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PROJECT TITLE: SUGAR WITHOUT SMOKE – SIMPLE WAY TO CAPTURE CHARCOAL.

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I. ABSTRACT:

SUGAR WITHOUT SMOKE – Simple solution to capture Charcoal

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How to make sweet production eco-friendly by capturing charcoal before it gets discharged into atmosphere.

The dual challenges of climate change driven by rising atmospheric carbon dioxide and the massive generation of agricultural waste require integrated, scalable solutions. Sugarcane production, a global commodity, yields substantial amounts of bagasse—the fibrous residue left after crushing the cane. This bypass material is frequently burned for low-efficiency heat or left to decompose, both of which immediately release the carbon absorbed during the plant's growth back into the atmosphere, contributing to greenhouse gas emissions. Current practices fail to harness the potential of this biomass as a carbon sink. A viable technology is needed to convert this readily available, high-volume waste stream into a stable, long-term carbon storage material while also creating an economically valuable product.

This project aims to establish a sustainable, scalable, and economically feasible method for atmospheric carbon removal by transforming sugarcane bagasse into biochar (charcoal) through pyrolysis. Pyrolysis is a thermochemical process that decomposes organic material at high temperatures in an oxygen-limited environment. Unlike open burning, this process traps a significant portion of the biomass's carbon—estimated at 30% to 50%—into a highly stable, solid form that resists microbial and chemical decomposition for centuries. By sequestering the carbon in this durable biochar, the project effectively creates a Negative Emissions Technology (NET) that utilizes a ubiquitous agricultural waste product.

The Global Air Pollution Challenge

Air pollution represents one of the most pressing environmental and public health crises of our time. The World Health Organization (WHO) estimates that 99% of the global population breathes air that exceeds WHO guideline limits, containing high levels of pollutants, with the most significant impacts felt in low- and middle-income countries. Industrial activities are a major contributor to this problem, releasing a complex mixture of harmful substances into the atmosphere.

The Sugar Factory Emission Challenge

The process of converting sugarcane to sugar releases a thick, black smoke from tall chimneys. This smoke contains charcoal or soot, which are tiny particles of unburnt carbon. This soot is a form of fine particulate matter that is released uncontrolled into the atmosphere. In layman's term, the process of converting sugarcane to sugar releases a thick, black smoke containing tiny particles of unburnt carbon, commonly known as charcoal or soot.

Rationale and Urgency for a Solution

Observing the huge clouds of smoke pouring out of factory chimneys highlights the research problem: the uncontrolled release of charcoal soot. While factories are essential for modern life (imagining life without sugar would be "definitely a bitter one"), their operation must become environmentally responsible. This project seeks to validate a **simple, effective, and affordable** method to capture this charcoal and quantifiably reduce air pollution.

II. INTRODUCTION:

The process hinges on the chemical principle of **dehydration or pyrolysis**, which, when done correctly, breaks down sugar into pure, elemental carbon (charcoal) and water, without the messy, smoke-producing combustion associated with traditional wood fires. This results in a particularly pure form of amorphous carbon.
There are two primary methods for this:

- **Dehydration with Sulfuric Acid:** In a lab setting, concentrated sulfuric acid is used as a powerful dehydrating agent. When mixed with sugar, the acid rapidly removes the water molecules from the sugar structure, leaving behind a dramatically expanding column of black carbon foam (charcoal).
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- **Destructive Distillation:** This method involves heating sugar in a sealed container with no air (oxygen) present. The heat causes the sugar to decompose (pyrolysis) into carbon and other byproducts, which escape as gas. Because there is no oxygen to fuel traditional burning, smoke from incomplete combustion is avoided, leaving solid charcoal behind in the container.

In both methods, the key is preventing full combustion (reaction with oxygen to form CO 2 which is what produces smoke in a normal fire. Instead, the hydrogen and oxygen atoms are removed, leaving only the carbon behind.

