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Design And Construction of a Mobile Dust Catch Using Wet Scrubber Technology in a Wood Factory

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***Abstract*— The wood industry generates significant airborne dust and wastewater that threaten human health and the environment. This study developed a mobile dust collector using a wet scrubber combined with electrocoagulation (EC) and filtration to control air and water pollution in a wood factory. Dust was sampled in the cutting and sanding sections using a High Volume Air Sampler, while wastewater was treated in a 55 L EC tank equipped with aluminum and iron electrodes. The wet scrubber removed 73.32% of dust in the cutting process and 69.86% in sanding, showing lower performance in capturing finer particles. In wastewater treatment, EC alone reduced Total Suspended Solids (TSS) from 440 mg/L to 250.55 mg/L (43.06%). Filtration further decreased TSS to 189.45 mg/L (56.93%). With the addition of 200 mg/L PAC, TSS dropped to 40 mg/L, achieving 87.50% efficiency, indicating that the hybrid system significantly improved removal performance. The results demonstrate the feasibility of compact, mobile technology for simultaneous dust and wastewater treatment with reduced chemical use. This integrated system is suitable for small- and medium-scale wood industries, offering practical advantages in mobility, operational flexibility, and dual-pollutant control.**

Keywords-- Electrocoagulation, Filtration, PAC, TSS, Wet scrubber, Wood dust.

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I. Introduction

Particulate matter (PM) in the atmosphere is considered one of the most serious global occupational and environmental threats. The World Health Organization (WHO) estimates that long-term exposure to fine particles ($PM_{2.5}$) causes about 4.2 million premature deaths every year, mainly related to cardiovascular and respiratory illnesses [1]. The health risks increase with prolonged exposure, particularly in industrial workplaces where particulate concentrations often exceed ambient air quality standards [2]. In Southeast Asia, industrial emissions account for more than 40% of PM pollution, with woodworking being a notable contributor [3].

In Indonesia, the woodworking industry holds a significant role in the economy, providing raw materials for furniture, construction, and export markets. However, the processes of sawing, sanding, milling, and cutting release substantial amounts of wood dust into the air [4]. The particle size distribution varies greatly, from coarse particles (>100 μm) to respirable PM_{10} and ultrafine $PM_{2.5}$, which can remain airborne for extended periods [5]. Fine wood dust is particularly dangerous because it can bypass nasal filtration, penetrate deep into the alveoli, and cause chronic bronchitis, asthma, and even nasal adenocarcinoma [6], [7]. Wood dust is identified as a Group 1 human carcinogen by the International Agency for Research on Cancer (IARC), supported by extensive evidence of its carcinogenic impact on humans [8]. Occupational exposure limits (OEL) for wood dust vary between countries. According to the American Conference of Governmental Industrial Hygienists (ACGIH), the threshold limit for hardwood dust is 1 mg/m³ [9]. In contrast, the Indonesian Ministry of Manpower Regulation No. 5/2018 stipulates a maximum limit of 5 mg/m³ for total workplace dust [10]. Field surveys have reported that in small to medium woodworking facilities in Indonesia, dust concentrations during sanding can exceed 10 mg/m³, far surpassing the regulatory limit [11].

Beyond airborne hazards, woodworking operations also generate dust-laden wastewater, especially in facilities using wet dust suppression or cleaning processes [12]. The wastewater typically contains high levels of Total Suspended Solids (TSS), turbidity, and organic matter. If discharged untreated, these pollutants can cause sedimentation, oxygen depletion, and ecosystem degradation in receiving water bodies [13]. In Indonesia, wastewater quality standards are regulated under the Ministry of Environment and Forestry Decree No. P.68/2016, which specifies maximum allowable limits for TSS, Chemical Oxygen Demand (COD), and pH [14].

Dust control technologies for the woodworking industry can be broadly classified into dry systems and wet systems. Dry systems, such as cyclone separators, bag filters, and cartridge collectors, are effective for larger particles but often have lower efficiency for $PM_{2.5}$ due to the limitations of inertial separation [15]. Wet scrubbers, on the other hand, utilize liquid droplets to capture airborne particles through inertial impaction, interception, and Brownian diffusion, making them more

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effective for fine particulates [16], [17]. Several studies have demonstrated wet scrubber efficiencies of over 90% for PM_{10} under optimized operating conditions [18]. However, one drawback of wet scrubbers is that they generate wastewater containing the captured particulates, which requires subsequent treatment [19].

