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Emission Control from Plastic Decomposition using Corn Cob-Based Bio-Filtration System

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ABSTRACT: This project focuses on the thermal decomposition of plastic waste and the subsequent control of toxic gas emissions using a cost-effective, bio-based filtration system made from corn cobs. Plastic samples, primarily from common sources like bottles, were collected, crushed into fine particles, and subjected to controlled heating in a thermal decomposition setup. The system included a steel vessel to contain the heated plastic, connected via a one-inch PVC pipe to a fume collector. The emitted gases were then passed through a corn cob-based filter, chosen for its porous, fibrous structure that enables effective adsorption of volatile organic compounds and particulate matter. Detailed procedures including sample preparation, moisture removal, uniform cutting, and high-temperature heating (up to 800°C) were followed to ensure consistent results. The outcomes showed that the corn cob filter efficiently captured a significant portion of the harmful emissions, demonstrating a promising, low-cost, and environmentally friendly solution for mitigating air pollution caused by plastic waste decomposition. The project highlights the dual benefit of managing plastic pollution while valorizing agricultural waste, suggesting strong potential for rural and small-scale applications in emission control technologies.

KEYWORDS: Plastic decomposition, corn cob filter, emission control, thermal degradation, toxic gas capture, bio-based filtration.

I. INTRODUCTION

The introduction of airborne emission screening for the thermal decomposition of plastic products represents a groundbreaking development in environmental science. This advanced screening technique aims to assess and quantify the emissions released during the decomposition of various plastics under thermal conditions. By implementing this method, researchers and regulators can better understand the potential hazards associated with plastic waste incineration and other thermal processes. This innovation not only enhances our ability to monitor and control environmental pollution but also supports efforts to develop more sustainable and environmentally friendly waste management practices. An advanced screening technique for plastic products aims to revolutionize our approach to environmental monitoring.

In the contemporary landscape of industrial development and consumerism, plastic products have become ubiquitous due to their versatility, durability, and cost- effectiveness. From packaging materials to automotive components, plastics play a significant role in daily life. However, their widespread use comes with substantial environmental and health challenges, particularly concerning their disposal and decomposition. The thermal decomposition of plastic products is of particular concern, as it has been linked to the release of a variety of harmful airborne emissions.

Thermal decomposition occurs when plastics are subjected to high temperatures, either during incineration processes or in accidental fires. This process breaks down the plastic polymers into smaller molecules, leading to the formation of various gaseous and particulate byproducts. The composition of these emissions depends on the type of plastic, the temperature, and the presence of other materials. Commonly observed emissions include volatile organic compounds (VOCs), carbon monoxide (CO), carbon dioxide (CO_2), and potentially hazardous compounds like dioxins and furans.
VOCs, including benzene, toluene, and styrene, are of particular concern due to their potential health effects, which range from respiratory irritation to long-term

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carcinogenic risks. Additionally, the production of particulate matter during thermal decomposition can contribute to air pollution and exacerbate respiratory conditions. Dioxins and furans, which are chlorinated compounds, are highly toxic and can have severe environmental and health impacts, including carcinogenicity and endocrine disruption.

Through advanced analytical techniques such as gas chromatography-mass spectrometry (GC-MS) and high-performance liquid chromatography (HPLC), we will identify and quantify the pollutants released during this process.
The specific objectives of this study are threefold: First, to characterize the emission profiles of commonly used plastic materials, including polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), and polystyrene (PS). Second, to evaluate the influence of decomposition conditions, such as temperature and time, on the nature and concentration of emissions. Third, to assess the potential health risks and environmental impact of these emissions based on current scientific understanding and regulatory standards.