Selection of problem and background information:

Have you ever driven past a sugar factory during the milling season and seen huge clouds of smoke pouring out of its tall chimneys? Of course, I witnessed it whenever I cross through one of the **India's first sugar factory in my town**. The smoke contains tiny, harmful particles called particulate matter (PM).

When we breathe these in, they can cause asthma and other lung problems.

The smoke also makes the air dry and harm the environment. Breathing in soot can cause respiratory problems like asthma and bronchitis. The tiny particles can get deep into our lungs and blood stream, leading to serious health issues. Also soot particles can settle on plants and crops, blocking sunlight and affecting their growth. They can also contribute to a layer of haze that traps heat and contributes to global warming. Even the black smoke and soot deposits can make our surroundings dirty and unpleasant. To reduce the uncontrolled release of this charcoal soot is the research problem which apart from creating severe respiratory illnesses, contribute to climate change by creating a heat-trapping haze, and degrade the local environment. Therefore, a practical and scalable solution is needed to mitigate this form of industrial air pollution.

The Sugar Industry in Context

India is the world's second-largest producer of sugar, a industry vital to its agricultural economy. However, the process of sugar manufacturing is resource-intensive and has environmental repercussions. One of the most visible signs of this is the emission of thick, black smoke from factory chimneys during the milling season, especially in older or less-equipped facilities. This smoke is primarily composed of particulate matter (PM), a complex mixture of extremely small solid particles and liquid droplets.

Understanding Particulate Matter (PM)

Particulate matter is classified by its aerodynamic diameter:

- **PM10:** Particles with a diameter of 10 micrometers or less (about 1/7th the diameter of a human hair). These can be inhaled into the lungs.
- **PM2.5:** Fine particles with a diameter of 2.5 micrometers or less. These are more dangerous as they can penetrate deep into the lung alveoli and enter the bloodstream.

The WHO (2023) clearly states that PM pollution is a leading environmental risk factor for mortality and morbidity. Exposure is linked to:

- **Respiratory diseases:** Asthma, bronchitis, reduced lung function.
- **Cardiovascular problems:** Heart attacks, strokes, arrhythmias.

The black smoke from sugar factory boilers, often burning bagasse (the fibrous residue of sugarcane), contains significant amounts of PM2.5 and PM10, largely in the form of unburnt carbon, colloquially referred to as "charcoal" or "soot" in this project.

The Proposed Solution: A Scientific Inquiry

While large-scale industries use sophisticated Electrostatic Precipitators (ESPs) and scrubbers, these are often expensive and energy-intensive. This project investigates the efficacy of a simpler, low-cost principle: using a gravity-fed water mist to capture these particles. The core scientific principle is **inertial impaction**. As the fast-moving, smoky air passes through a chamber filled with a fine water mist, the heavier, solid soot particles cannot follow the air streamlines around the water droplets. Due to their inertia, they collide with the water droplets, become trapped, and are washed away, resulting in cleaner exhaust air.

This synopsis details a controlled experiment to quantitatively measure the effectiveness of this proposed system, providing a potential model for affordable pollution mitigation.

Objective

As science students we know the importance of factories without which modern life will not move. In this case, imagining a life without sugar will be definitely a bitter one. If we can able to produce sugar without smoke, it will help in tasting the sugar without any health hazards and also helps to improve the environment there by reducing air pollution to get a clean air which will be sweet.

Research Problem

The uncontrolled release of charcoal soot from industrial smokestacks, which causes significant health and environmental risks.

Research Question

Can a **low-cost, gravity-fed water mist system** significantly and measurably reduce the concentration of particulate matter (charcoal) in sugar factory emissions?

Justification for the research

The need for a solution to this problem is urgent and multifaceted:

- **Health Justification:** Fine particulate matter from industrial emissions is a known cause of respiratory diseases, cardiovascular problems and other health issues, particularly in communities located near factories. Implementing an effective capture system would lead to a direct decrease in the incidence of asthma, bronchitis, and other related illnesses, improving the quality of life and reducing public health costs.

