Study Protocol for the Air Purification for Remediating Manganese, Lead, and Particulate Matter in Incense Stick Industry by *Air Purification Toxic Adsorbent* (APTA)

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Abstract. The incense stick industry is widespread in Asia. The burning of incense, particularly those containing synthetic ingredients, releases harmful pollutants such as particulate matter (PM), VOCs, and heavy metals. This study protocol outlines a comprehensive approach to remediating Mn, Pb, and PM emissions in the incense stick industry using Air Purification Toxic Adsorbent (APTA). This research design is a pilot project to create a study protocol of APTA that can reduce manganese, lead, and particulate matter emissions produced by the incense stick industry. This filter system used a multilayered approach to absorb these harmful substances or residue from incense stick production. Multi-layered APTA consists of HEPA filters, zeolite, silica gel, SAP sand, and dust cotton. This trial study will be in Dalisodo Regency, Malang City as a home industry for incense sticks. The anticipated outcomes of this research include significant reductions of residues like Mn, Pb, PM2.5, and PM10, leading to improved occupational safety standards in incense stick and public health implications. This study represents the purification of air pollution and emphasizes the importance of solutions for specific pollutants in incense stick production.

Keywords: Air purification, Lead, Manganese, Multi-layer, Particulate Matter, Remediation.

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1 Introduction

Incense sticks have long played an important role in spiritual and cultural societies around the world. The incense sticks industry is prominent in Asia and the Middle East, including Indonesia. Beyond its spiritual and cultural roots, the incense stick also finds a place in modern life, where its calming scents are used to set a mood for meditation, transform a room's atmosphere, or for aromatherapy [1]. Creating these incense sticks mixes the handcrafted techniques with modern and traditional production. Firstly, the process involves coating a slender bamboo stick with a paste made from aromatic wood powders, charcoal, and natural resins that hold everything together. This base is perfumed. After everything is

mixed, add essential oils from sandalwood, cinnamon, or various flowers. To make efficient, synthetic perfumed chemicals are sometimes used. By weight, a typical incense stick breaks down into about 21% herbal and wood powder, 35% fragrance, 11% adhesive, and 33% bamboo stick [2].

This industry is a vital source to increase economic income, while facing serious environmental challenges, especially regarding waste after production that can pollute the air and water. Mixing and burning incense products is the most common activity that can release pollutants in the air. These residues consist of particulate matter, volatile organic compounds, and chemicals such as manganese and lead [3]. The combustion process releases pollution that affects health risk in humans. For workers in incense stick production, the air conditioning is often filled with pollution from raw materials during manufacturing and from combustion.

The highest residue from incense stick production is dust or particulate matter. Particulate matter can be absorbed by inhalation for long periods and then penetrate into alveolar and diffuse into the blood circulation. This pollutant contributes to chronic diseases like asthma and bronchitis and even affect to cardiovascular system. If PM2,5 and PM10 absorb more than the quality standard from World Health Organization and the frequency is higher than the standards, it will affect health [3]. Beyond particulate matter, the emissions contain dangerous heavy metals like manganese and lead, which are ingredient of some incense production. Chronic effects from absorption of manganese can lead to a severe neurological disorder known as Manganism, Parkinson's, or heart problems. Lead exposure is equally concerning, as it is a potential for neurotoxin. Even at low levels, it can cause cognitive impairments and developmental delays, posing a problem for health. Therefore, the workers who are essential to this incense stick industry face pollution every day and can create chronic disease if they cannot manage it, even heavy metals have a half time to excretion [5].

Particulate matter, manganese, lead, and other chemicals create a dangerously polluted indoor atmosphere. This condition will be more harmful if there is no ventilation in the industry, because fresh air is limited. if PM2,5 and PM10. Based on these problems, researchers make an innovation to pilot project of Air Purification Toxic Adsorbent (APTA) hopefully this method can effectively reduce particulate matter, manganese, and lead as the most harmful pollution from incense stick production [6]. APTA system works by integrating a series of specialized materials as a multi-layer. The process begins as air passes through an initial layer of dust filter cotton, which catches larger particles. Next, a HEPA filter traps the particulate matter that is a major health concern. Finally, the air is drawn through of adsorbent materials including zeolite stones, silica gel, and SAP sand which act like molecular sponges to capture toxic heavy metals like lead and manganese and neutralize other dangerous chemical compounds. Together, this multi-layer filtration process provides a comprehensive defence against the industry's characteristic air pollution [7]. Layers of SAP sand and dust filter cotton work for capturing particulate matter, ensuring a comprehensive remediating process [8]. So, this study aims to develop a study protocol for the APTA model to remediate particulate matter, lead, and manganese as harmful indoor air pollution in the incense stick industry. To implement this solution effectively, the study protocol will follow several essential steps. It begins with assessment of the existing air quality, which informs the precise selection and configuration of the APTA filtration components. Following installation, clear operational guidelines will be established to ensure the system functions correctly. The final phase involves continuous data collection and analysis to verify the protocol's effectiveness and make any necessary adjustments. By systematically addressing the pollution at its source, this APTA-based protocol presents a sustainable and targeted strategy to tackle the pressing environmental and health concerns linked to the incense industry. This study protocol offers a sustainable solution for remediating air pollution so decrease the worker health risk.

