard test conditions	Test gas conditions		Normal air At 20±2°C, 65±5% RH	
	Circuit conditions		Vc = 5.0±0.01V DC V_H = 5.0±0.05V DC	
	Conditioning period before test		7 days	

The FIGARO TGS 2602 is an air contaminant sensor and is inside the MQ 135. The device was placed on the end of the pipe to sense the quality of the filtered air.

Figure 6. Pressure Gas Burner

Specifications:

Table 3. Specifications of the Pressure Gas Burner

Description	**Specification**
Power Source	LPG
Energy Capacity	130 Megajoules
Pressure Capacity	20PSIG
Material	Cast Iron
Dimensions	7 in. diameter
Extra High pressure regulator included	

The main purpose of the pressure gas burner was to provide continuous supply of gas inside the incinerator. An igniter was used to initiate fire.

Figure 7. Submersible Water Pump

Specifications:

Table 4. Specifications of the Submersible Water Pump

Description	**Specification**
Power Source	220vAC (70 mA)
Operating power	15w
Operating frequency	50hz ~ 60hz
Pump lift	1 meter
Flow rate	60L/hr
Material	Plastic housing
Dimensions	3.78 in x 2.91 in x 3.23 in

The submersible water pump was located at the water container; the water in the container was delivered to the highest part of the abaca fibers, water flow through it. Continuous operation of the pump served to circulate the water.

