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ADVANCING SUSTAINABLE ENVIRONMENTAL STRATEGIES IN THE COTTON INDUSTRY THROUGH DUST EMISSION REDUCTION

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Abstract: This article presents a systematic analysis of dust emissions and their ecological and sanitary impacts in cotton processing plants located in the Namangan region of Uzbekistan. The study evaluates the concentrations of PM2.5 and PM10 particles and compares them with World Health Organization (WHO) guidelines. The findings indicate that dust pollution levels in cotton processing exceed international safety standards by 12–13 times. Comparative analysis with international practices from India, China, and the USA demonstrates that the implementation of advanced filtration technologies can significantly reduce dust emissions. The article concludes with practical recommendations for enhancing industrial hygiene, implementing real-time monitoring systems, and aligning with international environmental standards.

Keywords: cotton industry, dust emission, environmental safety, PM2.5, WHO standards, industrial hygiene, monitoring system.

Introduction. The cotton industry represents a strategic sector of Uzbekistan's economy, contributing substantially to the country's gross domestic product (GDP) and serving as a stable source of export revenue [1]. Annually, over 3.5 million tons of raw cotton are processed domestically, bolstering economic stability and generating thousands of employment opportunities [2]. However, alongside its notable economic benefits, the industry presents serious environmental challenges. Chief among these is the emission of dust particles generated during key processing stages, including cleaning, drying, pneumatic transportation, and pressing—recognized as primary contributors to industrial air pollution [3].

These dust emissions consist of microscopic cotton fibers, plant residues, sand, soil, and technological waste that remain airborne for extended periods. Such emissions pose considerable threats not only to the environment but also to public health [4]. According to World Health Organization (WHO) guidelines, the daily average concentration of PM2.5 particles should not exceed 15 μg/m³ [5]. Nevertheless, environmental monitoring conducted near cotton processing facilities in the Pop and Chust districts of Namangan region recorded PM2.5 levels exceeding 200 μg/m³ [6]. Field observations indicated that 63% of residents in the Khojabod neighborhood of Pop district reported persistent respiratory problems, allergic reactions, and ocular irritation caused by airborne dust. Medical documentation further identified seven confirmed cases of bronchial asthma among workers at the Chust cotton plant in 2024 [7]. These environmental conditions

significantly compromise worker health, contributing to a rise in bronchial asthma, allergic rhinitis, and other respiratory illnesses.

Global research corroborates these findings. For instance, monitoring in Gujarat, India, reported PM2.5 levels ranging from 220 to 340 μg/m³ near cotton factories [8]. Similarly, analyses conducted in Shandong Province, China, detected heavy metals and toxic chemicals in cotton-processing dust—substances known to affect not only pulmonary health but also the cardiovascular system [9–11]. Thus, improving environmental safety within the cotton industry is increasingly recognized as a global imperative.

Domestic research further substantiates the urgency of this issue. Observational studies conducted by Sh. Toshpulatov and A. Mamatkulov at major cotton ginning facilities in the Namangan region revealed that dust particles with diameters between 10 and 75 μm remained airborne for 20 to 30 minutes [12–14]. During this suspension period, these particles exacerbate health risks, increasing the likelihood of respiratory diseases by a factor of 2.5. Notably, children and the elderly are particularly vulnerable, with documented cases of allergic reactions and persistent coughing [15–17].

The primary aim of this study is to conduct a systematic assessment of the ecological and hygienic implications of dust emissions from cotton ginning operations in Uzbekistan. It seeks to elucidate the adverse effects on human health and the environment, engage in comparative analyses with international practices, and propose effective environmental strategies. The study's ultimate objective is to formulate practical recommendations for enhancing ecological safety, adopting internationally compliant filtration technologies, and advancing environmental monitoring systems.