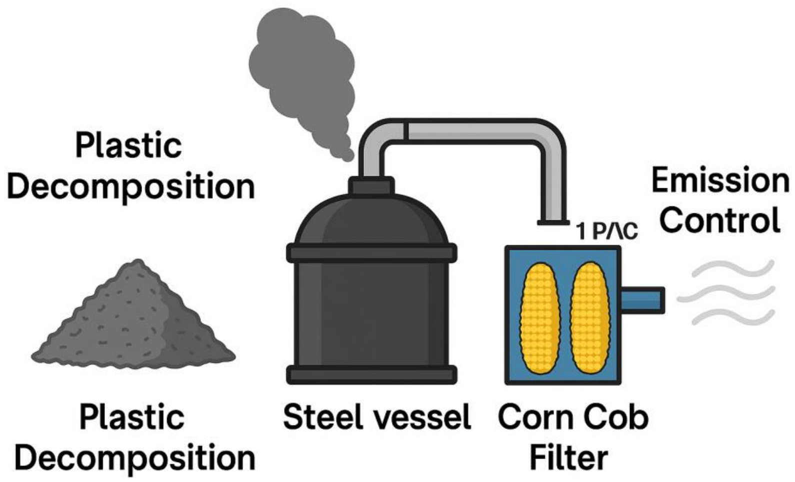

Fig 1.1: Overall Representation

Understanding the emissions associated with plastic decomposition is crucial for several reasons. Firstly, it supports the development of more effective waste management and recycling strategies that minimize harmful emissions. Secondly, it informs regulatory frameworks that aim to reduce the environmental and health impacts of plastic waste. Lastly, it enhances public awareness and safety by providing data on the risks associated with plastic disposal practices.

1.1.1 Types of Plastics Covered

This research investigates the thermal degradation of four commonly used plastic materials: Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), and Polystyrene (PS). Polyethylene is used extensively in packaging solutions and diverse consumer products, attributed to its natural flexibility and long lifespan. Polypropylene, known for its high-strength and heat-resistant properties, is used extensively in automobile parts and food packaging solutions. Polyvinyl Chloride is used extensively in building materials, including pipes and fittings, due to its hardness and chemical resistance properties. Polystyrene, known for its high insulating properties, is used extensively in disposable cutlery, foam packaging, and building thermal insulation. The selection of these plastics is attributed to their extensive use in daily consumer products and waste streams, thereby making the study a complete cross-section of material that causes plastic pollution

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1.1.2 Experimental Conditions

To simulate a range of thermal decomposition conditions as close to realistic operating conditions as possible, experiments will be carried out over a broad range of temperatures. This includes typical incineration temperatures of around 800°C to 1000°C, as well as lower temperatures that might possibly be encountered under the conditions of accident fires or uncontrolled fires. Decomposition will be followed at various times of intervals to assess the effect of thermal exposure time on character and concentration of emissions thus formed. All experiments will be performed in well-controlled laboratory environments to permit reproducibility and consistency. Environmental conditions such as airflow and ambient pressure will be closely controlled to simulate exactly combustion conditions and permit accurate emission measurement.

1.1.3 Analytical Techniques

A variety of advanced analytical techniques will be used to describe the emissions that are formed by thermal decomposition effectively. Gas Chromatography-Mass Spectrometry (GC-MS) will allow identification and quantification of volatile organic compounds (VOCs) and other gaseous emissions, thus providing information related to the chemical composition of exhaust in detail. High-Performance Liquid Chromatography (HPLC) will be used to detect and analyze any liquid products formed during the process of decomposition. Particulate emissions will be analyzed by gravimetric analysis to determine total mass, whereas electron microscopy will assist in the analysis of morphology and size distribution of airborne particles. All of these techniques in combination give an overall view of both gaseous and particulate emissions.

1.1.4 Emission Components

The thermal decomposition-emitted emissions will be expected to consist of a wide range of constituents with particular focus on Volatile Organic Compounds (VOCs) like benzene, toluene, and styrene—compounds known to possess toxicological and possibly carcinogenic impacts. Also, normal combustion products like carbon monoxide (CO) and carbon dioxide (CO_2) will be evaluated since they are good indicators of the combustion efficiency and environmental impact. Identification and quantification of hazardous byproducts like dioxins and furans, highly dangerous compounds which persist in the environment, is a very crucial aspect of the investigation. The particulate emissions will also be provided with detailed evaluation so that their size distribution, chemical composition, and possible health impact can be established, thus being able to fully understand the emission details. 1.1.5 Health and Environmental Effects Assessment The health impact of the documented emissions will be evaluated through an extensive toxicity analysis, taking both short-term and long-term risks of exposure into consideration. The analysis entails an investigation of potential respiratory irritation, neurological effects, endocrine disruption, and long-term carcinogenic risks of the different constituents of the emissions. The emission values will be measured against established environmental and public health standards to determine compliance and areas of deficiency or risk. The impact of the emissions on air quality will also be measured, providing an estimate of how plastic degradation contributes to overall air pollution issues. The analysis will be used to inform regulatory policy and guide efforts toward the adoption of safer and more sustainable plastic waste management practices.

