



Research article

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Dust atlas of construction works in point-pattern housing development

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Abstract. With the development of megacities, active construction is becoming a key factor in the deterioration of atmospheric air quality due to the release of fine particulate matter, such as PM_{0.5}–PM₁₀. These particles pose a significant environmental risk. Given the increasing demand for dense urban development, issues of air purification and environmental stability are coming to the fore. A thorough understanding of the physical and chemical characteristics of dust is fundamental to developing and implementing dust protection measures on construction sites, including the selection of suitable dust collectors. A new approach has been developed for the analysis of dust particles generated by construction work at various urban sites. As part of this approach, a dust atlas has been created that organizes and classifies the diverse types of construction dust, detailing their physical and chemical characteristics. The atlas is based on a unique methodology that enables the identification and description of the main properties of each type of dust encountered during construction operations. Each type of dust studied in this research was assigned its own specification, which includes both the analysis methodology and the identified characteristics of the dust. Documentation related to dust testing contains all the necessary information, including the type of dust, the method of data collection, the time of measurement, the materials used, and the results of dust analysis. For the study, dust samples were taken from the air during construction processes. The study of dust on construction sites revealed that particle size varies significantly, a phenomenon that cannot be attributed solely to measurement errors. These variations in dust particle size can be attributed both to the specific nature of the work performed and to external conditions, including changes in humidity and wind intensity.

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1. Introduction

Studies by Lumens & Spi [1] have shown an inextricable link between construction activity and dust formation. Dust particles in the air pose a serious threat to health, so their monitoring requires close attention [2]. At every stage of the construction process, whether it is the initial construction phase, its operation or dismantling, it is necessary to use resources efficiently and ensure personnel protection. An integrated approach to dust suppression plays a key role in ensuring environmental and industrial safety. From the start of preparatory work to the final cleaning of the site, it is critically important to comply with environmental regulations and safety requirements. The introduction of dust control methods is becoming a prerequisite for the protection of both humans and the ecosystem as a whole.

The construction industry makes a significant contribution to urban air pollution. Concreting, stone processing, preparation of building mixes and other operations on construction sites lead to the formation of microscopic dust particles. These particles, ranging in size from PM_{0.5} to PM₁₀, pose a serious threat to health [3, 4]. They are particularly dangerous for construction workers and residents of the surrounding

areas because if they enter the respiratory tract, they can provoke the development of various lung diseases. Loading of materials, excavation, plastering, and delivery of building materials – all these processes exacerbate the problem of air pollution in urbanized areas [5].

In 2016, Deborah Dickerson identified that construction activities, including drilling, excavation, and loading and unloading operations, are a source of significant dust pollution [6]. Ming Hu has established the equivalent risks for office staff and construction personnel during construction activities [7]. In 2017, a scientific group led by Jiang Zuo documented the negative effects of atmospheric dust pollution on the health of both office workers and construction workers [8]. It is necessary to create and use comprehensive monitoring and management methods to ensure the security of workers on construction sites, where dust pollution is widespread [9].

Protecting the population from the negative effects of construction work is becoming a critically important task in modern cities [10, 11]. A team of researchers led by Zezhou Wu has developed innovative ways to control dust on construction sites, which is especially important when building in cramped urban environments [12]. Experiments by a group of scientists led by Qiming Luo have revealed a serious problem: during construction operations, such as mixing concrete, processing it and working with marble, large-scale air pollution occurs [13]. The most alarming situation is observed when cutting bricks – the concentration of fine particles PM_{2.5} and PM₁₀ reaches values 60–100 times higher than the NAAQS (National Ambient Air Quality Standards) standards [14]. This problem is becoming particularly acute against the background of growing urbanization and increasing urban population density.

The problem of the spread of particulate matter in confined urban spaces has become the subject of close attention from the scientific community [15, 16]. A notable breakthrough in this area was made by a group led by Zhang Yisheng, who applied a combined research method: they combined computer simulations with experiments in a wind tunnel to study the behavior of dust on construction sites [17]. Successful results in solving the problem of air pollution caused by dust particles have been achieved by international scientific teams, including specialists from the USA, China, European countries, Korea, and the UK [18–21]. This innovative approach has allowed for a deeper understanding of the mechanisms of movement of construction dust in dense urban areas, which is especially important for megacities with high population density.

The problem of construction dust control has attracted the attention of many scientists who have proposed various solutions. Thus, a study by Sang-Woo Han and colleagues presented a hybrid model based on receptors for monitoring dust pollution [22]. Studying the characteristics of dust emissions during construction, the Bo Yu team analyzed their time parameters, intensity and concentration [23]. Optimization of the construction site layout using the MOPSO algorithm was proposed in Guowu Tao's work as a way to reduce dust pollution [24]. Special attention was paid to the protection of vulnerable groups of the population – Zachary M. Klaver and co-authors evaluated the effectiveness of HEPA PAF filters for air purification in the homes of elderly people living near construction sites [25].

The danger of construction dust to human health is confirmed by numerous scientific studies [26]. The Matthew Dietrich team has found that the chemical composition of dust particles entering the premises from construction sites poses serious risks to the public [27]. The specialists from the Russian Federation have also been actively studying this problem. A group of Russian scientists, including N. Sergina, D. Borovkov, V. Azarov, and A. Strelyaeva, discovered large-scale environmental violations during point-pattern housing development, especially in the context of air pollution by fine dust [28–31]. In densely populated urban areas, the problem of managing construction sites and controlling dust emissions is acute. The study revealed serious shortcomings in the implementation of anti-dust measures on construction sites.