Design and Development of Air Filtering System

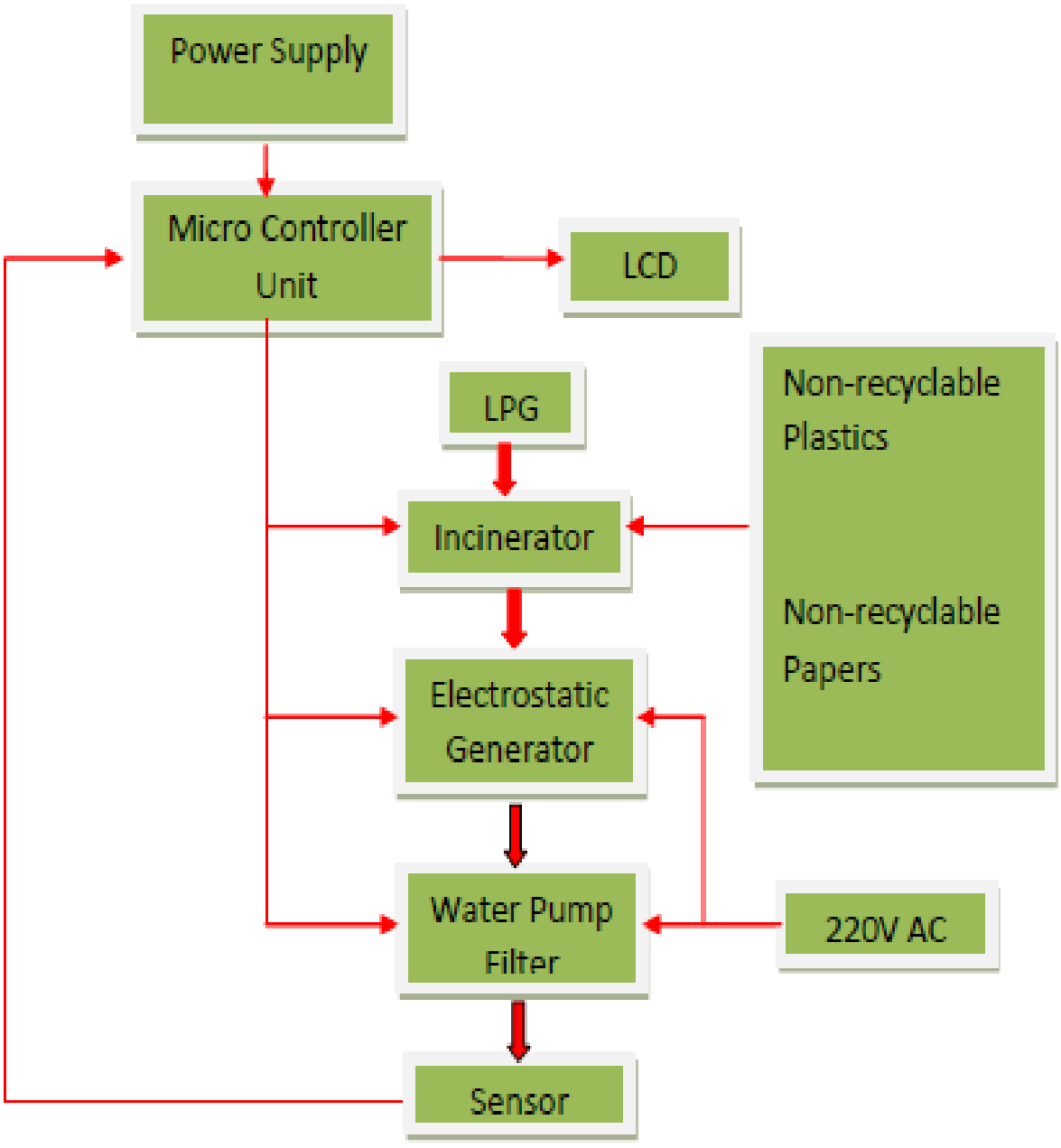

Figure 8. Air Filtering System Block Schema

This figure above shows the relationship of each component of the prototype to one another. The Microcontroller Unit is the heart of the system. It is supplied by a 12V DC power supply (220V AC input). The incinerator is connected to a LPG tank. The gas valve of the incinerator is automatically operated by a DC motor which is controlled by the MCU. There is also an igniter to start a fire. When the incineration starts, the MCU will simultaneously turn on the electrostatic generator and the water pump filter which is both supplied by a 220V AC supply. White arrows indicate the flow of the polluted air through the system. The emission caused by burning of the materials passes through the electrostatic high voltage air filter then through the water filtration onto the air quality sensor which gives the signal to the MCU which project the readings on the LCD.

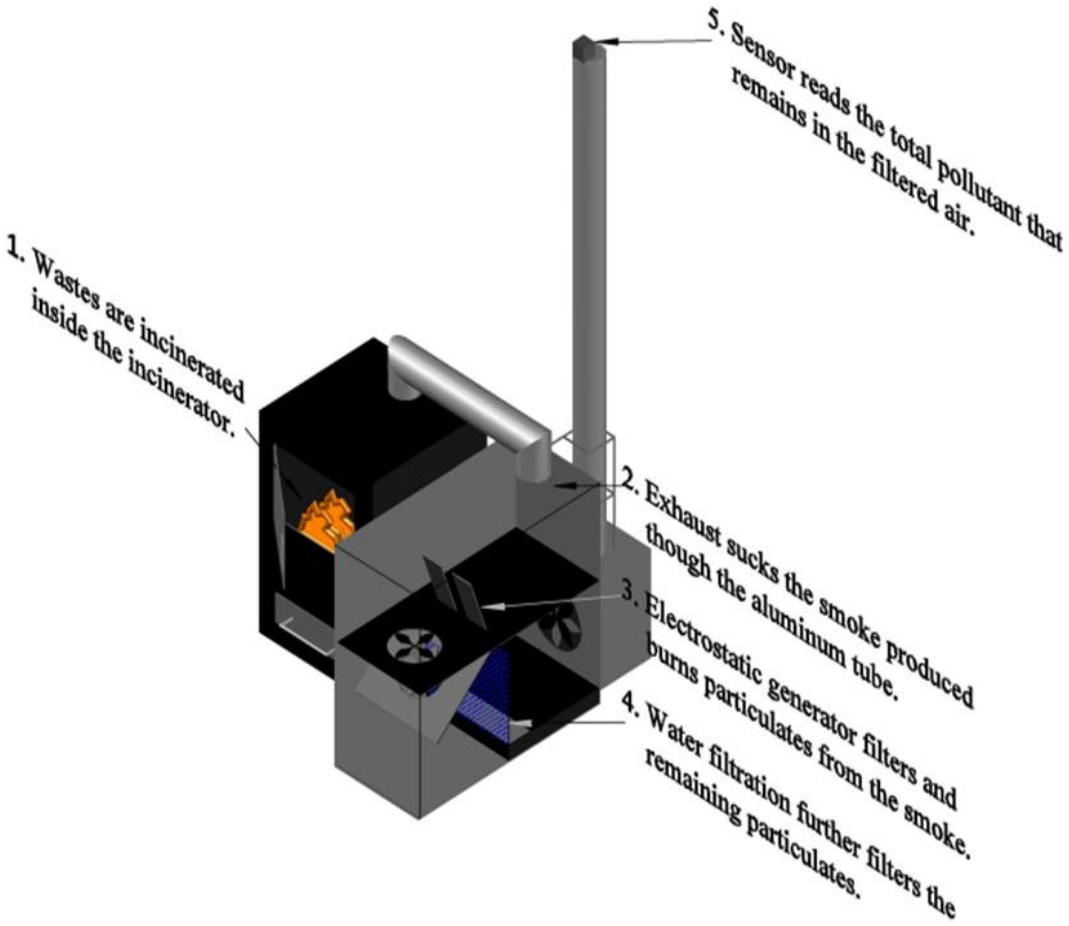

Figure 9. Step by step process of the Air Filter System

The figure above depicts the behavior of the parts of the air filter system. A material was incinerated at the incinerator. An exhaust served as suction which delivered smoke to the conducting plates of the electrostatic generator. After the smoke was filtered in the electrostatic generator, the water filtration filtered solid particles in the smoke. The number of pollutants that remained in the air was sensed by the air quality sensor located at the top of the pipe.