For wastewater treatment, electrocoagulation (EC) has gained attention as a sustainable alternative to conventional chemical coagulation. In EC, coagulants are generated in situ by dissolving sacrificial electrodes (e.g., aluminum or iron) under direct current, releasing metal ions that neutralize particle charges and promote aggregation [20], [21]. EC offers advantages such as lower chemical usage, reduced sludge volume, and ease of automation Studies have shown that EC can achieve 70–95% removal of TSS from various industrial wastewaters, depending on electrode configuration, current density, and reaction time [23], [24]. However, most existing studies focus on stationary treatment plants; the integration of EC into a mobile dust control system is still limited in literature.

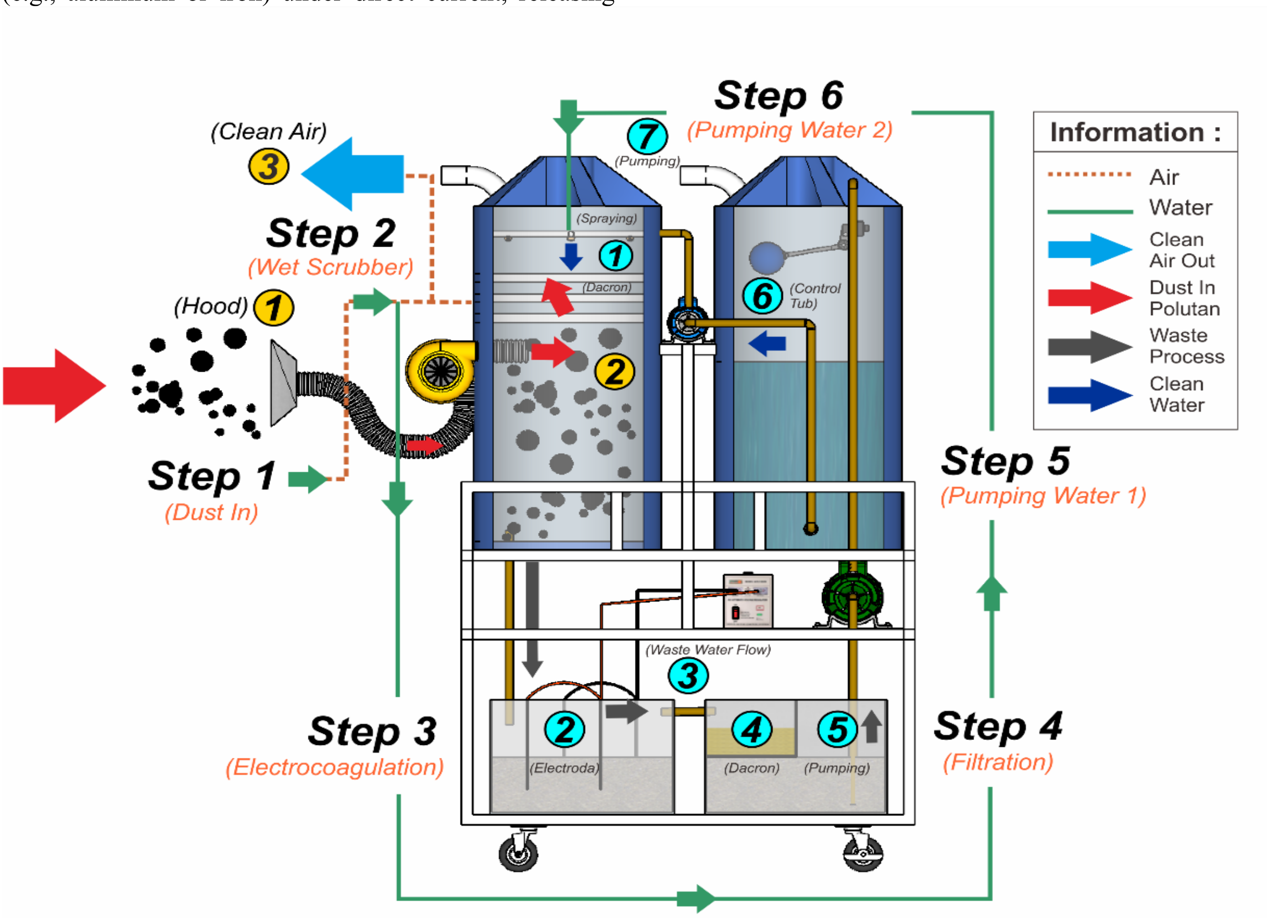

Figure. 1. Process flow diagram of the mobile dust collector with wet scrubber and electrocoagulation system