The lack of a clear pollution control system in dense urban areas requires urgent measures and close attention from responsible authorities.

A deep understanding of the physical and chemical characteristics of dust from construction work is the basis for the development and implementation of dust suppression measures on construction sites, including the selection of suitable dust collectors. Solving this problem requires the development of a new approach to the analysis of dust particles generated as a result of construction work at various sites in the city. As part of this approach, a dust atlas has been created that systematizes and classifies various types of construction dust according to their physical and chemical characteristics.

2. *Materials and Methods*

Rostov-on-Don is a rapidly developing metropolis. The construction of new buildings and other structures is always an integral part of urban infrastructure development. Today, a large number of different residential complexes have been built in Rostov-on-Don, and this list is constantly growing. Rostov-on-Don is the largest city in southern Russia and the eleventh most populous city in the Russian Federation. In

recent years, the city has experienced an unfavorable environmental situation to breathe polluted air. Air pollution is often observed at construction sites, primarily caused by emissions of inorganic dust. This dust, containing up to 70 % silicon dioxide, is found in various materials such as chamotte and cement, as well as in industrial waste. Dust with a silicon dioxide content of more than 70 % was also found in dinas. There is also an environmental threat at construction sites from suspended particles and nitrogen dioxide released during the construction process. Sources of dust emissions into the atmosphere at construction sites include: construction machinery (e.g., transportation, loading, and unloading of bulk materials); building materials (e.g., gypsum, cement, sand); and construction processes (e.g., cutting gas blocks, mixing plaster, and mortar). The construction site of the 11-floor residential building (Fig. 1) is one of the typical examples of point-pattern housing development in a megacity.



Figure 1. Schemes of the research site: 1–3 – sampling points at the construction site.

This construction site was chosen as a research object because, according to the data from the developed map of the distribution of suspended matter concentrations near point-pattern housing development construction sites in Rostov-on-Don (Fig. 2), it was located in an area with the highest dust levels. Here, dust samples were taken at the construction site during construction. The construction dust sampling was carried out during excavation, foundation installation, and bulk materials handling.

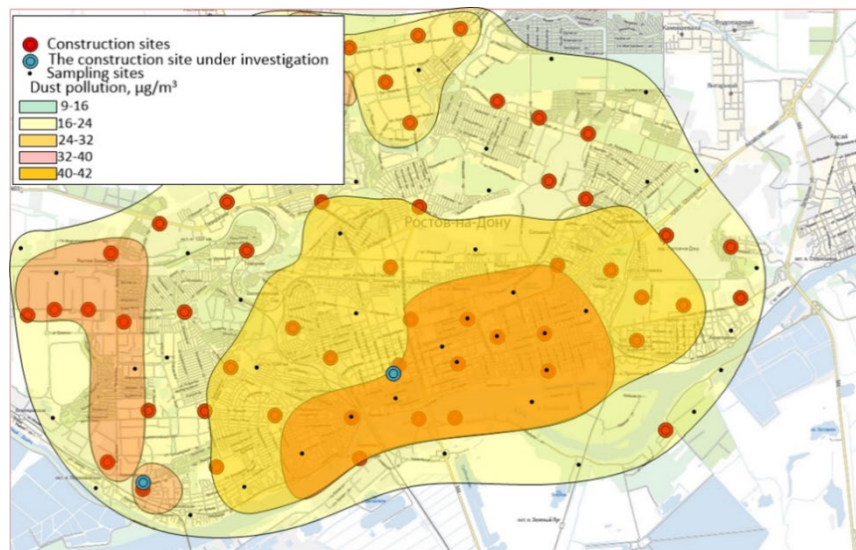


Figure 2. Distribution of suspended matter concentrations near point-of-construction facilities in Rostov-on-Don.

The study used two main devices to collect samples: a portable particle counter, Handheld 3016 by Lighthouse Worldwide Solutions (Medford, OR, USA), featuring 0.3 μm sensitivity, and a PU-3E/12 electric respirator by Ximko (Moscow, Russia). The respirator was used to detect dust and aerosol levels in the air with AFA VP aerosol filters having an active area of 10 cm^2 in both working and residential environments, as shown in Fig. 3.



Figure 3. Devices used in sampling: (a) Handheld 3016 particle counter; (b) PU-3E/12 electric respirator; (c) AFA aerosol filters by Krezol (Voronezh, Russia).

Dust particles filtered from various zones of the construction site were mixed to form a representative sample. The excess volume of the selected material was intensively homogenized, after which it was reduced to the required amount, thereby increasing the reliability of the analysis.