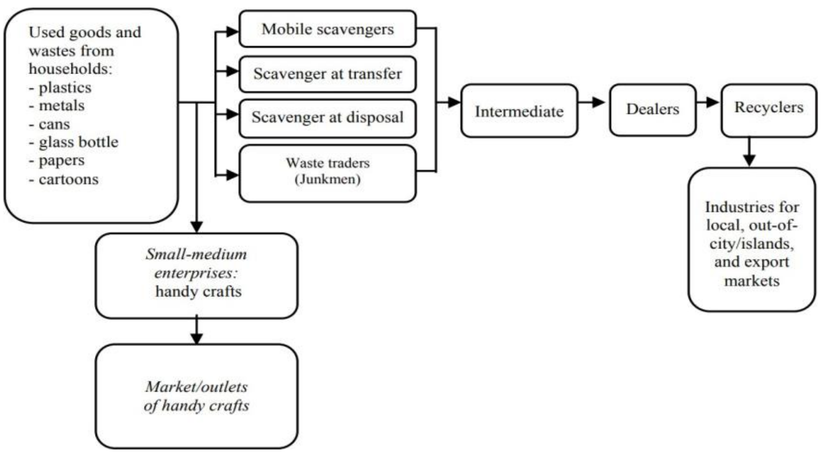

Fig:1.2: Interaction between informal sectors in waste recycling.

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Interaction between informal sectors in waste recycling. competitiveness, conserve natural resources, and protect the environment. Three models have been used to organize waste pickers: microenterprises, cooperatives, public and private partnerships. These can lead to more efficient recycling and more effective poverty reduction. Informal sector activities are not considered illegal in Indonesia. This group performs many economic activities, especially small businesses. All parties in Indonesia, including the government, appreciate its resilience in the face of the global economic crisis which affected the country and other regions during 1997 and 1998. It is documented that this sector has the ability to absorb many independent labours, because the formal sector has failed to provide good and adequate job opportunities. Many city inhabitants in Indonesia who have formal jobs also engage in informal sector business after working hours to increase their income. Informal sector activities are done openly and have not been deemed as illegal activities so security or law enforcement officers do not need to become involved. These types of activity can be found throughout the cities, either in people's own homes or on the public streets or unoccupied lands. In most cases, however, raids launched by legal officers are because these activities are disturbing civic order, such as using sidewalks for their business, or occupying forbidden areas, such as city parks. Many of these informal sectors go door-to-door, offering goods or services directly to prospective consumers. Usually, these activities are prevalent in cities, such as foods stores, electronic/electric appliance reparation/services, tailors, and other service sectors.

The most marked distinction between the informal and formal sectors is that the objects of the former are not taxation objects from their economic activities. In some cases, these informal sector activities have some linkages with the formal sector Used goods and wastes from households: - plastics - metals - cans - glass bottle - papers - cartoons Intermediate Dealers Recyclers Industries for local, out of city/islands, and export markets Small-medium enterprises handy crafts Market/outlets of handy crafts Mobile scavengers Scavenger at transfer Scavenger at disposal Waste traders. Post-Consumer Waste Recycling and Optimal Production economic chains, and they are mutually dependent (Figure 2). The informal sectors engage primarily in using wastes generated by a household, especially dry wastes such as plastics, papers, metals, and the like, whereas wastes generated by an industry will certainly be addressed by the formal sectors. The trading of dry wastes, which are non-compostable, has been the profession of choice of those people generally belonging to informal sectors. Cycles of potentially recyclable and financially valuable wastes start from their sources such as residential areas, industries and so on. These informal sector activities are most attractive for businesses, involving main actors such as scavengers and waste traders, who collect wastes or used goods door-to-door, or their customers/partners. In addition to their contribution to reducing waste handling costs, another benefit is that they serve as a generator of job opportunities.