The Evaluation of the System:

Condition 1: High Voltage Electrostatic Generator OFF, Water Filter OFF

Condition 2: High Voltage Electrostatic Generator ON, Water Filter OFF

Condition 3: High Voltage Electrostatic Generator OFF, Water Filter ON

Condition 4: High Voltage Electrostatic Generator ON, Water Filter ON

5. DATA AND RESULTS

Table 5. Condition 1 Results

Ambient Air: 73ppm					
Test Materials	Condition 1				Burning time
	Trial 1	Trial 2	Trial 3	Ave.	
Non-recyclable plastic	275ppm	302ppm	286ppm	288ppm	60s
Non-recyclable paper	381ppm	392ppm	393ppm	389ppm	30s
Dry leaves	218ppm	232ppm	254ppm	235ppm	45s
Assorted	453ppm	426ppm	440ppm	440ppm	60s

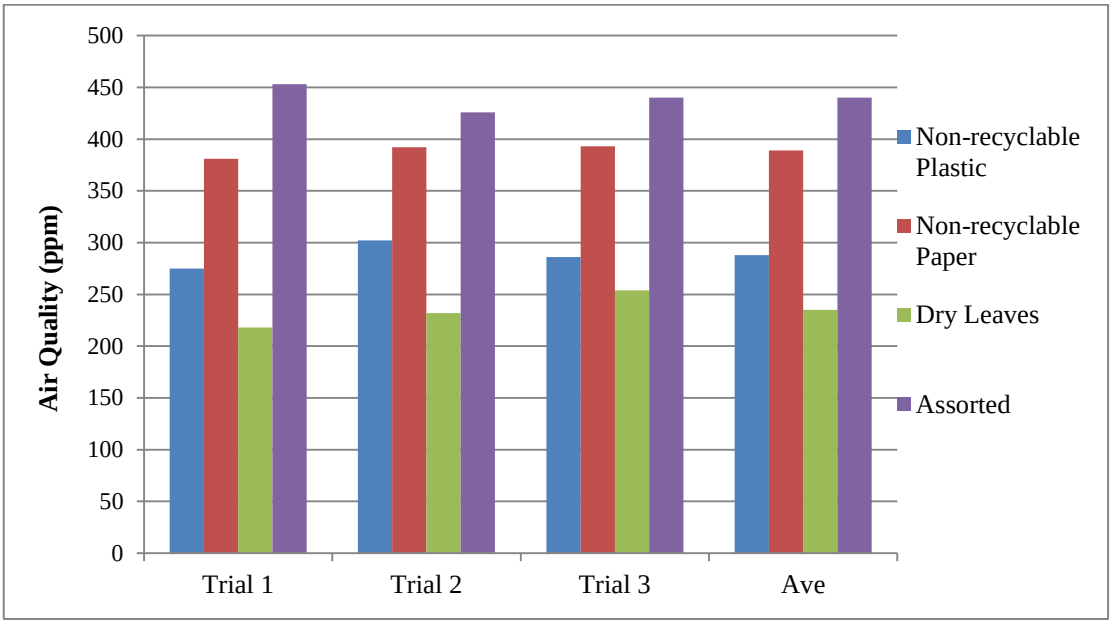

Figure 10. Condition 1 Results

The table above shows the numerical value of pollutants when high voltage electrostatic generator and water filter was off (Condition 1). The figure above shows the graphical representation of the data on the table.

Table 6. Condition 2 Results

Ambient Air: 73ppm					
Test Materials	Condition 2				Burning time
	Trial 1	Trial 2	Trial 3	Ave.	
Non-recyclable plastic	193ppm	182ppm	185ppm	187ppm	60s
Non-recyclable paper	265ppm	251ppm	246ppm	254ppm	30s
Dry leaves	184ppm	185ppm	172ppm	180ppm	45s
Assorted	336ppm	325ppm	341ppm	334ppm	60s