During sampling, special AFA filters were used to monitor aerosol particles in gaseous media and the atmosphere. Calibration and verification of measurement accuracy were carried out using the WIN-SFV32 v1.0 software package integrated with an electronic respirator. The filter elements were made using PVC-based fibers. The IRA-10 holders manufactured by the Russian company Krezol in Voronezh were used as retaining structures. The analysis of the collected samples was carried out using the methods for determining the concentration of pollutants in the air of the Russian Federation. According to the GOST R 58577-2019 standard [32], the sampling time for air samples to measure instantaneous concentrations at each control point was set to 20 minutes. The pretreatment of AFA type filters included their daily exposure in a desiccator containing calcium chloride as a moisture absorber. The filters were kept in open packages. After that, each sample was extracted using tweezers and weighed on a scale with a precision of 0.1 mg. The obtained weight data and the identification number were recorded on a paper package, into which the filter was then placed. An open filter holder was used to determine the dust concentration in the air. A filter, previously weighed to a constant weight, was placed in it. The prepared filters were stored in a room with a normal temperature, where there was no possibility of contamination. Before carrying out the weighing procedure, the filters delivered from the sampling site were left in the laboratory room for 24 hours. The process of weighing the dried samples was carried out several times until the weight became stable. During the dust particle sampling process, key characteristics of the air-dust mixture were measured, including humidity W (%), temperature t (°C), and flow rate V (cm/sec).

The dust concentration was determined by the following formula

$$C = \frac{m}{V_0}, \quad (1)$$

where m is the mass of dust trapped on the filter, determined by the gravimetric method as the difference between the mass of the filter after sampling and that of the clean filter before sampling, in milligrams; V_0 is the volume of the sample of air (gas) passed through the filter, in cubic meters.

The value of each sample was adjusted to normal conditions and calculated using the following formula

$$V_0 = \frac{V_1 \times 273 \times (P_i + \Delta P_{ac})}{(273 + t) \times 101.325}, \quad (2)$$

where V_0 is the volume of the selected gas emissions sample, m³; P_i is the atmospheric pressure during sampling, kPa; t is the gas temperature at the aspirator during sampling, °C; V_1 is the volume of the selected dust sample, m³; ΔP_{ac} is the vacuum at the aspirator, kPa.

During sampling, the environment was characterized by moderate temperatures around 25 °C, with relatively dry air showing 30–40 % humidity. A steady 5-meter-per-second breeze was present, while no rain or artificial moisture sources were detected throughout the duration.

The selected samples were sent to a scientific laboratory to determine the physical and chemical characteristics of construction dust according to the following parameters: morphological analysis of particles, dispersion, specific surface area, density (bulk, free-state, and dense-packing densities),

surcharge angle, adhesion, abrasiveness, electrical resistivity, chemical composition, hygroscopicity, and wettability. The devices used to determine the physical and chemical characteristics of construction dust are shown in Fig. 4. Table 2 shows the device specifications.



Figure 4. Devices used to determine the physico-chemical characteristics of construction dust: (a) TDS/pH-metr PH-986 analyzer by Hanna instruments (Germany); (b) MBS-10 stereoscopic microscope by LZOS (Moscow, Russia); (c) Versa 3D DualBeam electron-ion (bi-beam) microscope by FEI Company (Hillsboro, OR, USA); (d) PSKh-10 instrument by PSH (Moscow, Russia); (e) Pycnomatic Evo gas-weighing balloon by POROTEC (Germany); (f) SSL1 orbital shaker by Stual (Germany); (g) SWT-3M density analyzer by Emerging technologies corporate group (Russia); (h) ALC-80d4 digital weighing scale by Acculab (USA); (i) 80-2S sedimentator by Armed (Russia); (j) UT58B multimeter by UNI-T (China).

The process of studying the physical and chemical characteristics of construction dust took place in the following sequence.

1. Morphological analysis of construction dust particles was performed using an MBS-10 stereomicroscope equipped with a photodetector, which made it possible to obtain images magnified 200–2000 times. The resulting photographs were processed using the "Dust 1" software package, which made it possible to calculate the area occupied by the particles and determine their geometric shape based on these data. This technique relies on microscopic examination and photographic recording of dust particle sizes, followed by digital processing. The pH level in the dust samples was measured using a TDS/pH-meter PH-986 analyzer, which can measure pH and detect mineral particles.
2. The Versa 3D scanning electron microscope, which allows for detailed elemental analysis, was used to analyze the chemical state of construction dust. Using the software "STATISTICA 12.6," the data obtained during the analysis are visualized. The use of scanning transmission electron microscopy technology in combination with a suite of detectors (ETD, CBS, STEM) in high vacuum conditions made it possible to study the chemical elements in dust particles in detail and obtain their clear, highly detailed images. The mass percentage of component B for each chemical element was also determined.
3. The dispersion of construction dust was studied using a logarithmically normal distribution [33, 34]. Both theoretical models and experimental data were used to describe the characteristics of dust particles. In the presented results, the key parameters were the mass fraction percentage (g) of particles and their median diameter d_{50} , measured in microns. It is important to note that for cases of a logarithmically normal distribution, it is necessary not only to specify the median diameter of the particles but also to include the value of the standard deviation of the diameters

$$\delta = \frac{d_{50}}{d_{16}} = \frac{d_{84}}{d_{50}}, \quad (3)$$

where particles with sizes d_{16} and d_{84} represent the threshold values at which the total mass of small fractions reaches 16 % and 84 % of the total mass of the dust suspension, respectively. These patterns have been confirmed by studies [35, 36].