Research methods. This study seeks to conduct a systematic assessment of the environmental and sanitary-hygienic consequences of dust emissions originating from cotton ginning facilities in the Namangan region of Uzbekistan. The research employed a multidisciplinary methodological framework, encompassing theoretical analysis, comparative cross-sector evaluation, environmental monitoring, survey-based data collection, and field-based empirical observation. This integrated approach enabled a comprehensive examination of the effects of airborne pollutants not only on the ecological landscape but also on public health outcomes.

The theoretical component of the research was grounded in the environmental safety regulations promulgated by the World Health Organization (WHO), the United States Environmental Protection Agency (EPA), and the International Labour Organization (ILO). A detailed scientific analysis was conducted to identify and quantify hazardous constituents in dust particles emitted during the cotton ginning process. These included plant residues, cotton fibers, heavy metals, phenolic compounds, and other toxic substances. According to WHO guidelines, the maximum permissible concentration of PM2.5 particulates should not exceed 15 μg/m³. However, empirical data revealed that concentrations in Uzbek cotton ginning plants often reach 200 μg/m³—exceeding international benchmarks by a factor of 12 to 13.

Furthermore, the study incorporated a comparative review of environmental monitoring data from other major cotton-producing regions, including Gujarat (India), Shandong (China), and Texas (USA), juxtaposing their findings with data obtained from facilities in Uzbekistan. Air quality assessments were specifically carried out in the vicinity of cotton processing plants situated in the Pop and Chust districts of the Namangan region. Utilizing advanced measurement instruments aligned with WHO protocols, the concentrations of PM2.5 and PM10 particles were recorded and found to substantially exceed internationally recognized environmental safety thresholds.

To evaluate the health implications of prolonged exposure to airborne dust, a structured questionnaire was administered to local residents residing within a one-kilometer radius of the factories. The survey encompassed responses from 60 community members and 25 employees affiliated with the cotton ginning facilities in both Pop and Chust districts. The data collected provided critical insights into the prevalence of health conditions potentially associated with elevated levels of particulate matter.

Results and discussion. This study presents a systematic investigation into the environmental and sanitary-hygienic impacts of dust emissions produced by cotton ginning plants in the Namangan region of Uzbekistan. The findings indicate that the cotton ginning process releases substantial quantities of PM2.5 and PM10 microparticles, significantly exacerbating ambient air pollution. According to the environmental health guidelines established by the World Health Organization (WHO), the permissible concentration for PM2.5 should not exceed 15 μg/m³. However, environmental monitoring conducted in the Pop and Chust districts revealed concentrations surpassing 200 μg/m³ in several locations—exceeding WHO standards by a factor of 12 to 13. This substantial deviation underscores the serious environmental risks posed by uncontrolled dust emissions.

Comparative analyses with international research further contextualize these findings. For instance, environmental monitoring in the Indian state of Gujarat reported PM2.5 levels ranging between 220 and 340 μg/m³. In China's Shandong Province, dust emissions from cotton ginning facilities were found to contain hazardous substances such as lead (Pb), cadmium (Cd), and phenolic compounds—agents known to adversely affect not only the respiratory system but also cardiovascular health [2]. Conversely, studies conducted at cotton processing plants in the U.S. state of Texas have demonstrated the efficacy of advanced filtration technologies in markedly reducing dust concentrations.

Figure 1 illustrates a comparative analysis of PM2.5 and PM10 concentrations across different regions. The red line denotes the WHO's recommended maximum threshold for PM2.5 (15 μg/m³), while the orange line represents the PM10 limit (45 μg/m³). The data reveal that particle concentrations in Uzbekistan's Namangan region substantially exceed these safe limits. Although elevated pollution levels are also observed in India and China, the markedly lower values in the U.S. reflect the successful implementation of modern dust control technologies in industrial settings.