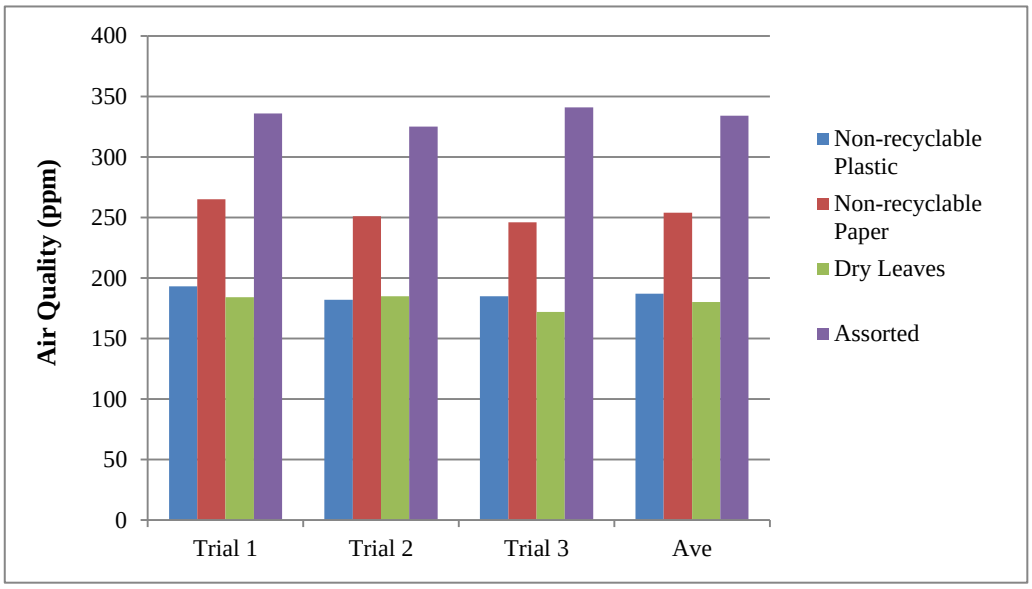

Figure 11. Condition 2 Results

The table above shows the numerical value of pollutants when high voltage electrostatic generator was the only one running (Condition 2). The figure above shows the graphical representation of the reduction in the amount of pollutants if the high voltage electrostatic generator was turned on.

Table 7. Condition 3 Results

Ambient Air: 73ppm					
Test Materials	Condition 3				Burning time
	Trial 1	Trial 2	Trial 3	Ave.	
Non-recyclable plastic	172ppm	176ppm	160ppm	169ppm	60s
Non-recyclable paper	288ppm	251ppm	253ppm	264ppm	30s
Dry leaves	151ppm	158ppm	143ppm	151ppm	45s
Assorted	301ppm	316ppm	307ppm	308ppm	60s

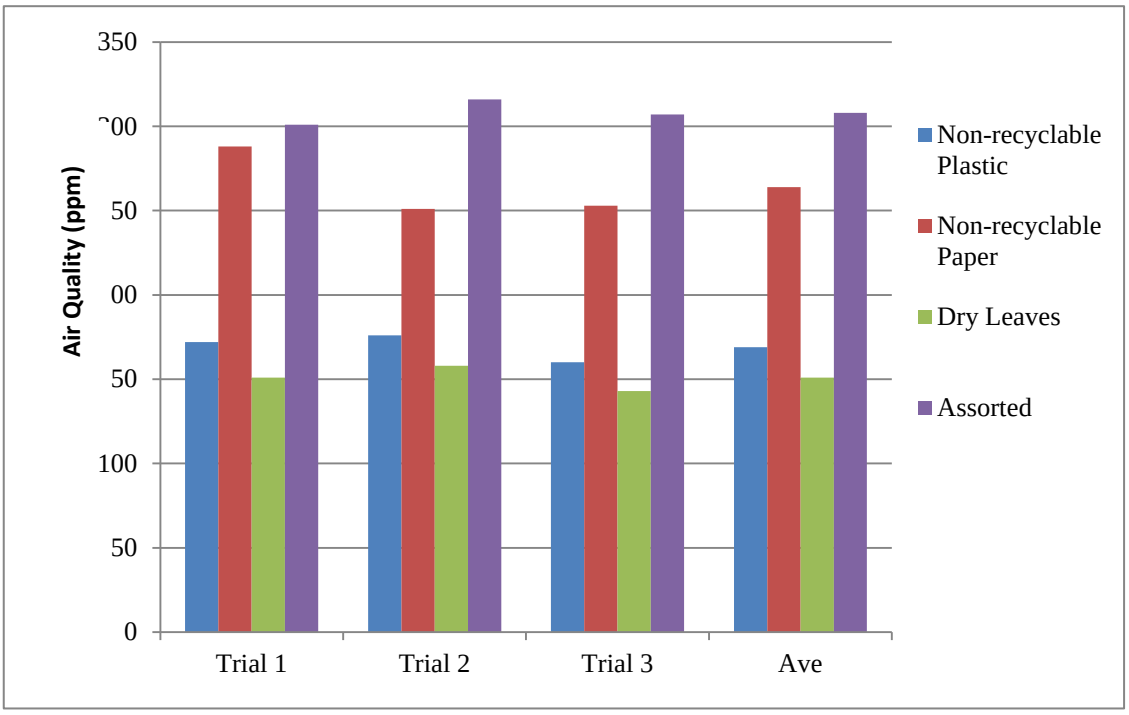

Figure 12. Condition 3 Results

The table above shows the numerical value of pollutants when water filter was the only one running (Condition 3). The figure above shows the graphical representation of the reduction in the amount of pollutants if the water filter was turned on.