4. The specific surface area indicator S_{SS} (cm²/g) was determined using a PSKh-10 instrument. This indicator characterizes the specific surface area of the material, expressed in square centimeters per gram. The measurement is based on recording the time interval, during which a given amount of air passes through a sample of material.
5. The Pycnomatic Evo gas-type pycnometer was used to determine the density ρ (kg/m³). It is important to determine the mass-volume characteristics of construction dust. One of the key parameters is bulk density, an indicator that reflects the ratio of the mass of a substance to the space it occupies, including voids between individual elements. Measurements are carried out using two methods. The first method involves determining the density of the material in its free state (ρ_{FS} , kg/m³), where the sample is simply filled into a measuring container. The second method involves pre-compaction of the substance using special equipment – a laboratory SSL1 orbital shaker – which makes it possible to obtain the densest packing of particles (ρ_{DP} , kg/m³).
6. The surcharge angle (α_{SA} , degrees) of construction dust was measured using a SWT-3M density analyzer. When the dust sample is poured, a cone-shaped mound is formed. The phenomenon under study is characterized by a static angle of collapse (α_{STA} , degrees), an indicator that determines the slope between the base and the side surface of the formed figure. This angle was also measured during the experiment.
7. The breaking strength of the dust layer, adhesion (σ , Pa), was measured using a special technique with the aid of an ALC-80d4 digital weighing scale. The procedure begins by loading a dust sample into an air intake syringe, where the material is sealed at a pressure of 0.5 bar. The creation of a vacuum is ensured by hermetically closing the syringe. The breaking force (F_B , g) is determined at the moment the integrity of the dust layer is violated during the reverse movement of the piston. A quantitative estimate of the tensile strength of the layer (σ , g/cm²) is calculated using an appropriate mathematical expression that takes into account the experimentally obtained data

$$\sigma = \frac{F_B - M_{IN}}{S}, \quad (4)$$

where M_{IN} is the weight of the device with dust particles, g; S is the transverse square of the dust layer at its cut-off point, cm².

Information on the classification of dust in construction according to its adhesion properties is shown in Table 1.

Table 1. Adhesion degrees of construction dust.

Adhesion degree	The breaking strength, Pa
Non-stick	<60
Baseline	60–300
Average	300–600
Strong	> 600

8. A special technique utilizing a steel capsule is employed to measure the coefficient of abrasiveness, which characterizes the ability of dust to abrade materials. The experiment is based on determining the difference in weight of the test container before and after exposure to dust particles. The testing process comprises several stages: first, the test container with a screw cap is weighed using an ALC-80d4 digital scale, then the dust sample is filled into it. Next, the container is placed in a laboratory 80-2S sedimentator, where, during rotation, mechanical interaction occurs between the dust particles and the inner surface of the container. The final weighing enables the recording of a decrease in mass of the steel container, based on which the desired dust abrasiveness index is calculated using a specific formula

$$k_{AB} = k_{AB}^{AN} \Delta g, \quad (5)$$

where Δg is the reduction of capsule weight, kg; k_{AB}^{AN} is the constant that is established based on comparison k_{AB} with known materials that have the greatest similarity.

9. A special technique was used to determine the electrical resistivity ER ($\Omega \times m$) of dust particles. The UT58B multimeter was used to measure current and resistance in an electrical circuit. At the first stage, the base resistance between the copper conductors was recorded. The experiment was carried out with controlled temperature and voltage parameters. The key point was to find the distance between the conductors, at which the circuit was closed. After that, a sample of dusty material was inserted into the point, where the circuit was closed, and the resistance measurement procedure was repeated to obtain new measurements taking into account the influence of dust. After that, the electrical resistivity of dust particles was calculated using the appropriate mathematical expression.

After that, the electrical resistance of dust particles per unit volume was calculated using the appropriate mathematical expression

$$ER = R_{DUST} \times \frac{S}{l} = \frac{U}{I} \times \frac{S}{l}, \quad (6)$$

where R_{DUST} is the dust resistance, Ω ; S is the conductor square, m^2 ; l is the gap separating a pair of electrically conductive copper elements, m; U is set voltage, V; I is the electric current intensity, A.

10. Special measurements were conducted to study the ability of dust to absorb atmospheric moisture. The process involved sequential weighing of samples: first in a completely dry state, and then with a gradual increase in ambient humidity. The most important parameter of the study was the equilibrium humidity of the dust φ_{DUST} (%), which indicates the percentage of moisture contained in a substance at a given relative humidity φ_{AT} (%). This key indicator φ_{DUST} was calculated for each sample after all measurements using a special formula

$$\varphi_{DUST} = \frac{m_{WDUST} - m_{DUST}}{m_{DUST}} \times 100, \quad (7)$$

where m_{WDUST} is the volume of dust particles that have reached the point of equilibrium in moisture saturation, g; m_{DUST} is the weight of dried dust particles, g.

This method made it possible to study in detail the hygroscopic properties of dust particles – their ability to absorb water from the environment.

11. The ability to control pollution through humidification and wet dust collection largely depends on the wettability (Wet , %), which characterizes the interaction of particles with water. The film flotation method is used to measure this characteristic. The procedure includes several steps: first, identical amounts of dust samples are weighed, which are then placed in an aqueous medium. After light mixing, a part of the material settles. The final stage consists of filtration, drying, and weighing of the settled particles. The final wettability index is calculated as the ratio of the mass of the sediment to the mass of dust initially introduced. This parameter is crucial in assessing the effectiveness of hydraulic removal of dust pollution. Experimental measurements make it possible to classify dust particles according to their wettability. When 80–100 % of the particles settle, a high level of wettability is observed. An intermediate value in the range of 30–80 % indicates an average degree of interaction with moisture. If the amount of settled particles does not exceed 30 %, this indicates a low wettability of the dust.