2 Method

2.1 Study Design and Setting

Design and assess the effectiveness of an APTA filter system to reduce manganese, lead, and particulate matter emissions produced by the incense stick industry. This filter system used a multi-layered so can filter and adsorb this pollution.

2.2 Data Collection

Air Quality Monitoring in the incense stick industry will be baselining measurements of manganese, lead, and PM will be taken before APTA installation using standard air sampling methods. We conducted pre and post-intervention assessment using APTA.

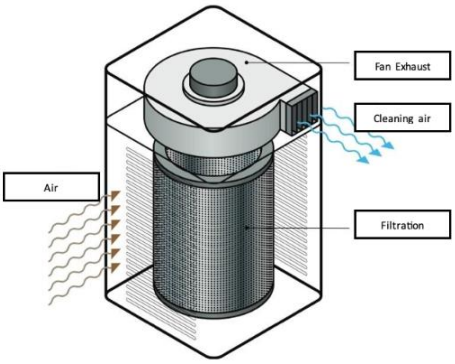

Fig. 1. Design APTA

2.3 Materials

Based on Picture 1. Design APTA, it used numerous of materials. For Blower System used 10-inch axial drum fan, 2800 RPM and lower high-speed, 220V frame and Housing. For constructing a stable housing structure that holds each filter layer and ensures proper airflow APTA used metal Plates and Perforated Plates. Electrical components used power Supply: CPU power cable with 220 Volt and MCB New Domain for Miniature Circuit Breaker for electrical protection. Filter media for APTA used HEPA filter for trapping fine particulate matter, zeolite for adsorption of heavy metals especially manganese and lead, silica gel For controlling humidity and capturing volatile organic compounds (VOCs), SAP sand for capturing coarse particulates, and the last laps is a cotton dust filter for filtering larger dust particles.

2.4 Assembly Steps

2.4.1 Constructing the Housing Frame

Flow chart Picture 2. Systematic Diagram of the APTA System, illustrates about constructing the housing frame using metal plates. First step is constructing a rectangular frame that will serve as the primary housing unit for the APTA system. Ensure the frame dimensions are large enough to hold all filtration layers as well as the fan and blower. Position perforated metal plates within the frame at intervals, creating compartments that will securely hold each filter layer and allow for unobstructed airflow between layers.

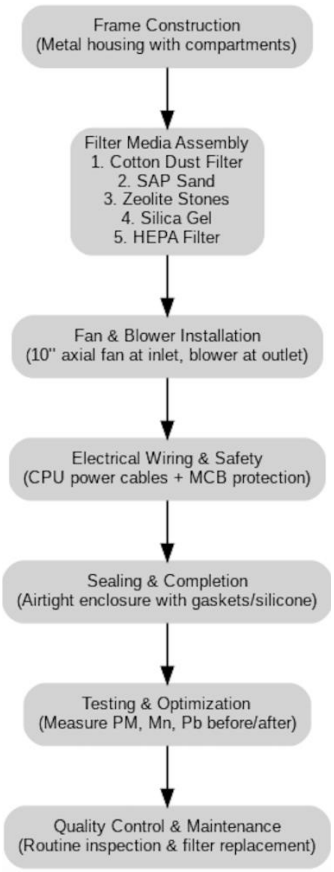

Fig. 2. Systematic Diagram of the APTA System

2.4.2 Assembling Filter Media Layers

Second step, placing the filter media inside the frame in the following sequence, ensuring each layer is securely positioned between the perforated plates: Cotton Dust Filter: First layer, positioned at the air intake, to capture larger dust particles. SAP Sand: Second layer, serving to trap coarser particulates. Zeolite Stones: Third layer to adsorb toxic heavy metals such as manganese and lead. Silica Gel: Fourth layer, for controlling moisture and adsorbing certain VOCs. HEPA Filter: Final layer, designed to capture fine particles (PM2.5 and smaller) and improve air purity.