Table 8. Condition 4 Results

Ambient Air: 73ppm					
Test Materials	Condition 4				Burning time
	Trial 1	Trial 2	Trial 3	Ave.	
Non-recyclable plastic	153ppm	145ppm	142ppm	147ppm	60s
Non-recyclable paper	232ppm	201ppm	226ppm	220ppm	30s
Dry leaves	132ppm	135ppm	129ppm	132ppm	45s
Assorted	275ppm	269ppm	251ppm	265ppm	60s

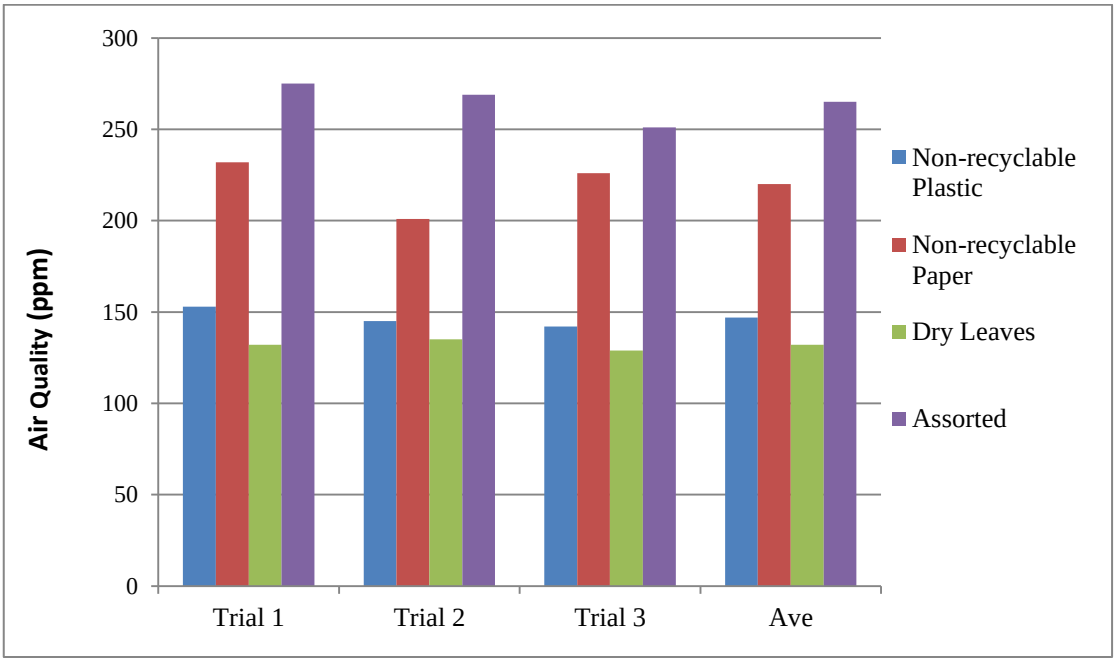

Figure 13. Condition 4 Results

The table above shows the numerical value of pollutants when both of the high voltage electrostatic generator and water filtration was running (Condition 4). The figure above shows the graphical representation of the reduction in the amount of pollutants if the high voltage electrostatic generator and water filtration is turned on.

Table 9. Average results

Ambient Air: 73ppm				
Test Materials	Average			
	Condition 1	Condition 2	Condition 3	Condition 4
Non-recyclable plastic	288ppm	187ppm	169ppm	147ppm
Non-recyclable paper	389ppm	254ppm	264ppm	220ppm
Dry leaves	235ppm	180ppm	151ppm	132ppm
Assorted	440ppm	334ppm	308ppm	265ppm