3. Results

The dust particles produced during the construction of point-pattern development, not exceeding 150 microns, are divided into several categories.

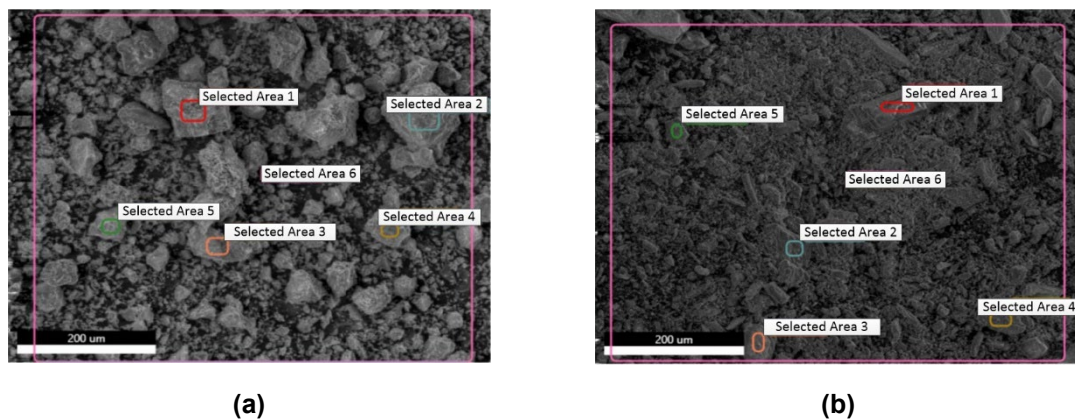
The smallest elements belong to medium-dispersed particles of 0.5–10 microns in size, which have specific intermediate properties. The larger fractions are represented by fine dust (10–50 microns), which can be viewed with low magnification under a microscope due to its slow settling. The largest particles belong to coarse dust (50–150 microns) – they are easily distinguishable to the naked eye and are

characterized by rapid deposition in the air. This four-step classification covers the entire spectrum of dust pollution encountered during construction work.

Microscopic studies have shown interesting features of construction dust. Its particles are characterized by solidity and do not form clusters. They stand out for their black color and hardness, and their surface is distinguished by its brilliance. Externally, these opaque elements resemble stone fragments with pointed edges.

Dimensional characteristics make it possible to divide dust particles into categories. Electron microscopy is necessary to study the smallest particles (less than 0.1 microns) that constantly perform Brownian motion. However, larger particles (0.1–20 microns) can be viewed using a conventional microscope; this fine dust is characterized by slow settling.

The structure of dust particles shows a significant variety of shapes. The formation of construction dust is dominated by particles with a rough, irregular structure, which is typical for crushed solids, as shown in Fig. 5.



**Figure 5. Images of dust particles obtained by microscopic scanning:
(a) cement dust; (b) gypsum dust.**

However, it is also possible to detect elements in the dust that have a fibrous or lamellar structure due to their crystalline nature [37].

The morphological analysis of construction dust helped to distinguish three main categories of particles, differing in their spatial characteristics. Some of them are plate formations with predominant sizes in two planes. Another type includes particles with a uniform size distribution along all axes – they can have the shape of both ideal and deformed spheres or polyhedra. It is interesting to note that when such particles combine into larger formations, the resulting clusters exhibit significant morphological diversity. The latter category includes one-dimensional structures, which are elongated objects represented by fibrous, needle-like, and prismatic particle shapes.

Depending on the production method, the particles acquire different geometries. Grinding creates pointed elements, while attrition forms rounded edges. The most dangerous materials are those with cutting edges, whether it is hard quartz, glass, or metal dust. Plastic substances like clay, plaster, and cement carry less risk due to their soft structure.

A whole range of oxide compounds can be detected in the composition of the dust generated during the construction of point-pattern housing developments. It is based on substances such as sodium and potassium oxides, as well as sulfur compounds in the form of SO_2 and SO_3 . A significant proportion is occupied by metal oxides – iron (Fe_2O_3), manganese (MnO), magnesium (MgO), and aluminum (Al_2O_3). In addition, phosphorus-containing components are present in the form of P_2O_5 , silicon-containing components are SiO_2 , and calcium compounds are CaO .

After analyzing the results obtained from studying the physical and chemical characteristics of construction dust from point-pattern housing developments in the laboratory, a compact dust atlas was created that systematizes dust particles of various sizes that occur in the construction industry. An individual specification has been compiled for each type of dust pollution, containing detailed information in tabulated form, shown in Figs. 6 and 7.