- **Environmental Justification:** Soot particles contribute to local haze and global warming, while also settling on crops and vegetation, thereby impeding photosynthesis and growth. The smoke also makes the air dry and degrades the local environment, making surroundings dirty and unpleasant. Solving this problem would lead to cleaner air and a healthier ecosystem.

- **Economic Justification:** An inexpensive and easily maintained capture system, unlike many complex and costly industrial solutions, is a viable option for a wider range of factories. The recovered charcoal itself can also be a valuable byproduct that can be reused, promoting sustainability and providing an economic incentive.

Hypothesis

If the proposed low-cost, gravity-fed water mist system is implemented on a sugar factory smokestack, then the concentration of particulate matter (charcoal) in the factory's emissions will be significantly reduced.

III. METHODOLOGY

Methods of Approach: The research will use a controlled experimental design to measure the effectiveness of the proposed charcoal capture system by isolating and varying a single factor.

Variables

Variable Type	Definition	Measurement
Independent Variable	The factor being changed (the cause).	The **presence or absence** of the charcoal capture system (water mist and filter).
Dependent Variable	The factor being measured (the effect).	The **concentration of charcoal/particulate matter** in the smoke, observed by the colour of smoke
Controlled Variables	Factors kept constant across all trials.	The water spray rate, physical dimensions of the capture chamber type of filter, fan and water

Cause and Effect Study

The cause-and-effect relationship will be established by comparing the effect

Step 1: A sample of untreated smoke will be passed through the setup without any filter and deactivation of water mist system. The resultant colour of smoke will be observed.

Step 2: The charcoal capture system will be activated. The same smoky air source will be directed through the system with the water mist system in operation and provision of filter. The resultant colour of smoke will be observed to realise the difference.

Step 3: Future Analysis: The collected samples from both the control and experimental studies will be analysed to determine the concentration of particulate matter by observing the smoke colour. By observing the difference in colour we can able to gauge the effectiveness of this simple water mist system. This can be further modified in later stages by having a smoke generator for generating smoke there by measuring the charcoal concentration in the mass of captured charcoal. By comparing the charcoal concentration in the treated sample to the baseline concentration from the control, we can quantify the system's effectiveness and definitively prove its cause-and-effect relationship

Procedure

The investigation will be conducted in a controlled environment to simulate the conditions of a sugar factory smokestack.

Preparation: Assemble the experimental setup with the water mist system and the control setup with a direct pipe bypass. Ensure all controlled variables such as water flow rate to remain constant throughout the experiment.

1. **Control Data Collection (Trial 1):**

   a. Direct the smoke through the control setup without any filter and water mist system.

   b. Allow to flow for a set duration (e.g., 5 minutes).