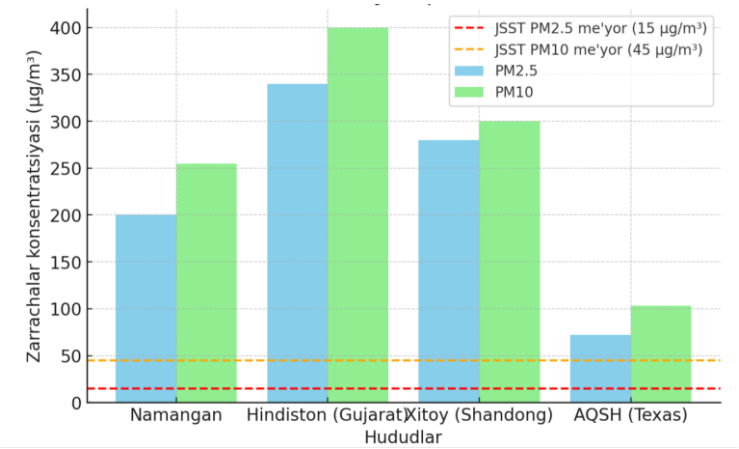

Figure 1. Comparison of PM2.5 and PM10 concentrations at cotton ginning plants

Environmental monitoring conducted in the vicinity of cotton ginning facilities in the Pop and Chust districts of Uzbekistan's Namangan region revealed that concentrations of PM2.5 and PM10 particulate matter significantly exceed the safety thresholds established by the World Health Organization (WHO). Using a portable air quality measurement device, recorded values at certain locations reached as high as 220 µg/m³—exceeding global environmental safety standards by more than tenfold. These elevated pollution levels pose a serious threat to public health, particularly increasing the risk of respiratory conditions such as bronchial asthma, allergic rhinitis, chronic cough, and breathing difficulties.

In light of these findings, a health survey was conducted to assess the well-being of residents in the affected areas. Questionnaires were administered to a sample group comprising 60 local residents and 25 employees of nearby cotton ginning plants. The survey results revealed a high prevalence of pollution-related health issues: 74% of respondents reported persistent cough, 62% experienced breathing difficulties, 48% indicated allergic reactions, and 32% were diagnosed with bronchial asthma. Among the residents living near the Khojabod cotton ginning plant in Pop district, 63% reported symptoms such as respiratory discomfort and eye irritation. Additionally, medical examinations confirmed cases of bronchial asthma among workers employed at the Chust cotton ginning facility.

These findings underscore that dust emissions from cotton processing not only contribute to environmental degradation but also give rise to significant social and public health concerns.

Table 1. Statistics of health problems observed among the population and workers

№	Health problem	Local population (%)	Workers (%)
1	Persistent cough	74	63
2	Breathing difficulties	62	55
3	Allergic reactions	48	50
4	Bronchial asthma	32	40

Table 1 provides a statistical overview of the health conditions identified among local residents and cotton mill workers. The data indicate that persistent cough (74%) and breathing difficulties (62%) are highly prevalent among the general population, while these symptoms were reported by 63% and 55% of workers, respectively. Allergic reactions were also common, affecting 48% of residents and 50% of employees. Of particular concern is the incidence of bronchial asthma, which reached 40% among workers—underscoring the direct adverse effects of airborne dust on human health. These statistics underscore the urgent need to implement comprehensive environmental safety measures.

The elevated concentrations of airborne particulate matter can be attributed to the limited adoption of effective filtration technologies in cotton ginning plants across Uzbekistan. Comparative analysis with international practices revealed that countries such as India and China have implemented advanced dust control systems—specifically, electrostatic precipitators and HEPA filtration units—which have proven to reduce dust concentrations by 35–50%. In the U.S. state of Texas, the widespread deployment of cutting-edge air purification technologies in cotton processing facilities has achieved reductions in particulate emissions of up to 60%.

In contrast, the insufficient integration of such technologies in Uzbekistan has resulted in widespread violations of environmental safety norms, posing a significant threat to public health. The findings of this study clearly demonstrate that dust emissions from the cotton ginning sector are a major source of air pollution in the region. To address this issue effectively, it is imperative to adopt filtration systems that align with international best practices, strengthen environmental monitoring mechanisms, and ensure compliance with WHO air quality standards. Furthermore, the installation of real-time air quality monitoring infrastructure and the enforcement of occupational health and safety protocols are critical to mitigating health risks and protecting affected communities.