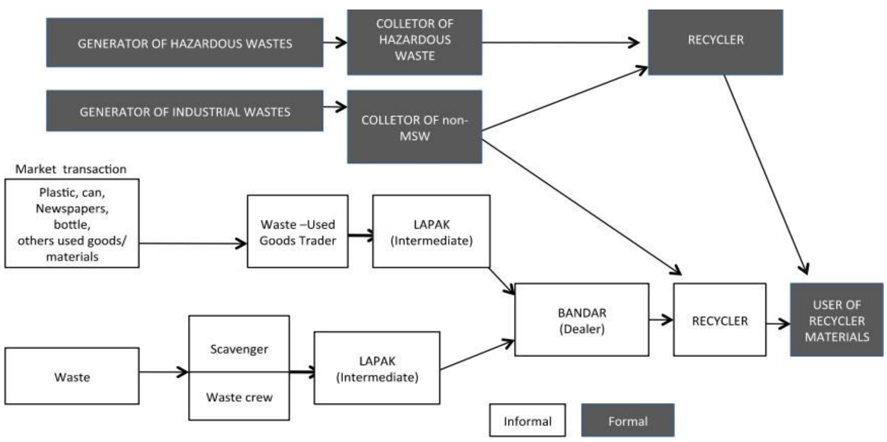

Fig:1.3: Formal and informal sectors in used goods/waste recycling

The Indonesian informal waste recycling industry is vital in enhancing environmental sustainability, natural resource conservation, the creation of employment, and poverty reduction. The industry consists of scavengers, waste collector crews, junkmen, intermediates (lapaks), and dealers, and it is an interdependent and complex chain. Scavengers, who are low-skilled and low-capital migrants, collect valuable dry waste such as plastics, paper, and metals from households, streets, and dumpsites and sell them to lapaks. Lapaks are intermediates who sort, clean, and package the waste and sell it to dealers. Junkmen operate door-to-door or fixed-point, buying used materials and selling them to

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lapaks. Waste collector crews, which are organized at the neighborhood level, collect domestic waste and also collect recyclables, earning income from waste handling fees, compost sales, and recyclable sales. The players are facilitated by microenterprises, cooperatives, and public-private partnerships that coordinate their activities, enhancing efficiency and competitiveness.

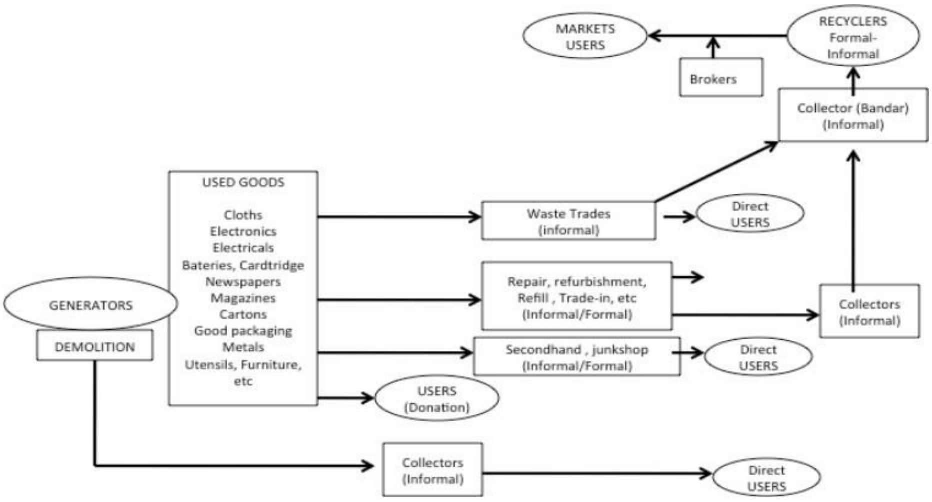

Fig:1.4: General destination of recyclable used goods.

Though they are outside the formal tax system, the informal sector is not illegal and is marked by resilience, particularly during economic crises such as in 1997–1998. Most employees in the formal sector also participate in informal activities as a means of supplementing income. Though the informal sector operates in the open, the problem arises when activities spill over into public areas. However, informal waste management complements the formal sector by alleviating the burden of waste disposal and playing a central role in recycling activities. Some communities, with the support of the government, set up small recycling centers that enhance composting and segregation under Indonesia's Law 18/2008 on Waste Management. Overall, the informal sector is vital in the waste management chain in the country, offering environmental, economic, and social benefits.