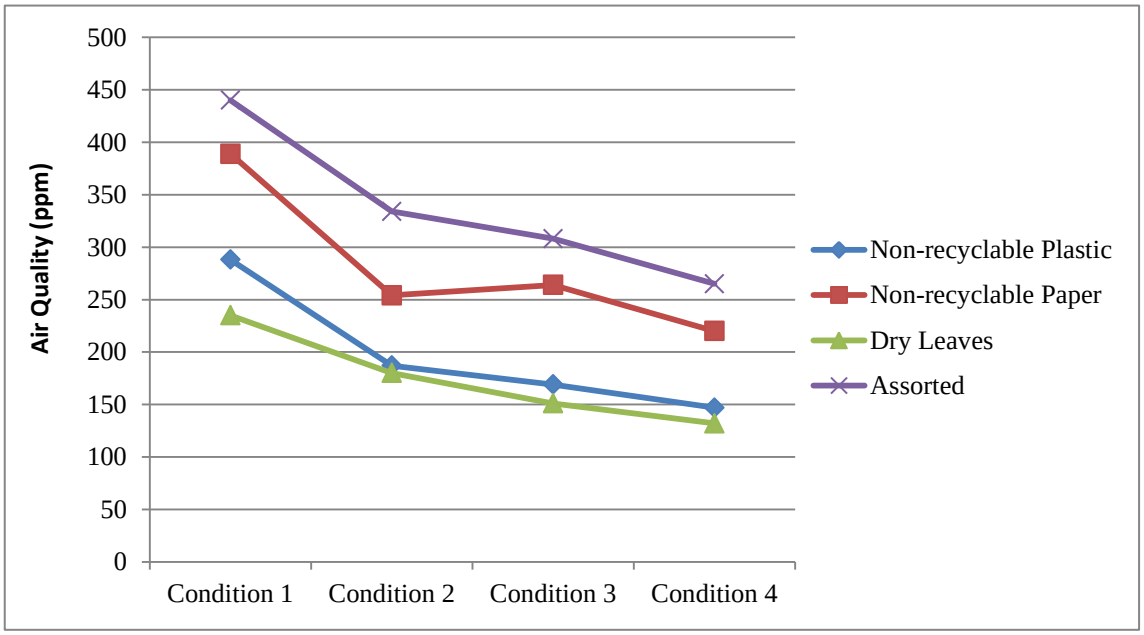

Figure 14. Average results

The table above shows the average numerical value of pollutants present in each condition. The figure above shows the change in the amount of pollutants over each condition. Based on the results, Condition 4 has the greatest reduction among any other conditions.

Computation for Average Percent Reduction:

$$\%RD = \left[1 - \frac{Output_{condX} - Ambient\ Air}{Output_{cond1} - Ambient\ Air}\right] x\ 100\%$$

Table 10. Tabulated Data of the Evaluation

Test Materials	Average Percent Reduction		
	Condition 2	Condition 3	Condition 4
Non-recyclable Plastic	46.97%	55.30%	65.58%
Non-recyclable Paper	42.72%	39.56%	53.48%
Dry Leaves	33.95%	51.85%	63.58%
Assorted	28.88%	35.97%	47.68%

The figures show that dry leaves emit the lowest pollutants while plastic emits the highest. Mode 1 has the highest filtration for both filters are running. On the other hand, mode 4 has the lowest filtration for none of the filters are running. It is clear that the output in Mode 1 is the closest in the value of ambient air. This shows that the air filtering system is working.

Statistical Analysis:

Non-recyclable Plastic

Condition	Mean	sd	F-value	p-value	Remarks
Condition 1	287.67	13.577	146.814	0.000	Highly significant
Condition 2	187.33	5.508			
Condition 3	169.33	8.327			
Condition 4	146.67	5.686			

Non-recyclable Paper

Condition	Mean	sd	F-value	p-value	Remarks
Condition 1	388.67	6.658	77.524	0.000	Highly significant
Condition 2	254.00	9.849			
Condition 3	264.00	20.809			
Condition 4	219.67	16.442			

Dry Leaves

Condition	Mean	sd	F-value	p-value	Remarks
Condition 1	234.67	18.148	53.945	0.000	Highly significant
Condition 2	180.33	7.234			
Condition 3	150.67	7.506			
Condition 4	132.00	3.000			

Assorted

Table 11. Statistical Analysis Results

Condition	Mean	sd	F-value	p-value	Remarks
Condition 1	439.67	13.503	143.394	0.000	Highly significant
Condition 2	334.00	8.185			
Condition 3	308.00	7.550			
Condition 4	265.00	12.490			

To determine the significant differences among the four conditions, Analysis of Variance (ANOVA) was used. This test was employed in order to compare means of two or more groups. Based on the results, the four conditions are found to be significantly different with p-values equal to 0.000 ($p < 0.01$). In addition, using the Post-Hoc analysis on the comparison of means, on Condition 2 vs Condition 3 have the same effect on the four types of wastes while the remaining combinations (Condition 1 vs Condition2; Condition1 vs Condition3; Condition 1 vs Condition 4; Condition 2 vs Condition 4; and Condition 3 vs Condition 4) are significantly different. Furthermore, among the four conditions, number 4 was found to be the most effective in reducing the amount of air pollutants.