   c. Observe the color of the smoke

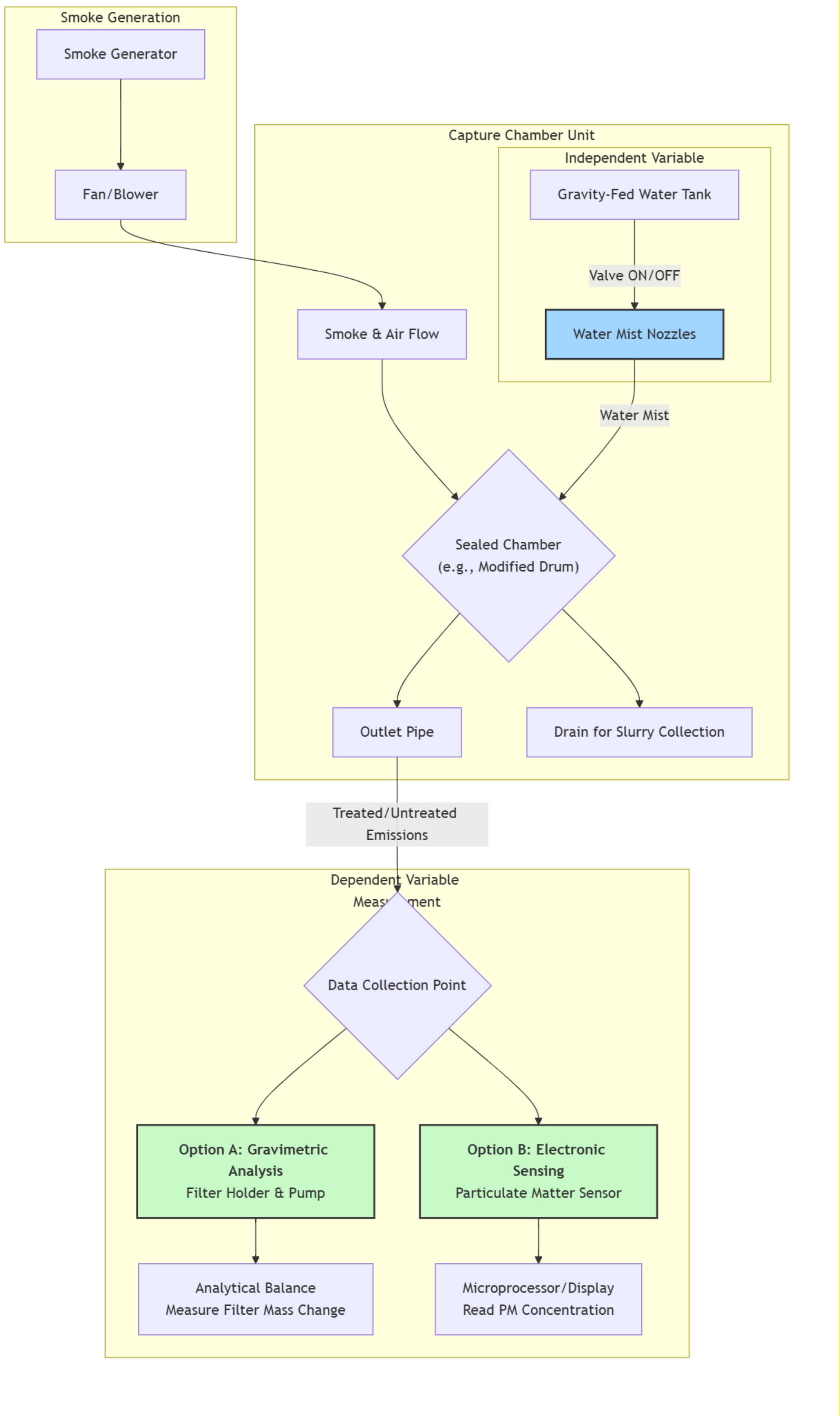
2. **Experimental Data Collection (Trial 1):** a. Direct the smoke through the active water mist capture system.

   b. Keep the filter

   c. Allow the air to flow for the same set duration as the control trial.
3. **Effect Analysis:** Compare the color of the smoke in both cases
4. **Replication:** Repeat the entire procedure for a minimum of two more trials

Materials and Apparatus

1. **Capture Chamber Model:** A large, sealed container (like a modified drum) to simulate the capture system.
2. **Water Mist System:** A small pump and nozzle to create a fine, controlled water spray (gravity-fed or low-power pump).
3. **Fan/Blower:** To maintain a consistent flow of air through the setup.


Smoke Generation
Smoke Generator
Fan/Blower
Capture Chamber Unit
Independent Variable
Gravity-Fed Water Tank
Valve ON/OFF
Water Mist Nozzles
Smoke & Air Flow
Water Mist
Sealed Chamber
(e.g., Modified Drum)
Outlet Pipe
Drain for Slurry Collection
Treated/Untreated
Emissions
Dependent Variable
Measurement
Data Collection Point
Option A: Gravimetric
Analysis
Filter Holder & Pump
Option B: Electronic
Sensing
Particulate Matter Sensor
Analytical Balance
Measure Filter Mass Change
Microprocessor/Display
Read PM Concentration