SPECIFICATION 1. CEMENT DUST						
During the construction of a residential building, when carrying out work on the construction of a frame structure, a sample of pulverized cement was obtained, which is used to prepare a building mixture: $t=20^{\circ}\text{C}$, $C=79\text{ mg/m}^3$, $V=0.79\text{ cm/sec}$, $W=60\%$.						
MORPHOLOGY OF DUST PARTICLES						
The gray dust mass consists mainly of particles up to 25 micrometers in diameter. When illuminated, individual grayish-white inclusions are visible, reaching 40 microns in size. In general, the sample is characterized by a dark gray color scheme, dominated by fine gray elements.						
PARTICLE SIZE DISTRIBUTION						
$d, \mu\text{m}$	0.5	1	2.5	5	10	
$g, \text{mass \%}$	88	76	79	85	96	
$V, \text{cm/sec}$	0.045	0.13	0.2	0.7	0.8	
$d_{50}=12\ \mu\text{m}$, $\delta=2.45$, $S_{SS}=3545\ \text{cm}^2/\text{g}$.						
MECHANICAL CHARACTERISTICS OF DUST						
$\rho=2680\ \text{kg/m}^3$	$\rho_{FS}=972\ \text{kg/m}^3$	$\rho_{DP}=1083\ \text{kg/m}^3$	$k_{AB}=2.8\times 10^{-11}$			
$\alpha_{SA}=39^{\circ}$	$\alpha_{STA}=52^{\circ}$	$\sigma=40\text{Pa}$	$Wet=98\%$			
ELECTRICAL RESISTIVITY OF DUST AT VARIOUS TEMPERATURES						
$ER, \Omega\cdot\text{m}$	1.5×10^{10}	6×10^{10}	4.3×10^{10}	3.4×10^{10}	2.1×10^{10}	$max\ ER$ 6.1×10^{10}
$t, ^{\circ}\text{C}$	50	100	150	200	250	118
ELEMENTAL COMPOSITION OF DUST						
Element	CaO	MgO	P ₂ O ₅	SiO ₂	Al ₂ O ₃	SO ₃
B, mass %	48.2	1.4	1	27.2	3.2	19
$pH=8$						
EQUILIBRIUM HUMIDITY OF THE DUST φ_{DUST} AT RELATIVE HUMIDITY φ_{AT}						
$\varphi_{DUST}, \%$	0.7	1	1.3	1.4	2.9	
$\varphi_{AT}, \%$	20	40	60	80	95	

Figure 6. Specification of suspended particles formed during cement production and processing.

SPECIFICATION 2. CARBIDE RESIDUE DUST						
During the construction of the frame structure of the building, a carbide residue dust sample of the material was taken, which belongs to calcareous substances.: $t=23^{\circ}\text{C}$, $C=79\text{ mg/m}^3$, $V=0.79\text{ cm/sec}$, $W=60\%$.						
MORPHOLOGY OF DUST PARTICLES						
In the passing light, you can see light beige specks of dust, although the bulk of the particles suspended in the air looks white. Dust particles are characterized by an asymmetric structure, with the largest of them reaching 40 micrometers. The predominant number of particles is white in color with a maximum size of up to 25 micrometers.						
PARTICLE SIZE DISTRIBUTION						
$d, \mu\text{m}$	0.5	1	2.5	5	10	
$g, \text{mass \%}$	75	79	81	84	96	
$V, \text{cm/sec}$	0.045	0.14	0.2	0.2	0.7	
$d_{50}=12\ \mu\text{m}$, $\delta=2.45$, $S_{SS}=3545\ \text{cm}^2/\text{g}$.						
MECHANICAL CHARACTERISTICS OF DUST						
$\rho=2480\ \text{kg/m}^3$	$\rho_{FS}=792\ \text{kg/m}^3$	$\rho_{DP}=1013\ \text{kg/m}^3$	$k_{AB}=3.1\times 10^{-11}$			
$\alpha_{SA}=40^{\circ}$	$\alpha_{STA}=52^{\circ}$	$\sigma=38\text{Pa}$	$Wet=85\%$			
ELECTRICAL RESISTIVITY OF DUST AT VARIOUS TEMPERATURES						
$ER, \Omega\cdot\text{m}$	1.3×10^{10}	5.8×10^{10}	4.6×10^{10}	3.4×10^{10}	2.2×10^{10}	$max\ ER$ 6.1×10^{10}
$t, ^{\circ}\text{C}$	50	100	150	200	250	105
ELEMENTAL COMPOSITION OF DUST						
Element	CaO	MgO	SO ₃			
B, mass %	95	3.4	1.6			
$pH=10$						
EQUILIBRIUM HUMIDITY OF THE DUST φ_{DUST} AT RELATIVE HUMIDITY φ_{AT}						
$\varphi_{DUST}, \%$	0.2	0.3	0.65	1.8	2.05	
$\varphi_{AT}, \%$	20	40	60	80	95	

Figure 7. Specification of suspended particles formed during welding of the building frame.

The documentation includes information on sample collection methods, time parameters, materials involved, and a detailed analysis of dust characteristics. An important part of the project was the formation of a classifier of construction dust with a detailed description of its chemical and physical characteristics, as well as the methodology for their determination. All data are structured as a single information complex with a simple and intuitive navigation system.

Based on a comparative analysis of the data obtained in Rostov-on-Don and the data presented in the works of researchers [7, 14, 17, 18–21], it can be concluded that studies of the morphological and chemical parameters of dust from construction activities are often scattered. There is no systematic approach to capturing and structuring data on dust pollution, nor is there a consistent application of this data in practice to develop design and technical solutions for controlling pollution on construction sites for future construction projects. The advantage of the proposed system for determining dust pollution parameters on a construction site is its unified approach, as areas of concentrated development have their own climatic characteristics, and a dust atlas must be developed for each specific construction project.