TABLE 1.
DUST CONCENTRATION MEASUREMENT RESULTS

Location	Dust concentration (mg/m³)	Quality standard threshold limit (mg/m³)
Cutting	413.33	150 (Decree of the Minister of Environment No. 45/1997, Indonesia)
Sanding	2453.33	150 (Decree of the Minister of Environment No. 45/1997, Indonesia)
Control	0	-

A. Problem Definition

Wood processing activities, including cutting, sanding, and milling, generate significant amounts of airborne dust and dust-laden wastewater [3], [4]. Airborne dust particles, particularly PM_{10} and $PM_{2.5}$, can penetrate deep into the human respiratory tract, causing chronic respiratory illnesses, skin irritation, and increased cancer risk [5], [6]. Simultaneously, dust particles carried into wastewater streams increase TSS concentrations, which, if untreated, degrade water quality and harm aquatic ecosystems [7].

In Indonesia, the Ministry of Manpower Regulation No. 5/2018 specifies a maximum allowable airborne dust concentration of 5 mg/m³ in workplaces [8]. However, on-site measurements in several wood processing facilities have shown dust levels exceeding this threshold, especially during high-intensity operations such as cutting and sanding. Conventional dust control systems, such as cyclone separators, are effective for larger particles but exhibit poor performance in capturing fine particulates smaller than 10 µm [9].

Furthermore, wastewater generated during wet dust suppression or cleaning processes often contains high TSS levels far above permissible discharge standards necessitating additional treatment before disposal [7]. Existing treatment methods, such as sedimentation or chemical coagulation alone, require large space, high chemical usage, and maintenance efforts [12]. Therefore, there is a need for a compact, mobile, and integrated system capable of reducing both airborne dust and wastewater TSS efficiently within operational constraints.

B. Proposed Solution

To address the above challenges, this research proposes the design, fabrication, and testing of a mobile wet scrubber system integrated with electrocoagulation for wood dust control. The proposed system operates in two stages:

1) Airborne Dust Control via Wet Scrubber
   a) The scrubber uses water sprays and packing materials to enhance particle capture through inertial impaction, interception, and diffusion [10], [11].
   b) The mobile configuration allows the unit to be positioned close to dust sources, minimizing particle dispersion.
2) Wastewater Treatment via Electrocoagulation
   a) Dust-laden water from the scrubber is treated in a compact electrocoagulation tank using alternating aluminum and iron electrodes to generate coagulants in situ [12], [13].
   b) The process promotes particle destabilization and aggregation, followed by removal through filtration using polypropylene and dacron media for final polishing.

The integration of these two processes into a mobile platform offers several advantages:

1) Dual pollutant removal (airborne and waterborne particulates) in a single unit.
2) Mobility for flexible deployment at different dust-generating points.
3) Reduced chemical usage compared to conventional chemical coagulation.
4) Compact footprint suitable for small to medium-sized industrial facilities.

This study evaluates the performance of the proposed system through field trials, focusing on dust removal efficiency in cutting and sanding operations, as well as TSS reduction in the scrubber wastewater, both with and without the addition of Poly Aluminium Chloride (PAC).

II. Method

A. Research Location and Equipment

The research was conducted at a wood processing facility producing high levels of airborne dust and dust-laden wastewater. Two primary operational points were selected for measurement:

1) Cutting Section – High-intensity sawing and shaping operations generating coarse and fine dust.
2) Sanding Section – Continuous sanding processes generating fine PM_{10} and $PM_{2.5}$ particles.

The experimental setup included:

a) Mobile Wet Scrubber Unit – Designed and fabricated by the researcher.
b) High Volume Dust Sampler (HVDS) – For airborne dust concentration measurement.
c) Electrocoagulation System – Equipped with DC power supply (10 A, 12 V).
d) Filtration Unit – Using polypropylene and dacron filter media.
e) ater Quality Testing Kit – For TSS, turbidity, pH, and COD analysis following APHA standards.