II. LITERATURE SURVEY

Austin L.G., Klimpel R.R (1964) present a detailed theoretical framework for understanding grinding operations. They conclude that grinding efficiency is highly dependent on the interplay between various factors such as particle size, material properties, and operational conditions. The developed model effectively links these parameters, offering a deeper insight into the mechanics of material removal during grinding. Their work underscores the importance of optimizing these parameters to enhance process efficiency and product quality. The study also highlights the need for continued research to refine these models and better align theoretical predictions with practical outcomes.

Austin L.G. (1971-1972) presents a mathematical framework for analyzing grinding as a rate process. He concludes that grinding efficiency can be effectively model using mathematical descriptions that account for factors such as particle size and material properties. The study provides valuable equations that help predict grinding rates and optimize operational conditions. Austin's work bridges theoretical modelling with practical applications, offering a foundation for improving grinding processes in industry. He also highlights the need for further research to refine these models and explore their broader applicability.

Bauer W. (2001) Investigates the single-particle size reduction process in cutting mills using polypropylene as a case study. He concludes that the efficiency of size reduction is significantly influenced by the material properties and operational parameters of the cutting mill. The research identifies key factors such as blade design, cutting speed, and feed rate that affect the particle size distribution and overall process effectiveness. Bauer's findings provide practical insights for optimizing cutting mill performance in industrial applications. Additionally, the study highlights areas for

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future research to enhance understanding and control of the size reduction process.

Bielinski M. (1998) the material and processing characteristics of selected secondary polymers are analyzed. The conclusion highlights that the properties of secondary polymers vary significantly depending on their source and processing history. Bielinski emphasizes the importance of understanding these variations to optimize their use in recycling and manufacturing processes. The research provides valuable insights into the behaviour of these materials during processing and suggests improvements for enhancing their performance in industrial applications. Future work is recommended to further investigate the impact of different processing conditions on the properties of secondary polymers.

III. METHODOLOGY

Thermal decomposition of plastic products can release various airborne emissions, including volatile organic compounds (VOCs), particulate matter, and hazardous gases. Understanding these emissions is crucial for assessing environmental and health impacts. This report details the materials and methods used for screening and analysing these emissions.

3.1.1. Plastic Samples:
The gathered plastic samples are then crushed in a plastic crusher to grind them into fine, minute particles ready for further analysis. The grinding stage is done at the first process to make it uniform in size, hence capable of withstanding consistent thermal treatment during decomposition. The ground plastic enhances the gas collection and analysis processes by becoming more efficient and accurate. Suitable crushing is also necessary to make the plastic particle surface area optimally effective to facilitate thermal decomposition and emission study.

3.1.2. Gas Collection Materials:
The gas collection setup incorporates bio-based and mechanical components designed to capture toxic emissions released during the heating of plastic. Corn cobs are selected for their fibrous and porous nature, making them effective as bio-filters for absorbing airborne emissions. A one-inch PVC pipe is used to collect and transport the fumes generated from the heated plastic. This pipe is used to join the steel vessel to the corn cob filter so that gases can flow smoothly and be contained. The steel vessel, which covers the heating plastic sample, is provided with a one-inch hole at the bottom for attaching the PVC pipe. This vessel guarantees that the gases are effectively led into the filtering system so that they do not escape into the environment.

3.2. Methods
3.2.1. Sample Preparation:
To start the emission study, a set of plastic items—usually involving plastic bottles—are chosen. The samples are cut into uniform pieces, usually 1–2 cm² in size, for equal and uniform exposure to thermal conditions. Uniformity in size is important to provide repeatable results in the decomposing phase. After cutting, the samples are desiccated to remove moisture, which may interfere with heat degradation and alter the accuracy of gas emission information. Evaporation of moisture guarantees that only the plastic materials degrade as they are being heated.

FIG:3.1: FINELY GRINDED PLASTIC SAMPLE

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Fig:3.2: 1 INCH PVC PIPE

Fig:3.3: CORN COBS

3.2.2. Thermal Decomposition:

Thermal decomposition of plastic samples is done by using a high-temperature furnace or thermal degradation chamber with a capacity of up to 800°C. Within the chamber, the conditioned plastic samples are placed with caution and heated under controlled conditions. The chamber should be provided with sampling ports and attached to an emission collection system to effectively and safely collect gases emitted during decomposition. The temperature of the chamber is constantly monitored to ensure stability and that decomposition takes place in uniform thermal conditions, which is important for the proper analysis of emissions.