4. Discussion

When participating in tenders and contractual prices for contractors involved in point-pattern housing development can gain significant advantages over competitors by applying data from the dust atlas of a model of a construction site or developing a dust atlas for a specific construction project. This can be achieved by including rational methods in projects of protecting the air environment from pollution and competent organization of construction work that minimizes the negative impact on the environment, knowing the list of works to be carried out on the urban area construction site and what building materials and mechanisms will be used [38].

Rationally selected dust collecting equipment helps not only to reduce costs but also to increase the profitability of point developments by reducing the environmental costs of combating and cleaning the territory and atmospheric air of the urban environment from dust pollution from point-pattern construction. The selection of dust collecting equipment requires a detailed analysis of the polluting components and their characteristics. Before installing a new dust collection system, it is important to conduct a comprehensive survey of the area, where point-pattern housing development will be implemented, including measurements of background concentrations of harmful substances, analysis of dust dispersion, assessment of temperature conditions and humidity levels, as well as dust pollution that will be generated during construction work.

It is difficult for an inexperienced contractor to independently choose the optimal solution that takes into account both the economic component and the cleaning efficiency. The physical and chemical characteristics and volume of pollutants directly affect the technical requirements for the equipment to be installed.

The proposed methodology for developing a dust atlas that takes into account the characteristics of dust for the construction of a specific point development facility will make it possible to optimize and control dust emissions at the construction site of an urban area located near the construction industry. Manufacturers often overestimate the efficiency of dust collection systems, especially when they claim performance above 98 %. It is necessary to conduct a full analysis of construction work with respect to dust before evaluating the declared characteristics of cleaning equipment and analyzing manufacturing companies' statements about their effectiveness. It is important to keep in mind that equipment testing is usually carried out on typical dust in the laboratory, so the actual efficiency may vary significantly when working with particles of different sizes and densities, as well as at different temperatures and humidity conditions.

There are many criteria to consider when choosing a cleaning system. Humidity parameters, temperature conditions of the gas environment, as well as spatial constraints for equipment installation, play a key role. It is necessary to take into account the consumption of water resources and wastewater disposal methods. The nature and characteristics of the pollutant are essential, including the resistance of particles to air flows, their dimensions and density in the medium. The difference between 99 % and 99.9 % efficiency indicators is minimal. However, if we consider this difference from the point of view of the ability to suppress and reduce the concentration of dust pollution, then the difference can be tenfold. When choosing equipment, its cost and installation location play a key role. These criteria are closely linked and require integrated assessment. In conditions of limited space, it is often necessary to give preference to compact but expensive installations, although there are equally efficient and more economical alternatives of a larger size. The specifics of the location of the facility also affect the choice – for hard-to-reach areas and cramped construction sites, more advanced and expensive equipment may be needed. There is no universal solution – each case requires individual consideration of all parameters. Making the best decision involves a thorough analysis of both technical characteristics and economic feasibility. It is necessary to study all aspects in detail, since the obvious choice at first glance may not be the most rational.

Choosing the most cost-effective dust control equipment requires an analysis of certain economic and technical indicators.

1. Equipment utilization rate K_U shows the ratio of the time of the actual operation of the machine for a certain period of time to the duration of this period

$$K_U = \frac{t_{ACTUAL}}{t_{OP}}, \quad (8)$$

where t_{ACTUAL} is the actual operation time of the dust control equipment on the construction site, months;
 t_{OP} is the overall time spent by the equipment on the construction site.

The value of the equipment utilization rate K_U for periodically used equipment in technological operations ranges from 0.05 to 0.1. The continuously operating installations have $K_U \leq 1$, since part of the time is spent on maintenance and repair work. Under these conditions, the choice of equipment will depend on the actual parameters of the abrasiveness of the dust which will be deleted by this equipment.

1. Profitability of equipment P is the ratio of the useful return UR of the equipment for a certain period to the total cost of the equipment C_{EQ} for the same period

$$P = \frac{UR}{C_{EQ}}. \quad (9)$$

Let us consider the economic effect of the introduction of a wet dust collector at a construction site. Prior to its installation, the company incurred significant costs. They included expenses for dust control: regular humidification, cleaning, cleaning and updating of work clothes. In addition, the company was losing funds due to frequent sick leave. All these costs UR form a basic amount of money that can be saved after installing the dust collection equipment with the technical characteristics of dust collection that correspond to the data of the analysis of the physical and chemical characteristics of the dust, which will be deleted by this equipment.

2. The total costs C_{TOTAL} associated with the operation and maintenance of dust collection systems can be calculated by this expression

$$C_{TOTAL} = C_{EN} + C_{CS} + C_{ER} + C_{DE}, \quad (10)$$

where C_{EN} is the cost of consumed electricity; C_{CS} is the cost of consumables (for example, filter media that is periodically replaced, water); C_{ER} is the cost of equipment repair, payment of maintenance personnel for repairs, tools necessary for maintenance during operation of the equipment; C_{DE} is the costs of depreciation that reduce the cost of equipment due to its wear and tear.

When choosing efficient equipment, $P > 1$. The rational selection of equipment, taking into account the data of the dust atlas, reduces these costs.