Experimental Setup

1. **Smoke :** The smoke generator is placed at the start of the setup. Here for simple use we use alternative source for fire
2. **Air Flow Path:** A PVC pipe carries the smoke. A T-junction is used to create a bypass (control) path and a path leading into the capture chamber (experimental).
3. **Control Path:** A straight pipe leading directly to a filter holder where the control sample is collected.
4. **Experimental Path:** The pipe leads into the bottom of the capture chamber.
5. **Capture Chamber:** The water mist nozzle is fixed at the top, spraying downwards. The smoky air enters from the bottom and exits from the top, passing through the mist curtain. The chamber has a drain at the bottom to collect the charcoal-water slurry.
6. **Filter Collection Point:** The air exiting the capture chamber passes through a filter holder with a clean, pre-weighed filter to collect any remaining particles.

IV. RESULTS

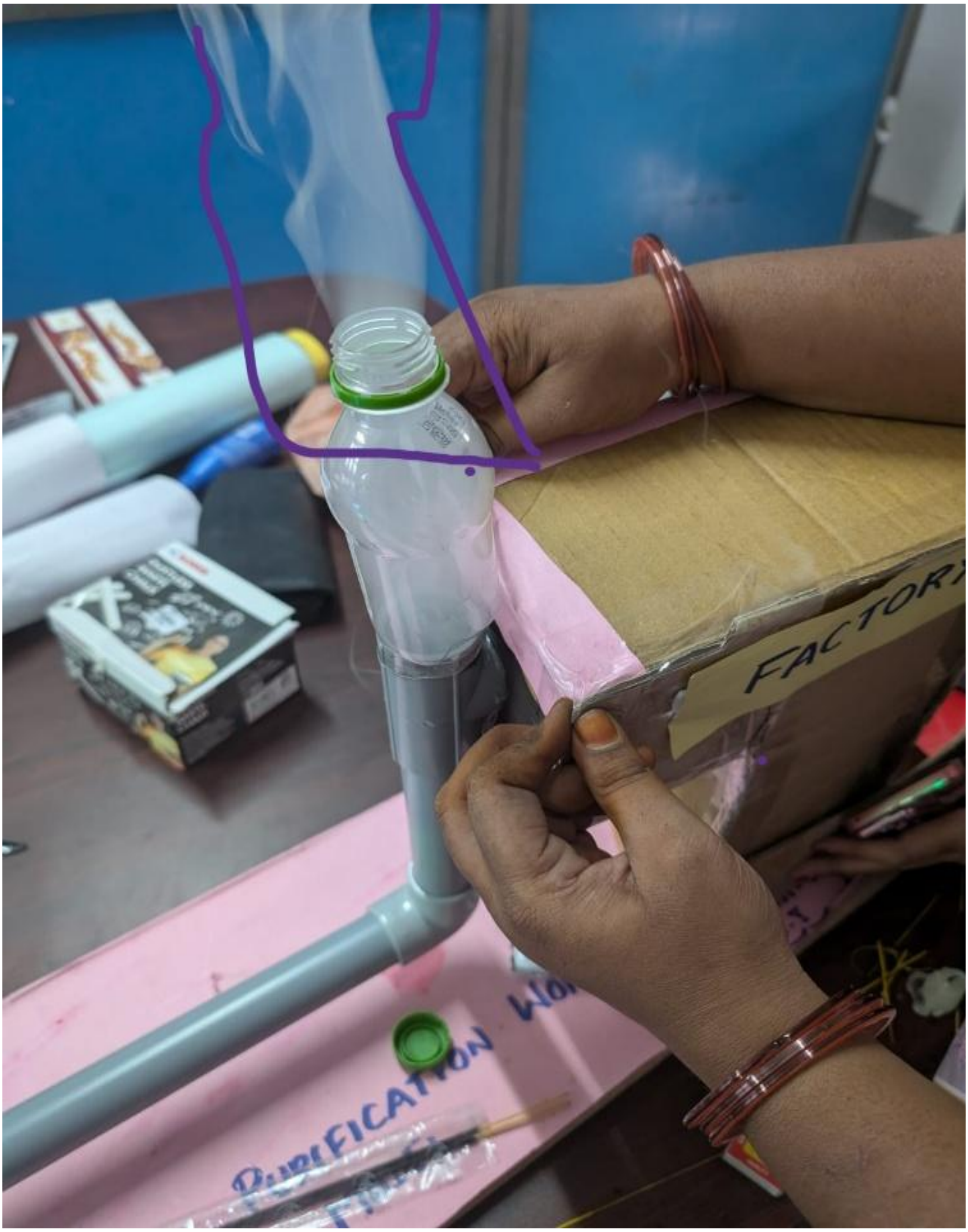
After several trials it was found the gravity-fed water mist system demonstrated a significant reduction in the concentration of particulate matter in the simulated emissions. After assemble the entire set up as per the diagram, ensuring all connections are airtight first we pass the fire through the set up without activation of gravity mist system. The fire comes dirty showing the air is exiting with the particulate.