B. Design and Construction

1) Wet Scrubber Design
   a) Type: Packed column wet scrubber.
   b) Packing Material: PVC packing with a high surface area to volume ratio to enhance dust-water contact.
   c) Column Dimensions: Height and diameter calculated to achieve adequate contact time, using:

$$Z = NT \times \text{HETP} \quad (1)$$

   where N_T is the number of theoretical stages, and HETP is height equivalent to a theoretical plate.
   d) Operating Principle: Counter-current contact between dust-laden air moving upward and scrubbing liquid moving downward, enabling particle capture through inertial impaction, interception, and diffusion.
2) Blower System
   a) Centrifugal blower powered by an electricmotor.
   b) Airflow rate (Q) determined by:

$$Q = 1.4 \times P \times V \times D \quad (2)$$

   where P is hood perimeter (m), V is face velocity (m/s), and D is distance from the dust source(m).
3) Electrocoagulation Tank
   a) Capacity: 55 L.
   b) Electrodes: 4 aluminum and 4 iron plates (20 × 25 cm) with 3 cm spacing, arranged alternately for enhanced coagulation efficiency.
   c) Total Effective Surface Area: 0.8 m².
   d) Power Supply: DC 10 A, 12 V.
   e) Mechanism: During electrocoagulation, the sacrificial electrodes release Al^{3+} and Fe^{2+} ions into the solution, which neutralize particle charges and promote the formation of aggregates.
4) Filtration Unit
   a) Media: Polypropylene and dacron layers (15-20 mm thickness).
   b) Function: Post-treatment polishing to further reduce TSS and turbidity.

C. Experimental Procedure

1) Airborne Dust Removal Test
   a) HVDS positioned at the inlet (before scrubber) and outlet (after scrubber).
   b) Sampling duration: 60 minutes per point.
   c) Sampling flow rate: ±1.1 m³/min.
   d) The dust concentration was calculated based on the difference in filter weight measured before and after the sampling procedure. The TSS were analyzed according to APHA 2540D by filtering the sample through a pre-weighed filter, followed by drying at 103–105°C and reweighing the filter.
2) Wastewater Treatment Test
   a) Wastewater from the scrubber collected into the electrocoagulation tank.
   b) EC system operated for 24 minutes retention time.
   c) Samples taken at three points: raw influent, post-electrocoagulation, and post-filtration.
   d) Additional test with PAC (200 mg/L) to compare with chemical coagulation.

D. Measurement and Analysis Methods

1) Airborne Dust Concentration
   a) Calculated gravimetrically:

$$\eta_{\text{dust}} = \frac{C_{\text{in}} - C_{\text{out}}}{C_{\text{in}}} \times 100\% \quad (3)$$

where C_{in} and C_{out} are inlet and outlet concentrations (mg/m³).

2) TSS Measurement
   a) Following APHA 2540D: filtration through pre-weighed filter, drying at 103–105°C, and weighing.
   b) Efficiency:

$$\eta_{\text{TSS}} = \frac{TSS_{\text{in}} - TSS_{\text{out}}}{TSS_{\text{in}}} \times 100\% \quad (4)$$

III. Results and Discussion

A. Airborne Dust Removal Performance

Field tests were conducted to measure the efficiency of the mobile wet scrubber in removing airborne dust at the cutting and sanding sections. The measured inlet and outlet dust concentrations, along with removal efficiencies, are presented in Table 2.

TABLE 2.
DUST CONCENTRATION BEFORE AND AFTER TOOL USE

Location	Before Tool (mg/m³)	After Tool (mg/m³)	Quality Standard (mg/m³)	Efficiency (%)	Status
Cutting	387.26	103.30	150	73.32	qualify
Sanding	479.2	144.34	150	69.86	qualify
Control	0	0	-	-	-

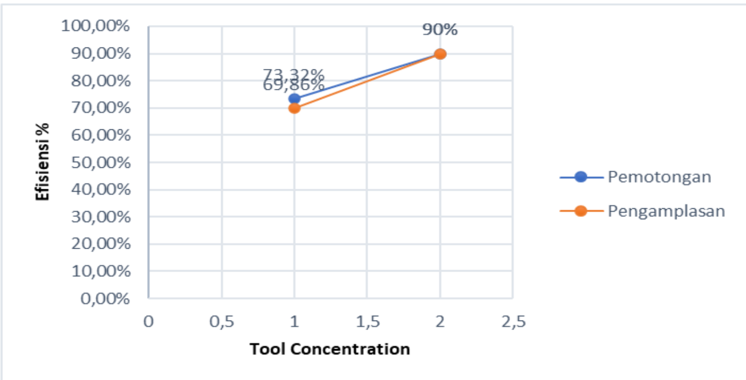

Figure. 2. Comparison of actual removal efficiency vs target 90%

The cutting section achieved a slightly higher efficiency (73.32%) compared to sanding (69.86%). This difference can be attributed to particle size distribution; cutting generates larger particles that are easier to capture via inertial impaction, while sanding produces finer particles that require higher contact efficiency for removal [9], [10].