3. Assessment of the financial benefits FB of upgrading the facility using technical means

$$FB = UR - C_{TOTAL} = UR \left(\frac{C_{TOTAL}}{UR} \right) = UR \left(1 - \frac{1}{P} \right). \quad (11)$$

4. The total economic benefit $\sum E$ accumulated over the entire period of operation of the technical means is

$$\sum E = t_{OP} \times [UR - (C_{EN} + C_{ER})] - \sum C_{ER} - \sum C_{DE}. \quad (12)$$

5. The assessment of the economic efficiency of the equipment K_{EF} reflects the ratio between the total operating costs and the initial cost of the technical means and takes into account all costs during use

$$K_{EF} = \frac{\sum C_{TOTAL}}{C_{EQ}}, \quad (13)$$

where C_{EQ} is the cost of buying or renting equipment.

6. The equipment cost coefficient K_{EC} is the percentage ratio of the cost of the machine to the amount of costs

$$K_{EC} = \frac{C_{EQ}}{\sum C_{TOTAL}} \times 100. \quad (14)$$

As the service life of t_{OP} increases, there is a significant increase in the K_{EF} indicator, reflecting operating costs, which can reach values from 50 to 100. This leads to the fact that the share of depreciation charges C_{DE} in the structure of total expenses shows a tendency to decrease.

Based on the collected information on the physical and chemical characteristics of construction dust, presented in a dust atlas, the calculation and selection of optimal dust collection equipment for a point-pattern housing development facility – an 11-storey residential complex – was carried out. Tables 2 and 3 show the initial parameters and the final calculation results. The analysis included a comparison of several installations with identical cleaning and performance indicators, shown in Fig. 8, but differing in operational characteristics and maintenance costs. The information obtained on the dust composition made it possible to adjust the calculations and optimize the choice of equipment, taking into account technical and economic factors.



Figure 8. Dust collecting equipment for the construction site:
(a) vehicle-mounted water mist cannon atomizer sprayer Fog Elefante 70 by INDROBASE (Italy);
(b) WLP 500 dust suppression system by WLP (Italy).

Table 2. Initial data and parameters for assessing the economic feasibility of using dust cleaning systems.

No.	Initial data	Units	Fog Elefante 70	WLP 500
1	K_U	USD	1 323.81	1 632.45
2	U_R	USD	1 224.34	1 224.34
3	t_{OP}	Months	6	6
4	C_{EN}	USD	271.39	46.93
5	C_{ER}	USD	336.69	73.46
6	t_{ACTUAL}	Months	4	4
7	C_{CS}	USD	38.26	20.41
8	C_{DE}	USD	12.24	26.12

Table 3. The results of the calculation of the feasibility study.

No.	Indicators	Fog Elefante 70	WLP 500
1	K_U	0.67	0.67
2	C_{TOTAL}	658.59 USD	166.92 USD
3	P	1.85	7.3
4	E	563.19 USD	1 065.17 USD
5	K_{EF}	0.49	0.1
6	K_{EC}	201	977

When choosing dust-collecting equipment, the key role is played by its efficiency indicators, including productivity and durability, which in turn depends on the characteristics of the dust emissions, with which it operates. A rational decision on the purchase of equipment can be made by analyzing the total cost of transportation, maintenance, and repair during the entire period of use. An individual calculation of operating costs for a specific case allows us to assess the economic feasibility of introducing equipment into the production process and make the best choice in terms of financial costs.

A study of previous work on the formation of dust particles in construction sites [4, 39] revealed both common features and discrepancies with the data we obtained. Our work focused on a detailed study of the chemical composition and physical properties of dust pollutants that occur during construction work. The main goal was to find effective methods of controlling dust emissions to protect the ecology of urban airspace and protect the health of residents whose homes are located near point-pattern housing developments. In our study, we did not limit ourselves to the chemical analysis of construction dust but also

studied in detail its dispersed characteristics. In point-pattern housing developments, this analysis technique shows the most accurate results in determining the properties of dust particles, surpassing traditional methods for estimating dust emissions on construction sites. Of particular value is the fact that we measured the concentration of dust, its chemical composition, density, surcharge angle, adhesion, abrasiveness, electrical resistivity, hygroscopicity, and wettability for each individual type of construction work. Thanks to this, the created dust pollution atlases can be effectively used in a variety of situations – from the construction of new buildings to the reconstruction of existing facilities and even during repair activities. In this scientific work, the main focus was on the study of particulate matter, although the analysis of silica particles is equally important in assessing construction emissions. It is noteworthy that the degree of harmful effects of dust pollution on construction sites is largely determined by the concentration of silica in the dust. It is worth noting that the conducted research is not without certain drawbacks, and the study of the silica component remains a promising area for further scientific research in the field of construction dust pollution.

5. Conclusions

The physical and chemical characteristics of construction dust, including its size, shape, composition, and electrical charge, determine the degree of its impact on the environment and human health. Fine particles ranging in size from PM_{0.5} to PM₁₀, which are formed during construction work, are particularly dangerous. Their influence extends to both workers and residents of the surrounding areas. The ability of particles to stay in the air for a long time and penetrate deep into the respiratory tract directly depends on their size. This parameter also determines their chemical activity and electrostatic properties. Therefore, measuring the size of dust particles on construction sites is crucial for assessing potential harm to health and developing protective measures.

In modern cities undergoing rapid development, it is critically important to control air quality, especially in the context of construction activities. Throughout the entire life cycle of a building, from construction to dismantling, there is a constant impact of dust pollution on the environment. The scientific community, both internationally and locally, pays increased attention to environmental degradation caused by dust pollutants. When designing new facilities, it is necessary to take into account research data on particulate emissions, which makes it possible to create a more environmentally friendly urban environment.

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