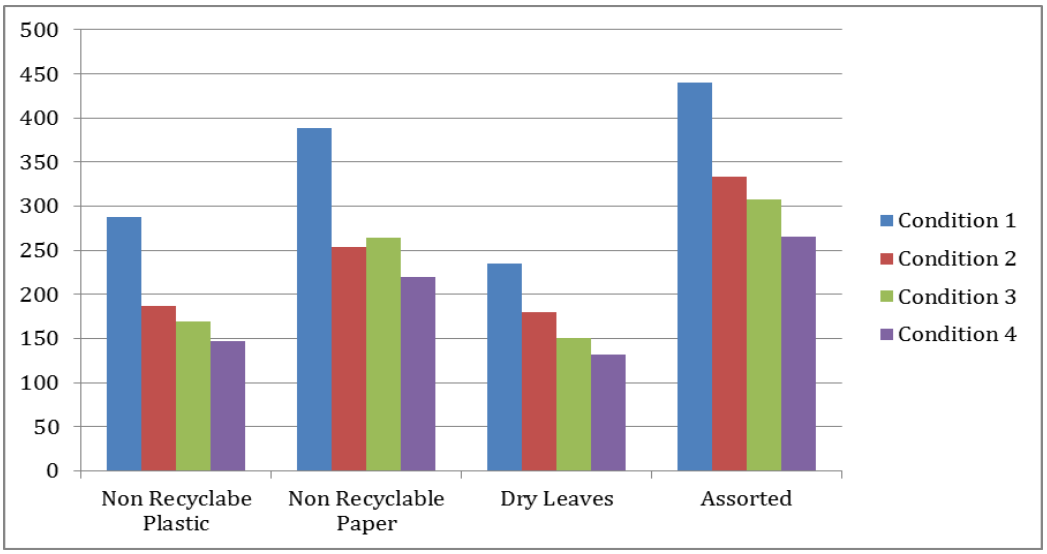

Figure 15. Statistical Analysis Results

6. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

SUMMARY:

The study was conducted for the purpose of the development of an electrostatic high voltage air filter system used for the reduction of emission from waste incineration of Lyceum of Philippines University – Cavite**.** This study was conducted from June 2014 to September 2015 and was placed at the back of the school near the parking area and Civil Engineering Laboratory of the Lyceum of the Philippines University – Cavite located at General Trias, Cavite.

Without a filtering system, incineration can be rather harmful to the environment. On that account, two filtration methods were provided for this study; electrostatic air filter and water filtration. The electrostatic air filter disinfects the air, while the water filtration traps solid particles. Without the presence of air, incineration and filtration cannot function well. Thus holes were provided for the circulation of air inside the incinerator and filters. Those holes also served as the cooling system.

The data gathering was essential to the study, so the researchers collected the data for the design of the project. Aside from pure research, the researchers also conducted interviews and consultation. The researchers interviewed some professionals and consulted their professors that could help in the design project. The data gathered from the said procedure gave clarity to the development of the study.

Four modes were provided; normal operation (both electrostatic and water), without water, without electrostatic and without both. These modes are provided for the purpose of evaluation as shown on page 29 (Evaluation of the system).

The evaluation of the system was performed by running the system in four different modes, measuring the air quality output, and analyzing each results. After each test, the system rested for at least five minutes to reduce the heat flowing inside. The measured average percent reduction were 65.58% in non-recyclable plastic, 53.48% in non-recyclable paper, 63.58% in dry leaves, and 47.68% in assorted (combination of the three materials).

CONCLUSION:

Based on the results and information gathered by the researchers, it shows that the air filter system was able to reduce the amount of pollutants significantly.

1. According on the gathered information, the researchers were able to design an air filter system that can reduce the amount of pollutants emitted by burning garbage.

2. Based on continuous study and analysis on the air filtering system, the researchers were able to develop an electrostatic high voltage air filter system used for the reduction of emission from waste incineration of LPU- Cavite. The water pump filtration which was designed and constructed for this project ran in continuity to provide continuous filtering of the particulates that remained on the incinerator after burning.

3. The series of testing conducted on the system as shown in chapter 4 (Data and Results) proved that this study was able to reduce the amount of pollutant emitted by burning garbage.

- The researchers were able to determine the amount of pollutants emitted by burning different types of materials without the air filtering system shown in Table 5.
- The researchers were able to determine the amount of pollutants by burning different types of materials with only the electrostatic air filter running shown in Table 6.
- The researchers were able to determine the amount of pollutants by burning different types of materials with only the water filtration running shown in Table 7.
- The researchers were able to determine the amount of pollutants by burning different types of materials with the whole air filtering system shown in Table 8.
- The researchers were able to determine the average amount of pollutants in each condition shown in Table 9. The researchers were also able to compare and analyze the calculated the average percent reduction in the pollutants shown in Table 10.

Based on the data provided on Chapter 4, the air filtering system works better when the garbage is segregated. The researchers also observed that it is better to shred the garbage first since it burns much faster.

The result of Statistical Analysis shown at Table 11 explains that the reduction of pollutants was highly significant. Based on the results, the four conditions were found to be in significant difference. It was found that Condition 4 was the most effective in reducing the amount of air pollutants.

RECOMMENDATIONS:

This study was recommended because this can lessen the amount of pollutants emitted by an incinerator in Lyceum of the Philippines University – Cavite.

