Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2024, 11(3):1-11

Research Article ISSN: 2394 - 658X

Sustainable Industrial Practices: Creating an Air Dust Removal and Cooling System for Highly Polluted Areas

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DOI: https://zenodo.org/records/10776875

ABSTRACT

The conceptualization of the industrial air dust removal and air-cooling machine is rooted in the principles of fluid mechanics and the practical application of applied chemistry. Dust contamination in industry has a significant impact on both production safety and worker health. In recent years, wet-type and bag-type dust collectors with high efficiency have been widely utilized for dust removal. However, several issues exist, including high resistance and energy consumption. An air pump is utilized to draw in contaminated air from the severely polluted industrial area, guiding it into the central chamber. Within this space, the contaminated air undergoes purification as it passes through a plastic net, a transparent cloth, and water. Another air pump is subsequently engaged to extract the purified air from the chamber and reintroduce it into the industrial environment. The cooling effect is inherent in this process, given that the water temperature consistently remains lower than the air temperature. This dual-action system provides the industrial setting with both clean and cooled air, contributing to the efficiency of the air conditioning system.

Key words: *Conditioning system, Dust Control, Cooler, Dust Hazard*

INTRODUCTION

Every year nearly 5.5 million people around the world die directly or indirectly from air pollution according to the data of Global Burden Disease Projects. And the air pollution is more severe in the industrial area where air pollution is overlooked. But industries like jute mills, rice mills, flour mills, pesticides industries and even garments industries air pollution is in rampant March. Pollution can be caused by particulates, biological molecules, or other harmful gases into Earth's atmosphere, causing disease and damage to other living organisms. In contemporary industrial landscapes, where the demands of production often coexist with environmental stewardship, the need for sustainable practices has become increasingly paramount. The detrimental effects of air pollution on both the environment and public health have prompted a paradigm shift in industrial operations, propelling the development of innovative solutions. This discourse explores the intersection of sustainability and industrial engineering, focusing on the creation of an advanced Air Dust

Removal and Cooling System tailored for highly polluted areas. Industrial activities have historically been synonymous with emissions, particulate matter, and air pollutants, posing significant challenges to the ecological balance and human well-being. The adverse consequences of unchecked industrial pollution have propelled researchers and engineers to seek sustainable alternatives that mitigate environmental impact without compromising productivity. As industries grapple with the imperative to reduce their carbon footprint, the development of air dust removal and cooling systems emerges as a pivotal area for innovation, addressing both air quality concerns and energy efficiency. The envisioned Air Dust Removal and Cooling System, positioned as a beacon of sustainable industrial practices, is conceptualized upon a foundation of fluid mechanics principles and the application of applied chemistry. The system's design is inherently rooted in the ethos of environmental responsibility, aiming to curtail the deleterious effects of industrial air pollution in heavily impacted areas. This project not only aligns with the broader global commitment to sustainability but also acknowledges the imperative for industries to adapt and evolve in response to the growing climate crisis. At its core, the system operates through the seamless integration of fundamental engineering principles. An air pump, serving as the system's respiratory mechanism, adeptly draws in polluted air from the industrial hotspots, setting the stage for the transformative processes within the main chamber. This chamber, a nexus of purification and cooling, becomes the epicenter of innovation in combating air pollution. The polluted air undergoes a meticulous purification journey, traversing through a strategically positioned plastic net, a transparent cloth, and a water-based medium. The plastic net acts as an initial filter, capturing larger particulate matter and impurities, preventing their entry into subsequent stages of the purification process. Simultaneously, the transparent cloth serves as a finer filter, adept at capturing microscopic pollutants that have eluded the initial screening. They have described in a decent way how breast cancer and brain cancer with other disease diagnoses done with deep learning and machine learning algorithm [55-61]. The water component, a dynamic element in this environmental symphony, plays a multifaceted role. Beyond purification, water introduces a cooling effect to the air as it circulates through the system, an integral feature that enhances the overall efficiency and sustainability of the industrial processes. The purified and cooled air, now revitalized and free from the shackles of pollutants, is ushered out of the chamber through the orchestration of another air pump. This purified air is then delicately reintroduced into the industrial milieu, creating a cyclical and sustainable solution to the challenges posed by air pollution. The positive feedback loop of this system not only contributes to cleaner air within the industrial setting but also mitigates the environmental impact on the surrounding areas, fostering a harmonious coexistence between industry and nature. The sustainability of this Air Dust Removal and Cooling System extends beyond its immediate environmental benefits. By integrating seamlessly into existing industrial infrastructures, the system demonstrates adaptability and scalability, ensuring its applicability across diverse industrial contexts. Furthermore, the energy efficiency inherent in the system's design aligns with the broader goal of reducing carbon emissions, a cornerstone in the global pursuit of a sustainable future.