3.2.3. Collection of Emissions:

Gaseous emissions during decomposition are trapped through strategically located sampling ports placed in the degradation chamber. These ports lead to a well-planned collection system. The collection system consists of a condenser unit that removes particulate material and a filtration system to absorb toxic components. Also, bio-based filters like activated carbon or corn cob filters may be employed to increase the trapping of volatile organic compounds (VOCs) and fine particulates. The multi-stage filtering method guarantees that emissions are carefully examined while keeping their environmental impact to a minimum.

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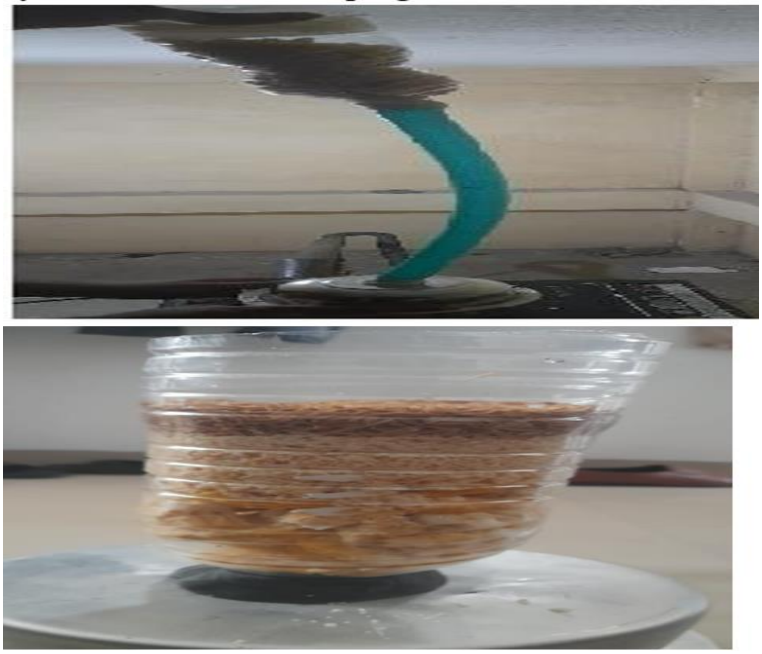

FIG:3.5: EMISSION COLLECTOR

3.3 IMPLEMENTATION

The implementation of corn scrubs (corn cobs) as bio-based filters for capturing emissions from thermally decomposed plastic was carried out to explore a sustainable and cost-effective gas filtration method. Corn cobs were chosen due to their porous and fibrous structure, which provides a high surface area ideal for absorbing toxic fumes and volatile organic compounds (VOCs). During the experimental setup, crushed plastic samples were placed in a steel vessel and subjected to high temperatures within a thermal degradation chamber. As the plastic decomposed, toxic gases were released and guided through a one-inch PVC pipe into the corn cob filter unit. The corn cobs acted as a natural filter, capturing harmful airborne particles and reducing the concentration of pollutants emitted into the environment. The outcome of the implementation showed that corn scrubs were effective in adsorbing a significant amount of visible soot, odor-causing compounds, and particulate matter. Gas sensors placed after the filter unit confirmed a noticeable reduction in harmful gas concentrations, demonstrating the potential of corn cobs as an eco-friendly alternative to synthetic filters. This low-cost, biodegradable filtration method not only reduced environmental impact but also presented a viable solution for emission control in plastic recycling and decomposition processes.