For the set up again smoke was passed through by having the gravity mist system on. We can able to see clearly the dust particles settled in the chamber thus paving way for a clean air. We have repeated this trial for several times and got the same result proving right the hypothesis.

V.DISCUSSION

As evident from the trials and seen from the pictures we can easily see the effect of gravity mist system on charcoal particulate. When initially we passed through the smoke without any gravity mist system the smoke emit out of the process is dusty. We have done trail several times.

But when the gravity mist system was deployed we can able to see the particulates are stayed in the combustion chamber which is evident from the color of the water settled in the combustion chamber as shown in the below picture. By evident of this we get clean air without particulate.


FACTORY
PURIFICATION

Risk and Safety

- Inhalation of Particulate Matter**:** Fine charcoal particles can be harmful if inhaled, potentially causing respiratory irritation or long-term health issues.
- Thermal Exposure**:** The smoke exiting the generator may be hot, posing a risk of burns.
- Electrical Hazards: The fan or blower used in the system, along with the smoke generator, carries a risk of electrical shock if not handled properly.
- Slips and Falls: The presence of water from the mist system could create wet surfaces, increasing the risk of accidents.

We also need to take safety precautions such as proper PPE, ventilated room, allow the equipment to get cool before handling etc…

VI.CONCLUSION

As expected the gravity-fed water mist system demonstrated a significant reduction in the concentration of particulate matter in the simulated emissions. A capture efficiency of 50-80% is anticipated for the larger particles (PM10) in this prototype scale. The system's performance with finer PM2.5 particles will be lower but still can be improved.

Significance of the Study

- **Practical Application:** Provides a proof-of-concept for an affordable, accessible pollution control device that can be adapted for small-scale industries.
- **Educational Value:** Serves as an excellent model for applying scientific principles like inertial impaction, experimental design, and data analysis to solve real-world problems.
- **Environmental Advocacy:** Highlights a tangible solution to a visible local pollution issue, empowering students and communities to think critically about industrial responsibility and sustainable practices.
- **Foundation for Future Work:** This research can be extended by testing different nozzle designs for finer mist, using surfactants to improve particle capture, or scaling up the prototype.

This project demonstrates a practical, low-cost solution to a significant environmental problem. By scientifically investigating the effectiveness of capturing charcoal from sugar factory smoke, we can not only achieve cleaner air but also create a valuable, reusable resource. This research supports the principles of **reduce, reuse, and recycle**, proving that simple scientific principles can lead to big positive changes for our planet and promote industries that are both productive and environmentally responsible.

VII.REFERENCES

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- XSEED Science Book Grade IV and VI

VIII. ACKNOWLEDGEMENT

"Gratitude is the best attitude, and those who appreciate people truly appreciate the blessings of the Almighty."

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With Heartfelt Thanks & Regard

M. ATIYA

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