The system's removal efficiency, although slightly below the 90% target, aligns with reported efficiencies for similar wet scrubber applications handling mixed particle sizes [11]. **Figure 2.** illustrates the comparison between measured and target efficiencies.

B. Wastewater Treatment Performance

The electrocoagulation system was evaluated for its ability to reduce TSS from the dust-laden water collected in the wet scrubber. Table 2. summarizes the TSS reduction results at different treatment stages.

TABLE 3.
TSS REMOVAL PERFORMANCE

Treatment Stage	TSS (mg/L)	Removal Efficiency (%)
Raw Influent	440.00	–
Post-Electrocoagulation	250.55	43.06
Post-Filtration	189.45	56.93

The EC process alone achieved a 43.06% TSS reduction, and the combination with filtration increased the efficiency to 56.93%. These results indicate that while EC effectively destabilizes and aggregates suspended particles, The filtration stage provides an additional polishing step, ensuring that the treated water meets the required quality standards [12], [13].

C. Effect of PAC Addition

A separate test was conducted to evaluate the effect of adding Poly Aluminium Chloride (PAC) at a dosage of 200 mg/L. The results are shown in Table 4.

The addition of PAC significantly improved TSS removal to 87.50%, highlighting the potential of combining EC with a small dose of chemical coagulants to achieve high treatment performance, especially for fine particles that are difficult to settle by EC alone [12].

D. Comparative Discussion

The integrated mobile wet scrubber electrocoagulation system demonstrated:

1) Airborne dust removal efficiency comparable to standard fixed wet scrubbers, which typically achieve 70–95% efficiency depending on particle size [10], [11].
2) TSS reduction in wastewater consistent with reported EC performance ranges of 40–90% depending on operational conditions [12], [13].

TABLE 4.
TSS REDUCTION WITH PAC

Treatment Condition	TSS (mg/L)	Removal Efficiency (%)
Raw Influent	320.00	–
With PAC (200 mg/L)	40.00	87.50

The system's mobility allows deployment at multiple dust sources without the need for complex ducting, reducing installation costs and improving operational flexibility. Although the measured airborne dust removal did not reach the targeted 90%, optimization through increased packing height, water spray rate, or blower capacity may enhance performance.

In wastewater treatment, while EC+filtration achieved 56.93% TSS removal, the significant improvement with PAC addition (87.50%) suggests that hybrid approaches can be considered when higher removal efficiencies are required.

IV. CONCLUSION

This research successfully designed, fabricated, and tested a mobile wet scrubber integrated with electrocoagulation for controlling airborne dust and treating dust-laden wastewater in a wood processing environment. The system was tested under real industrial operating conditions at two main dust generation points: cutting and sanding.

In terms of airborne dust reduction, the wet scrubber removed 73.32% of particles in the cutting process and 69.86% during sanding, indicating slightly lower efficiency in handling finer particles. These values, while slightly below the target of 90%, are within the performance range reported for similar wet scrubbers handling mixed particle sizes. The difference in removal efficiency between the two sections is primarily due to particle size variation, where cutting generates larger particles that are easier to capture, and sanding produces finer particles that are more challenging to remove.

In the wastewater treatment stage, when applied without additional treatment, the electrocoagulation system decreased the TSS from 440.00 mg/L to 250.55 mg/L, equivalent to a 43.06% reduction. After passing through the filtration stage, the concentration was lowered further to 189.45 mg/L, which represents 56.93% removal. With the addition of 200 mg/L of PAC, the TSS concentration decreased markedly to 40.00 mg/L. This corresponds to an efficiency of 87.50%, showing that combining EC with a small dose of chemical coagulant significantly enhances removal performance.

1) From a technical standpoint, Combining a mobile wet scrubber with electrocoagulation provides key benefits, such as simultaneous treatment of air and water pollutants, the ability to move the unit easily to different dust sources, a space-saving design suitable for small industries, and reduced reliance on chemical additives.
2) Operational flexibility through mobility, allowing deployment at various dust sources without the need for permanent ducting.
3) Compact footprint, suitable for small to medium-scale wood industries with limited space.
4) Reduced chemical consumption, with the option of PAC addition for higher removal targets.

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