3.4 Dataset Analysis

The analysis of the dataset shows the occurrence of several volatile organic compounds (VOCs) and gases emitted in the course of thermal plastic waste decomposition, offering information on the emission pattern of such processes. Interestingly, carbon dioxide is mentioned several times, pointing towards it as a dominant product of combustion and a central greenhouse gas, related to the significant carbon composition in plastics. Ethylene oxide , a poisonous and combustible substance, indicates partial hydrocarbon oxidation and is responsible for health hazards and environmental threats. Acetaldehyde , found in several cases, is a typical pyrolysis product, with a characteristic smell and carcinogenicity. Propane , a light hydrocarbon, indicates incomplete combustion and degradation of long-chain polymers, further highlighting the combustibility of the emissions. Acetic acid and butene (butena) indicate polyvinyl material degradation, contributing to the reactivity and acidity of the gaseous phase. Hexane (hexana) , a saturated hydrocarbon, and acetophenone , a ketone derivative, are intermediate cracking compounds in plastic decomposition based on styrene plastics. The occurrence of vinyl benzoate and benzoic acid suggests degradation of aromatic compounds and plasticizers in some plastics, pointing to possible hazards to air quality and health. Furfural and 3-furaldehyde , furan derivatives, usually arise from thermal degradation of cellulose or other bio-additives in plastic mixtures, adding to the aromatic toxicity. Pyrazole, 1,4-dimethyl- , a nitrogenous heterocycle, suggests complicated thermal reactions with nitrogen-containing additives or pigments. These compounds altogether depict a

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sophisticated emission profile with flammable gases, aldehydes, acids, hydrocarbons, and aromatic derivatives. The high abundance and range of m/z ratios highlight the necessity for emission control measures. This underlines the importance of employing bio-based filters like corn cob scrubbers , which assist in adsorbing VOCs and lowering the environmental footprint of plastic pyrolysis, rendering the process safer and more sustainable.

