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ANALYSIS OF METHODS FOR REDUCING AIRBORNE DUST CONCENTRATION IN COTTON PRIMARY PROCESSING ENTERPRISES

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Abstract
This study analyzes dust generation sources, existing collection systems, monitoring challenges, and modernization opportunities for improving air quality in cotton primary processing enterprises.

Keywords: Cotton processing; dust concentration; air pollution; dust collection systems; environmental protection; monitoring systems; mechatronic devices; industrial ventilation.

Introduction

Industrial dust can be classified according to various criteria: its effect on the human body (neutral or toxic), origin (organic, inorganic, or mixed), and physicochemical properties, including particle size, shape, density, hardness, solubility, adsorption capacity, electrical conductivity, and others. Among the wide range of dust characteristics, the most significant factors determining the nature of airborne particles and their hazard level to the environment and human health are particle shape and size distribution (dispersion).

The degree of particle dispersion is a key characteristic of dust emissions from both dust collection and sanitary-hygienic perspectives, as it determines the residence time of particles in the atmosphere (settling velocity) and the depth of their penetration into the human respiratory tract. During inhalation, larger dust particles are predominantly retained in the upper respiratory tract, from which they are gradually removed by mucus through expectoration. Fine particles, however, can penetrate directly into the lungs, where they remain deposited for long periods, leading to damage of pulmonary tissues and impairment of respiratory and circulatory functions. Furthermore, for an equal mass, fine particles possess a larger specific surface area in contact with lung tissue, making them more biologically active. It should be noted that industrial dust generally belongs to highly dispersed systems.

The shape of dust particles is also of considerable sanitary and hygienic significance. Particles with irregular, sharp, or angular shapes (such as metal and mineral dust) remain suspended in the air for longer periods and are more likely to penetrate the respiratory tract. Owing to their geometry, such particles may exert irritating or traumatic effects at points of contact, including the mucous membranes of the eyes, upper respiratory tract, and skin, thereby increasing their harmful impact on the human body. In addition, particle shape influences the settling velocity of dust particles.

The chemical composition of dust determines its biological effects on the human body. Based on chemical composition, dust can be divided into two principal groups: toxic and non-toxic. Toxic dust may cause acute or chronic poisoning when inhaled or otherwise absorbed, whereas non-toxic dust does not result in intoxication of the body even at relatively high concentrations and prolonged exposure durations.

The overall set of operations aimed at converting raw cotton into finished products is referred to as the technological process of primary cotton processing. This process includes drying and cleaning raw cotton in drying and cleaning departments, removing fine and coarse impurities in primary processing workshops, ginning, cottonseed delinting, and the primary processing of fibrous waste. During these operations, it is essential to preserve the natural physical and mechanical properties of cotton fiber and seeds while ensuring compliance with state standards and minimizing material losses. Proper organization of the primary processing process is therefore a decisive factor in achieving these objectives.

The technological process is implemented through a system of interconnected machines operating according to established schemes and strictly regulated modes determined by the condition and quality of both the incoming raw material and the processed products. In cotton processing plants, technological schemes are developed based on the characteristics of raw cotton, advanced industrial practices, and scientific research aimed at improving processing efficiency. These schemes ensure the proper organization of operations from cotton reception, storage, and transportation to the production of products meeting national quality standards.

One of the principal indicators of technological efficiency is the overall cleaning effect achieved by all machines integrated into the processing chain. In addition to cotton fiber, significant quantities of fibrous by-products, including fiber waste, regenerated cotton fiber, and lint, are generated and further processed into useful materials.

Environmental protection measures focus on the rational use of natural resources and the prevention of harmful impacts of industrial activities on nature and human health. A key aspect of environmental protection is the reduction of pollution through the implementation of waste-free technologies, efficient purification of wastewater and exhaust gases, and the introduction of closed-loop production systems.

The technological process of primary cotton processing is accompanied by significant emissions of dust from technological and transportation equipment into production facilities and the atmosphere. Dust accumulation contaminates workshops and factory premises, creating unfavorable conditions for workers and equipment operation. According to sanitary and hygienic standards, the permissible dust concentration in cotton processing facilities should not exceed 10 mg/m^3, while emissions released into the atmosphere should remain below 150 mg/m^3.

Dust generated during cotton processing consists of both organic and mineral fractions. The organic fraction includes crushed particles of cotton plant components and short fibers, whereas the mineral fraction consists mainly of soil, sand, and other impurities introduced during harvesting, transportation, and storage. At the initial stages of processing, particularly during transportation and cleaning, mineral dust predominates. In contrast, during ginning and linting operations, organic dust becomes the dominant component. The exhaust air of pneumatic transportation systems generally contains 10–20% organic dust and 80–90% mineral particles, whereas the exhaust air from linting systems may contain up to 80–90% organic dust.

Despite the importance of dust control, many cotton processing enterprises continue to use outdated and inefficient dust collection systems. The modernization of existing dust removal systems is complicated by limited installation space and the absence of reliable real-time dust monitoring technologies. Most currently available devices are designed for laboratory measurements and are unsuitable for continuous industrial monitoring. Therefore, there is a growing need for compact monitoring stations and mechatronic devices capable of continuously measuring and controlling dust concentrations in cotton primary processing enterprises.

Conclusions

1. The modernization of existing dust collection systems in cotton processing enterprises is often hindered by insufficient space for installing new equipment. As a result, many factories continue to operate obsolete and inefficient dust collectors, leading to significant environmental consequences.
2. Existing dust measurement devices are primarily intended for laboratory applications and do not provide continuous monitoring under industrial conditions. Consequently, there is a strong demand for mini monitoring stations and mechatronic systems capable of real-time determination and monitoring of dust concentration levels in cotton primary processing enterprises.

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