2.4.3 Installing Fan and Blower for Airflow

In the third step, fan and blower installation ensure unidirectional airflow from the inlet through all filter layers to the outlet. Attach the 10-inch axial drum fan to the air intake side of the housing, ensuring that it draws air through the filter layers. Place the blower at the exhaust end to expel the purified air out of the system, ensuring efficient air circulation and filtration. This is supported by the fourth stage, electrical wiring and safety, which integrates CPU power cables and a miniature circuit breaker (MCB) to protect the system from overloads. The fifth stage, sealing and housing completion, guarantees that airflow remains airtight, ensuring that contaminated air passes exclusively through the designed filtration media.

2.4.4 Electrical Connections and Circuit Protection

Connect the fan and blower to the power supply using the CPU power cable. Install the MCB (Miniature Circuit Breaker) between the power source and fan/blower connections to safeguard against electrical overloads. Test the electrical setup by turning on the fan and blower, ensuring they operate smoothly, and the MCB functions correctly.

2.4.5 Sealing and Finalizing the Housing

Inspect the housing for any potential air leaks and seal all edges with rubber gaskets or silicone if necessary, ensuring an airtight setup so that all air passes through the filtration layers without bypassing them.

2.4.6 Testing and Optimization

Air quality testing is placing the APTA filter in a controlled test environment exposed to incense smoke to simulate typical conditions in incense stick production facilities. Measure air quality pollution that is particulate matter, manganese, and lead concentration, before and after used APTA. Then, adjust fan speed or blower power to optimize airflow. Ensure that the system is effectively remediating pollutants so can decrease till air quality standards based on World Health Organization.

2.4.7 Quality Control and Maintenance

Regular maintenance checks and component replacements (e.g., HEPA filter, cotton dust filter) will be scheduled based on usage duration and filter saturation to ensure optimal performance throughout testing.

3 Result and Discussion

3.1 Validation

Air Quality Improvement

The primary goal of this study is to assess the reduction of airborne pollutants in incense manufacturing environments. The following validation points will be measured [9]:

1. Manganese Reduction: Initial assessments suggest that APTA, in conjunction with HEPA filters, can achieve a reduction of manganese levels below WHO guidelines (0.05 $\mu g/m^3$) within three months of implementation [5].
2. Lead Concentration: The combination of APTA and zeolite is expected to effectively adsorb lead, reducing concentrations below the recommended limit of 0.01 $\mu g/m^3$ [10].
3. Particulate Matter (PM) Reduction: Utilizing HEPA filters and silica gel is anticipated to decrease PM levels significantly, aiming for concentrations below 35 $\mu g/m^3$ for PM2.5

Validation of Filtration Efficiency

The study will validate the efficiency of each filtration used in conjunction with APTA [11]

Table 1. The Expected Pollutant Reduction Targets for APTA Filter System

Filter Component	**Target Pollutants**	**Expected Reduction (%)**
HEPA Filters	$PM_{2.5}$, PM_{10}	≥ 99.97% of particles ≥ 0.3 microns
Zeolite	Manganese (Mn), Lead (Pb)	40% - 85% (based on heavy metal adsorption data from literature)
Silica Gel	VOCs and humidity control	Significant VOC adsorption (30-70%)
SAP Sand	Particulates and moisture	Moderate improvement in moisture control and particulate capture (estimated 20-50%)
Dust Cotton Filters	Larger particulate matter	Preliminary large particle capture (effectiveness varies, 30-60%)

Table 1. The Expected Pollutant Reduction Targets for APTA Filter System shows that APTA filtration system's multi-layer design incorporating HEPA filters, zeolite, silica gel, SAP sand, and dust cotton filters offers an optimized approach to addressing the complex pollutant profile characteristic of incense stick manufacturing. This method is superior to other filtration strategies for several reasons:

1. Comprehensive Pollutant Capture: Unlike single-layer or single-function filters, APTA's combination integrates physical filtration (HEPA and dust cotton) and chemical adsorption (zeolite, silica gel, SAP sand), enabling effective removal of both particulate matter ($PM_{2.5}$ and PM_{10}) and toxic heavy metals (manganese and lead), alongside volatile organic compounds.
2. High Efficiency and Specify: HEPA filters ensure near-complete capture of fine particulates ≥0.3 microns (≥99.97%), which are a major health risk during incense burning. Zeolite's high surface area and ion-exchange functionality specifically adsorb heavy metals more effectively than generic filters.
3. Humidity and VOC Control: Silica gel and SAP sand layers manage moisture and adsorb VOCs prevalent in incense smoke, which many conventional filters cannot address simultaneously with particulates and metals.
4. Layered Protection and Filter Longevity: Preliminary dust cotton filtration captures larger particles, preventing rapid clogging of the finer filters and extending operational lifespan, thereby enhancing consistency and cost-effectiveness.
5. Adaptability and Practicality: The design balances advanced filtration capability with materials and technologies that are accessible and scalable, suitable for small-scale industries like incense manufacturing.