Hence, the imperative to reconcile industrial progress with environmental sustainability has led to the conceptualization of the Air Dust Removal and Cooling System. This innovative solution, grounded in fluid mechanics and applied chemistry, exemplifies the marriage of technological prowess and ecological mindfulness. As industries navigate the complex terrain of sustainable practices, this system emerges as a testament to the transformative power of engineering in creating a harmonious equilibrium between industrial progress and environmental preservation. Air pollution may come from reliable industries or natural sources. The atmosphere is a complex natural gaseous system that is essential to support life on planet Earth. Stratospheric ozone depletion due to air pollution has been recognized as a threat to human health as well as to the earth’s ecosystems. Sometimes it becomes impossible for the workers to work within the factory or industry for the pollutants. Ao and Lee showed that higher level of pollutant NO removal can be achieved using TiO_2/AC filter compared to TiO_2 filter [1]. Goswami described the theoretical background of the technology and results of its effectiveness against volatile organic chemicals, bacteria, spores, and dust mite allergens [2]. Khan and Ghoshal presented the available Volatile Organic Compounds control technologies and their appropriateness [3]. Exposure to primary and secondary pollutants depends on the complex interplay of many sets off actors and processes, including cleaning product composition, usage, building occupancy, emission dynamics, transport and mixing, building ventilation, sorptive interactions with building surfaces, and reactive chemistry [4]. Nazaroff et al. developed a new technology for dust control by foam and studied the relationship between the foaming agent concentration and liquid surface tension [5]. Bunker reviewed the examinations of the origins of shaped film cooling and summarized the extant literature knowledge concerning the performance of film holes [6]. Fleming et al. reported an investigation into the competitive position of systems for heating and cooling which made use of ambient air as the working fluid [7]. Kakaras et al. discussed the state of the art in applications for reducing the gas turbine intake air temperature and examined the merits from integration of the different air-cooling methods in gas-turbine-based power plant [8]. Amin et al. proposed a revised version of E-crane to reduce the waste of raw materials during unloading from the vessels, which indirectly decrease the amount of dust from air but our developed air dust removing machine can help to reduce air dust directly in more efficient way [51]. Mustaquim (2024) contributes to two distinct papers focusing on remote sensing methods in land surface interpretation, a critical aspect as we leverage this technology in the production of equipment for dust removal from the motor system [27,38]. Parvez et al. (2022) extensively discuss ergonomic factors influencing worker efficiency in production line balancing work, recognizing the importance of ergonomics in enhancing dust removal processes in various industries [13,14]. Rahman (2015) explores the impact of supplier selection on the electronics sector, acknowledging its significant role in product procurement, a factor of considerable influence when acquiring dust removal equipment for overall profit optimization [11]. Rahman and colleagues (2023) implement machine learning algorithms, particularly focusing on predicting performance in the healthcare operations sector, especially in scenarios involving substantial amounts of big data. This study is deemed highly beneficial, laying a foundation for potential expansions in future research endeavors [18,19]. Molla et al. (2024) provide substantial insights into COVID data in the United States and globally, offering valuable information for adhering to COVID protocols in the development and maintenance of rules and regulations for productivity optimization work in any environment and is crucial when removing dust from industry [23]. Noman et al. (2020) & (2024) undertake a noteworthy project on data retrieval approaches, with coding technology playing a pivotal role in our research, specifically when adjusting different parameters in production environments for the production [28,29]. Egan et al. made an experimental study on one of the smallest commercially available miniatures. Fans, suitable for cooling portable electronic devices, used in conjunction with both finned and finless heat sinks of equal exterior dimensions [9]. Chan et al. presented the construction and use of poly (dimethyl siloxane) microfabricated soft polymer devices with mass spectrometry for protein analysis [10]. Helming showed techniques of selective removal of ozone. From the air sample [48] and Linder et al. presented simple and reliable technique for storing and delivering a sequence of reagents to a microfluidic device [49]. Malmstadt et al. presented a method for forming these sub-5-nm-thick free- standing structures based on a self-assembly process driven by solvent extraction in a microfluidic channel [50]. In the paper that is why it is proposed air purification machine mechanism which deals with both purification and cooling of the industrial air. The mechanism here is used is new and sustainable for long time uses.