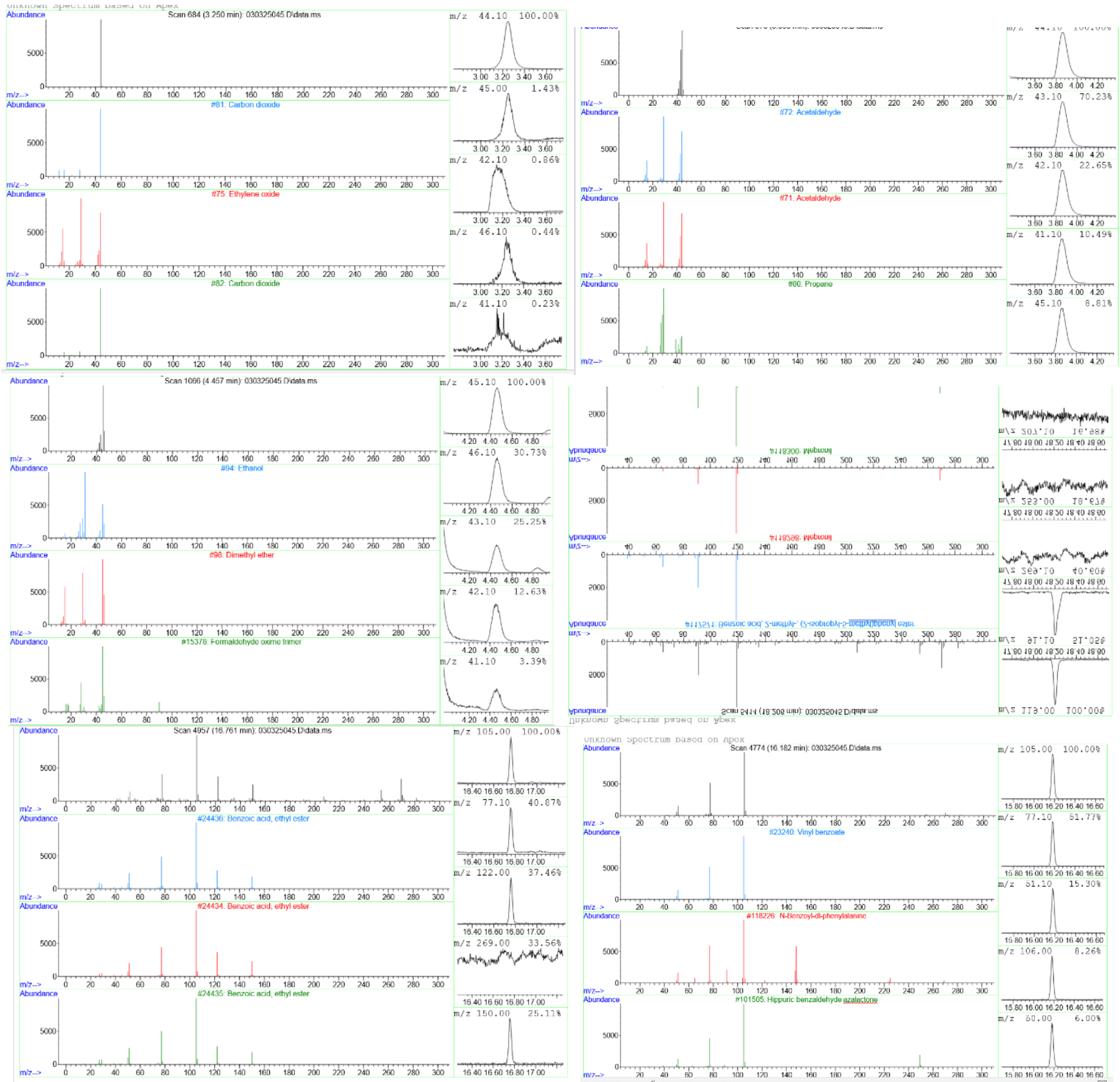

Fig 3.5 Dataset Analysis

1. EVALUATION OF THE OUTCOME

The screening of airborne emissions resulting from the thermal decomposition of plastic products is a critical area of research with significant environmental and health implications. This process involves a range of sophisticated materials and methodologies to ensure accurate and comprehensive analysis of emissions

.

The core materials in these studies include a variety of plastic samples, such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), and polystyrene (PS), which are selected based on their prevalence and significance in the waste stream. The forms of these plastics—ranging from pellets and films to moulded objects—allow researchers to simulate real-world conditions and assess emissions from different types of plastic waste.

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Gas collection materials are equally crucial. Tedlar bags and other gas-tight sampling containers are used to capture and store air samples during decomposition. Filters, particularly high-efficiency particulate air (HEPA) filters, are employed to trap particulate matter released during the process. Calibration gases and chemical reagents are utilized to ensure the accuracy of analytical instruments and the integrity of post-sampling analyses.

4.1 METHODS EMPLOYED

The methodology for analysing airborne emissions involves several key techniques. Thermal decomposition is typically studied using Thermogravimetric Analysis (TGA) and thermal analysis furnaces. TGA provides data on weight changes as plastics are heated, revealing thermal stability and decomposition characteristics. Thermal furnaces allow for controlled decomposition, mimicking real-world conditions.

For emission collection and analysis, Gas Chromatography (GC) paired with Mass Spectrometry (MS) or Flame Ionization Detection (FID) is extensively used. This technique enables the identification and quantification of volatile organic compounds (VOCs) emitted during decomposition. Fourier Transform Infrared Spectroscopy (FTIR) is another vital method, providing detailed information on specific gaseous emissions based on infrared absorption spectra.

Airborne emission screening involves various sampling systems. Active sampling systems use pumps to collect air samples over time, while passive systems rely on diffusion for capturing emissions. Particulate matter is assessed using gravimetric analysis or optical particle counters to measure the concentration and size distribution of airborne particulates.

Data analysis is a crucial aspect of emission studies. Quantitative analysis using GC/GC-MS and qualitative analysis with FTIR provides comprehensive information on the composition and concentration of emissions. Statistical methods are employed to interpret the data, identify trends, and assess variability.

4.2 SAFETY AND QUALITY CONTROL

Ensuring safety and quality control in emission screening is paramount. Safety protocols involve proper handling of potentially hazardous materials and emissions, with the use of appropriate protective equipment such as masks, gloves, and fume hoods. Quality assurance practices include regular calibration of analytical instruments and validation of methods to maintain accuracy and reliability.

IV. CONCLUSION

The research was able to effectively prove the feasibility of utilizing corn cobs as an effective and environmentally friendly technology for purifying poisonous emissions produced from thermal decomposition of plastic waste. With the incorporation of an elementary setup in the form of a steel container, PVC pipe, and corn cob filtration, toxic gases and particles were successfully lowered. The fibrous and porous composition of corn cobs was useful in filtering volatile organic compounds and soot, and thereby provided a natural and biodegradable solution to regular filters. The method not only helps in reducing plastic waste's environmental footprint but also encourages the use of agricultural waste products as tools in environmental management. On the whole, the deployment proved to be an affordable, accessible, and environmentally friendly approach to emission control that can be developed further for wider industrial and environmental application.

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