APTA's multi-layer filtration system combines synergistic physical and chemical mechanisms to achieve superior removal of the diverse and hazardous pollutants released during incense stick production, outperforming simpler or single-function filtration methods.

Health Impact Assessment

The health outcomes for workers exposed to incense smoke will be evaluated through pre- and post-intervention surveys [4]:

1. Reduction in Respiratory Symptoms: Workers are expected to report a decrease in symptoms such as coughing, wheezing, and shortness of breath after implementing APTA and filtration systems
2. Long-term Health Benefits: The study aims to demonstrate a correlation between reduced exposure to manganese and lead and improved respiratory health among workers over time

Expected Outcomes

1. Reduction in airborne concentrations of manganese, lead, and PM2,5 and PM10
2. Improvement in health outcomes among workers, as indicated by reduced respiratory symptoms

APTA is specifically designed to target heavy metals and particulate matter emitted from incense burning. APTA purification methods focus on general air pollution reducing. APTA's formulation includes materials that enhance its capacity to adsorb particulate matter, manganese, and lead [12].

1. Targeted Adsorption: Research indicates that manganese and lead are prevalent in incense burning more than the quality standard. Every layer in APTA allows it to effectively remediate these metals so can reduce the concentration in the air.
2. Synergistic Filtration: The combination of HEPA filter and zeolite enhances filtration efficiency. HEPA filters are known their ability to capture particulate matter, while zeolite can adsorb volatile organic compounds and heavy metals due to its high surface area and ion-exchange properties. This synergistic effect is expected with better results than using any single filtration [13].

Anticipated Outcomes

The implementation of this study protocol is expected improve several outcomes [3]:

1. Reduction in Pollutant Levels: It is anticipated that using APTA compare with others, will lead significantly decrease of pollution in airborne. Previous studies have shown that PM levels from burning incense can decrease if used multi-layer technology.
2. Improved Indoor Air Quality: By lowering concentrations of harmful pollutants, the study aims to improve overall indoor air quality in incense manufacturing facilities and areas where incense is frequently burned. Enhanced air quality can contribute to better respiratory health outcomes among workers and users alike.
3. Health Benefits for Workers: The reduction of hazardous pollutants is expected to correlate with a decrease in respiratory symptoms among workers exposed to incense smoke. This aligns with findings from other studies indicating that prolonged exposure to incense smoke can lead to serious health issues, including respiratory diseases and increased cancer risk due to elevated levels of PM2.5 and VOCs.

Research Direction

Key priorities for advancing research on incense stick industry pollution and APTA filtration system include:

1. Detailed Emission Characterization

Conduct focused studies on emissions from various incense products, emphasizing and identify of harmful VOCs, including carcinogens like benzene and formaldehyde.

2. Longitudinal Health Monitoring
   Implement regular health assessments for incense workers paired with frequent exposure monitoring to evaluate chronic or acute disease.
3. Filtration System Optimization
   Explore and enhance APTA multi-layer by testing combinations of filtration media for a significantly decrease of heavy metals and VOC. Not only it, but also increase the air quality
4. Ventilation Air Circulation
   Evaluate ventilation in the incense stick production that can reduce indoor pollutant concentrations from air circulation.
5. Public Awareness and Policy Advocacy
   Promote education for all workers to use personal protective equipment when production running and support policies that regulate emissions to protect their health.

4 Conclusion

This study protocol highlights a proactive approach to filter and remediate indoor air pollution caused by the incense stick industry. The anticipated outcomes emphasize significant improvements in air quality and substantial health benefits for workers which exposed to harmful emissions such as manganese, lead, and particulate matter. APTA project has the potential to decrease air pollution from the incense stick industry and increase air quality based on WHO standard. Using APTA could establish a new multi-layer innovation that contains HEPA filter, zeolite, silica gel, SAP sand, and dust cotton filter. These multi layers can remediate particulate matter, manganese, and lead as a residue from incense stick industry.

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