METHODOLOGY

Industrial air dust poses a significant challenge for industries, prompting researchers to explore various solutions. In contemporary technology, it is imperative that the entire process be either semi- or fully automated. The pioneering work by Eisert and Pawliszyn introduced the initial steps towards developing an automated SPME-HPLC system (Eisert & Pawliszyn,) [53]. The study of total gaseous mercury concentrations in Guiyang, China, revealed a substantial elevation compared to global background values. The primary atmospheric source of this increase was attributed to coal combustion, encompassing both industrial and domestic usage [47]. In alignment with modern practices, the present study also operates the entire process in a semi-automated format. The ensuing research is dedicated to exploring methods for controlling dust [52]. Ullah et al. (2024) utilize value stream mapping with a robust mathematical process, offering utility in research, especially in scenarios where extensive vehicle production is essential for production and manufacturing work, and dust removing is one of them [15]. Bazgir et al. (2023) interprets security system and IoT in a cloud system, which is utilized in our paper for further improvement [35]. Buian et al. (2024) and Iqtiar et al. (2024) describe in their paper regarding production and parking of car-related issues with sensor technology. Also, they describe manufacturing operations with new technology that impacts significantly for production works during the dust removal [36,39,40,43,44]. Ahmed et al. describes how brain tumor classification works, and it is one of the consequences of dust absorb impact when a person takes so much dust from the industry [46]. Rahman et al. (2023) describes how line balancing works in production environments and how the efficiency and associated cost are related to the overall profit of a company, and we have used this useful information regarding simulation optimization based on different scenarios for production line optimization works in our research methodology specifically when we are going to set the whole system in dust removing structure [12].

Research on dust control methods:

Table 1: Research on dust control methods

No.	Dust control method	Main application sites
1	Ventilation for dedusting	Blasting working face, mining working face, and roadway
2	Sealed dedusting	Workplace for ore drawing, unloading, crushing, screening, and transportation
3	Spray dedusting	Blasting working face, mining working face, roadway, ore drawing, unloading, crushing, screening, transportation, loading, and road surface
4	Dust suppressants	Rock drilling, blasting, and road surface
5	Dust collectors	Workplace for mining, ore drawing, unloading, crushing, screening, and transportation
6	Curtain dust isolation	Mining face and roadway

Working Principle

The housing on the left side of the wooden frame accommodates a 220 Volt AC air pump capable of extracting 233 liters of air per minute from the industrial vicinity. However, in practical application, the air volume and pump speed are excessively high. To address this, a regulator is integrated in series with the air pump to diminish and regulate the speed as needed. One end of the air pump is connected to a PVC pipe to draw in dusty air from the industrial environment, utilizing the deflation port of the air pump. On the other hand, the inflation port is connected to a plastic pipe to channel the air into the water chamber. Ullah and colleagues (2023) and (2024) eloquently present insights in four distinct papers addressing manufacturing excellence, operational scheduling, and equipment efficiency. These contributions hold paramount importance for our industry's dust removal process, establishing a cohesive connection [20,22,24,30]. Rahman et al. (2023) delves into the significance of cryptocurrency systems, particularly in the electronics sector, influencing the selection of production efficiency during the dust removal procedure [17,30]. In this case authors describe sentiment analysis and real time scenarios with predictive simulation modelling software that can do highly secured encryption for real-time speech signals and can ensure safety during nuclear power reactor [61-68]. Fayshal et al. (2023) emphasize environmental factors and safety risk assessments, significantly influencing considerations for dust removal work in any industry [25,32,54]. Kamal et al. (2019) showcase evidence of RFID technology for warehouse management through an Android application, highlighting its profound impact on the electronics industry, which is crucial for future study [45]. Shakil et al. (2013) offer an informative process flow chart for a jute mill, enriching industry data that has a substantial impact on dust removal work in any type of industry [21]. Hossain et al. (2023) discuss electricity generation from moving vehicles, proposing its potential application for ensuring machine continuity in a factory, aligning with the objectives of our motor section work for the dust removal system [16]. Molla et al. (2023) & (2024) underscore the importance of medical textiles with plantable and implantable options, serving as a focal point for the future extension of our production work [31,37].