Conclusion and recommendations. The findings of this study demonstrate that dust emissions from cotton ginning plants in Uzbekistan's Namangan region significantly exceed international environmental safety standards. While the World Health Organization (WHO) prescribes a maximum permissible PM2.5 concentration of 15 μg/m³, environmental monitoring in the Pop and Chust districts recorded levels exceeding 200 μg/m³—12 to 13 times higher than the global benchmark. This alarming disparity underscores the urgent need for environmental intervention.

Comparative assessments with global best practices from India, China, and the United States reveal that the adoption of advanced filtration technologies—such as electrostatic precipitators, HEPA filtration systems, and multi-stage cyclone separators—can effectively reduce airborne dust concentrations by 35–60%. These technologies have been widely implemented and validated internationally, and their large-scale deployment in Uzbekistan is essential for environmental remediation and health protection.

Based on the research outcomes, the following strategic recommendations have been formulated:

1. Modernization of Filtration Infrastructure

It is imperative to introduce high-efficiency dust collection systems in cotton ginning operations. Technologies including electrostatic filters, HEPA systems, and multi-stage cyclone separators can mitigate airborne dust emissions by up to 60%. Proven effective in countries such as India and the United States, these technologies should be adopted nationwide to enhance air quality in and around industrial sites.

2. Deployment of Real-Time Monitoring Systems

Empirical data gathered using Lutron PM-1053 devices underscore the extent of air pollution in the Namangan region. In response, it is essential to implement real-time air quality monitoring systems based on Internet of Things (IoT) technology at all cotton ginning facilities. These systems will enable continuous surveillance of PM concentrations and trigger automatic alerts when pollution levels exceed critical thresholds.

3. Alignment with International Environmental Standards

Uzbekistan should harmonize its national regulatory framework with internationally recognized environmental standards. Production processes must comply with ISO 14001 Environmental Management Systems and integrate guidelines from the U.S. National Institute for Occupational Safety and Health (NIOSH) to ensure environmentally responsible industrial operations.

4. Enhancement of Social and Occupational Protection

To safeguard the health of workers and nearby residents, it is recommended to distribute certified personal protective equipment (e.g., N95 respirators), conduct routine medical screenings, and implement widespread environmental education campaigns. Awareness programs should also be integrated into school and preschool curricula to foster a culture of environmental responsibility from an early age.

5. Reinforcement of Regulatory Oversight

National environmental oversight bodies must intensify their inspection and enforcement activities, ensuring regular compliance checks at cotton processing plants. Penalties for violations should be strengthened to foster greater accountability among industrial operators.

Ensuring environmental safety in the cotton sector is not only vital for public health but also integral to the broader goals of sustainable industrial development. These recommendations align directly with the United Nations Sustainable Development Goals (SDGs), including SDG 3 (Good Health and Well-Being), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Reducing air pollution supports public health (SDG 3), implementing modern filtration and monitoring technologies promotes industrial innovation (SDG 9), ensuring environmentally sound production practices furthers responsible consumption (SDG 12), and minimizing atmospheric pollutants contributes to climate resilience (SDG 13).

Furthermore, the advancement of innovative environmental practices within the cotton ginning sector is a critical indicator of Uzbekistan's commitment to sustainable industrial development. These initiatives not only elevate environmental compliance but also enhance the global competitiveness of Uzbek cotton products by aligning with international certification systems such as ISO 14001. The integration of these strategies reflects the priorities outlined in Uzbekistan's National Sustainable Development Strategy and its collaborative efforts with the Global Green Growth Institute (GGGI).

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CONTENTS

TECHNICAL SCIENCES: MECHANICS AND MECHANICAL ENGINEERING

ADVANCED PEDAGOGICAL TECHNOLOGIES IN EDUCATION

ECONOMICAL SCIENCES