For the enhancement of this study, it is recommended that the future researchers should study and search for an alternative means for the circulation of air inside the system. This will provide better insulation of smoke. The holes that are provided on the system can serve as the mean of escape for the smoke. Another recommendation is to choose another sensor which can read two or more element particulates that are present on the output air. This will help for more specific evaluation and results. The researchers also recommend using multiple electrostatic plates that can be alternately activated. This allows the continuous operation of the electrostatic generator and at the same time avoiding premature failure of the plates. Increasing the volume of water will further increase filtering capability. It is also recommended for future researchers to provide a shredder machine which will increase the rate of burning garbage materials. Moreover, it is recommended to increase the size of the incinerator which will increase the volume of waste materials burned per unit time.

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APPENDIX – A

FIGURE:

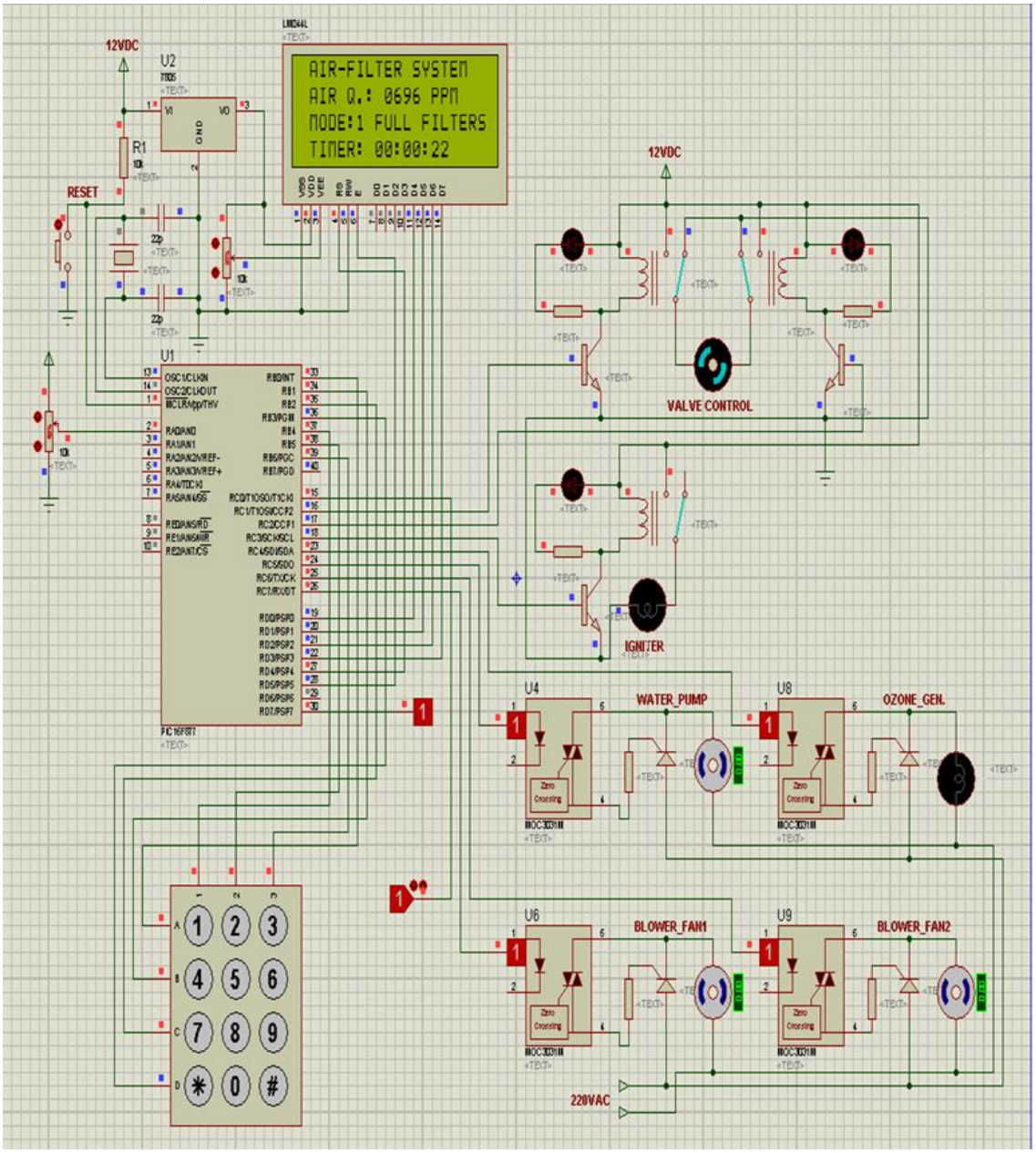

Figure: Micro Controller Unit Circuit Diagram