Figure 1: Flow chart of working principles for Industrial Air Dust Removing and Air-Cooling Machine

1. The central housing of the frame accommodates a chamber comprising water, plastic netting, and transparent fabric. This chamber facilitates a three-step air purification process. Initially, the dusty air entering from the intake port is directed into the water, causing the dust particles to react and submerge in the water. Additionally, as industrial air tends to be hot, the interaction with the cooler water results in the air being effectively cooled during this phase. Subsequently, the air traverses through the plastic net, capturing any vapors present in the process. Finally, the last filtration stage involves the transparent fabric, ensuring that purified air is released through the chamber's exit.
2. The housing on the right side of the wooden frame hosts an air pump that operates as an AC unit, drawing in the purified air from the upper section of the chamber. Subsequently, the cooled and purified air is released into the industrial environment. The regulator affixed to the air pump allows for the control of inflation speeds, providing flexibility in managing the airflow. It is crucial to carefully choose the location for setting the inflation nozzle, as improper placement may contribute to additional air contamination. Therefore, it is imperative that the chosen setting for the nozzle is free from dust to prevent any further air pollutants.

System Components

The components employed in the industrial air dust removal and air-cooling machine may not all meet optimal standards. However, for the purposes of the prototype, they can be deemed satisfactory, considering the scale of the machine miniature. The industrial air dust removal system is meticulously crafted, incorporating essential components to ensure optimal functionality. The core components required for this system are strategically selected to form a robust and efficient dust removal apparatus. At the heart of the setup are three electric air pumps, meticulously chosen for their capacity to effectively extract air from the industrial environment. These air pumps serve as the driving force behind the entire dust removal process, ensuring a continuous flow for effective purification. To regulate and control the air pump's performance, three controllers, also known as regulators, are incorporated into the system. These regulators play a crucial role in adjusting the speed and volume of the air pumps, providing flexibility in managing the airflow and optimizing the dust removal process. The transportation of air within the system is facilitated by three meters of polyvinyl chloride (PVC) pipes. These pipes act as conduits, guiding the air through the various stages of the dust removal mechanism. Additionally, a net made of durable plastic material, measuring 0.550 by 0.60 meters, is strategically placed within the system. This plastic net serves as a filter, capturing impurities and preventing them from progressing further. The electrical infrastructure of the dust removal formation is supported by 2000 grams of galvanized iron (GI) electric wire. This wiring ensures a reliable and secure connection, maintaining the integrity of the electrical components within the system. Two transparent fabric materials are introduced into the setup, serving as the final filtration stage. These fabrics act as barriers, allowing only purified air to pass through while trapping any remaining particles or impurities. The entire structure is supported by a robust timber framework, providing stability and a secure foundation for the components. This timber structure ensures the proper alignment and integration of each component, contributing to the overall effectiveness of the industrial air dust removal system. In essence, dust removal formation is a well-thought-out assembly of components, meticulously chosen and integrated to create a comprehensive system capable of efficiently purifying industrial air from dust particles. This setup exemplifies a careful balance of functionality and durability, addressing the challenges posed by industrial air dust with a systematic and effective approach as shown in below table 1.

Table -1 Parts & Equipment of Industrial Air Dust Removal

Parts requirements	Quantity
Air pump (electric)	3
Controller (Regulator)	3
Polyvinyle chloride pipe	3 meter
Net (Plastic)	0.550*.60 m
Electric wire (GI)	2000 gram
Fabric (transparent)	2
Timber structure	2

Figure 2: Industrial Air Dust Removing and Air-Cooling Machine

The control method employed in the dust removal formation is a pivotal aspect of ensuring efficiency, adaptability, and responsiveness to varying industrial conditions. At the heart of this control mechanism are the three regulators or controllers integrated into the system. These regulators play a crucial role in managing the performance of the electric air pumps, offering precise control over the speed and volume of air extraction. The controllers are strategically positioned to regulate the operation of each air pump, enabling the system to adapt to fluctuating dust levels within the industrial environment. This adaptability is crucial, considering that dust concentrations may vary based on production activities, atmospheric conditions, or other external factors. By allowing for adjustable settings, the control method ensures that the dust removal formation can cater to the specific needs of the industrial setting it operates in. Additionally, the inclusion of regulators provides an element of automation to the system. The ability to adjust the speed and volume of air pumps ensures an optimized dust removal process without requiring constant manual intervention. This automation not only enhances operational efficiency but also contributes to energy conservation by tailoring the system's performance to the actual dust load. Furthermore, the control method encompasses safety measures. By incorporating regulators, the system can be configured to shut down or reduce its operation in the event of excessive dust levels or irregularities, preventing potential damage to components and ensuring the longevity of the equipment. The integration of a control method in the dust removal formation demonstrates a commitment to precision and effectiveness. This approach not only addresses the immediate need for dust removal but also ensures that the system is adaptable, automated, and equipped with safety features, making it a reliable solution for sustained and efficient industrial air purification as shown at below figure 3.

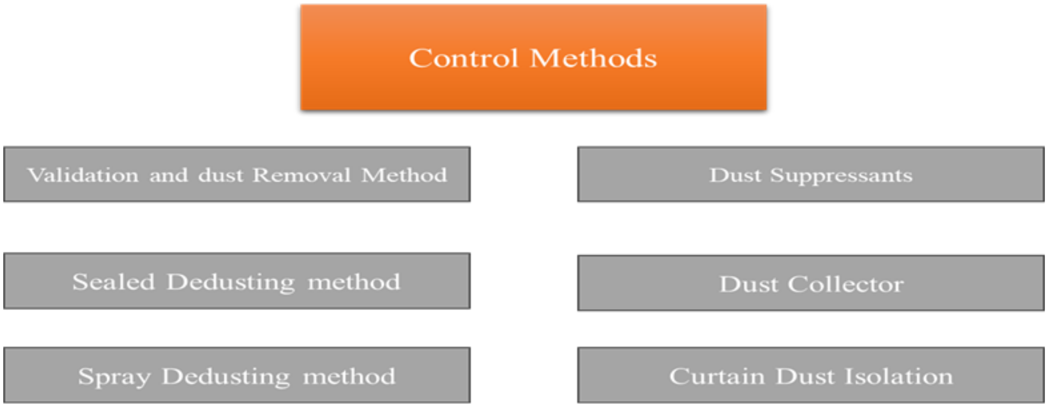

Figure 3: Control Method for dust pollution

RESULTS AND DISCUSSION

The experimentation revolves around the purification and cooling of air within industrial settings. Water serves as the solvent, and its composition can be adjusted based on the specific pollutants emitted by different industries. While water is well-suited for industries releasing organic pollutants like jute or rice mills, industries emitting chemical or heavy metal pollutants may necessitate altering the solvent—for instance, using alkaline solvent for acid pollutant particles and vice versa. Further research is essential to enhance our understanding of the optimal solvent for various applications. The current chamber design lacks a water change port, requiring a customized design for efficient water circulation. The air pump's efficacy is compromised due to inadequate performance, and future iterations should consider using more robust air pumps for prolonged operation. Introducing a sensor within the chamber to monitor air pressure and automatically shut down in cases of excess pressure could enhance the system in subsequent designs. The current prototype would benefit from improved airtightness, ensuring optimal machine performance. As the experiment progresses, these considerations and potential enhancements will contribute to the refinement and advancement of the model.

CONCLUSION

In conclusion, the development and experimentation of a sustainable air dust removal and cooling system for highly polluted industrial areas marks a significant stride toward addressing environmental challenges. The utilization of water as a versatile solvent, subject to customization based on specific industrial pollutants, underscores the adaptability of the system. Industries emitting organic pollutants, such as jute or rice mills, can benefit from water as the solvent, while those releasing chemical or heavy metal pollutants can tailor their solvent choice accordingly. The experimentation phase has brought to light crucial insights for future enhancements. The absence of a water change port in the current chamber design highlights the need for a more sophisticated and customized structure to facilitate efficient water circulation. Additionally, the identified weakness in the air pump's strength necessitates the incorporation of higher-performing air pumps in future iterations for prolonged and effective operation. Looking forward, the integration of a sensor within the chamber to monitor air pressure presents an avenue for automated system control, enhancing overall efficiency. Furthermore, ensuring airtightness in the machine's design emerges as a crucial consideration for optimal performance. The presented system not only contributes to mitigating air pollution but also embodies a sustainable approach by utilizing water as a solvent and integrating features that enhance operational efficiency. The research highlights the importance of continual exploration and improvement in industrial practices to develop environmentally conscious solutions for highly polluted areas. As industries evolve, embracing sustainable technologies becomes imperative for the well-being of both ecosystems and communities.

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