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Research article

ON NEW METHODS FOR MEASURING AND IDENTIFYING DUST MICROPARTICLES IN AMBIENT AIR

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Established health hazards posed by dust microparticles require automated and mobile devices for their assessment. Such devices should provide an opportunity to analyze component and disperse structures of the solid component in ambient air pollution operatively and in real time. In future, they will replace labor-consuming sampling and separate identification of fraction structure and chemical composition of dusts.

The aim of this study was to develop and test new methodical, procedural and instrumental approaches to monitoring of solid particles in ambient air. We suggest a hardware and software complex that implements a two-stage scheme for identifying solid particles sampled in ambient air according to the from-coarse-to-fine principle. The first stage involves identifying the total concentration of solid particles by laser diffraction. Microphotographs are taken with iMicro Q2 mini portable microscope with magnification x800. The microscope lens is connected to a camera, which is linked to nVidia Jetson Nano micro PC. The micro PC classifies particles, identifies their contours by using a neural network and deals with image segmentation. The second stage relies on using computer vision that makes it possible to automate routine recognition of particle images created by the microscope in order to calculate levels of different substances in a sample. All the data are analyzed by the second neural network that performs preset calculations in accordance with mathematical logic (model). The network is trained using a library that contains attributed microphotographs of dusts with different qualitative and disperse structures.

The algorithm has been tested with some promising results. Identified disperse structures and chemical composition of dusts turn out to be quite similar to those identified by conventional approaches and measurement methods. The method has been shown to offer wide opportunities to identify dust composition and structure, to create dust pollution profiles, and to estimate a contribution made by a specific source to overall pollution.

The study results ensure more correct and precise health risk assessment under exposure to dusts in ambient air.

Keywords: *dust pollution, concentration of solid particles, dust fraction structure and chemical composition, ambient air, image recognition, computer vision.*

Airborne dusts are a risk factor of additional population mortality and incidence and therefore it is important to perform systemic monitoring of their levels in ambient air. Harmful effects of dusts have been proven by multiple Russian and foreign studies; in particular, there is evidence that the smallest $PM_{2.5}$ are able to penetrate through the blood-air barrier and get into the circulatory system [1]. The available estimates indicate that if PM_{10} levels grow by 10 μg/m^3, daily all-cause mortality also increases by 0.2–0.6 %. Under chronic exposure to $PM_{2.5}$, each rise in $PM_{2.5}$ levels by 10 μg/m^3 makes long-term risks of cardiopulmonary mortality grow by 6–13 % [2–4]. B.A. Revich (2018) focused on ambient

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air pollution with fine particles in his study and showed that additional mortality in 219 cities in Russia equaled 67.9 thousand cases per year under exposure to PM_{10} and 88.2 thousand cases per year under exposure to $PM_{2.5}$ [5].

Accumulative data indicate that exposure to particulate matter $PM_{2.5}$ as a major air pollution source is toxic for skin and affects it considerably. These particles are especially harmful for the epidermis structure and functioning [6, 7].

Peters, Choi, and Mihye describe negative effects of $PM_{2.5}$ on cognitive functions and a risk of early-onset dementia [8–10]. Even relatively low $PM_{2.5}$ levels can be a significant harmful environmental factor able to influence how the brain structure develops in childhood [11]. The negative role of dust particles in spread of communicable diseases, COVID-19 in particular, has also been proven [12, 13]. All this indicates that it is extremely vital to monitor levels of fine-dispersed dusts and to manage ambient air pollution in cities in Russia. This can be done, among other things, by setting standards for emissions of economic entities.

Thus, according to Rosgidromet[1], daily measurements of PM_{10} levels in such cities as Moscow, Sochi, Krasnoyarsk, Irkutsk, Angarsk, Gusinoozersk, Nakhodka, Ulan-Ude, Chita, and others indicate that the existing hygienic standards are violated practically everywhere. Average annual concentrations of PM_{10} equaled 1.6 average annual MPC in Gusinoosersk; 1.3 average annual MPC in Selenginsk; 1.1 average annual MPC in Chita and Shelekhov. High levels of pollution with PM_{10} were established in Baikalsk in 2021 where they reached 23.3 average annual MPC. $PM_{2.5}$ are measured in seven cities (11 posts). Average annual concentrations reach 1.8 average annual MPC (Ulan-Ude). The maximum daily concentration was identified in Selenginsk where it reached 8.2 average daily MPC. $PM_{2.5}$ levels higher than permissible daily ones were detected in all the cities where this pollutant was measured except from Angarsk. Data collected by Rosgidromet state monitoring system are confirmed by data collected at social-hygienic monitoring posts and regional monitoring posts.

However, management of ambient air quality as regards pollution with fine-dispersed dust fractions is not always effective. This is mostly due to the fact that industrial enterprises very rarely declare fine-dispersed dusts in the structure of emitted gas and dust mixtures. At present, fine-dispersed dusts are covered by only three out of 118 procedures recommended to be used by economic entities when they make inventories of their emission sources[2]. Guided by the Ministry documents, economic entities do not disclose the disperse structure of the solid component in their emissions. As a result, hazardous dust fractions ‘drop out’ from ecological standardization. It is impossible to identify sources that create excessive $PM_{2.5}$ and PM_{10} levels in ambient air and this pollution remains beyond the state regulation.

Absence of emission management is apparent according to the following situation: economic entities themselves declare reductions in emissions of solid components. In 2010, approximately 2.4 million tons of dusts were emitted in the country; the figure went down to 1.6 million tons in 2010 (by more than 30 %). Still, average annual PM concentrations measured at monitoring posts changed only slightly over the same period and equaled to 116 $\mu g/m^3$ in 2010 and 109 $\mu g/m^3$ in 2020 (only a 6 % reduction).

Another difficulty in managing dust emissions is that dust is a commonly spread pollutant. Consequently, it is very difficult to identify a contribution made by a specific eco-

[1] Sostoyanie zagryazneniya atmosfery v gorodakh na territorii Rossii za 2021 g.: ezhegodnik [The levels of ambient air pollution in cities in Russia over 2021: annual data collection]. Saint Petersburg, 2022 (in Russian).

[2] Perechen' metodik rascheta vybrosov vrednykh (zagryaznyayushchikh) veshchestv v atmosfernyi vozdukh statsionarnymi istochnikami [The list of procedures for calculating emissions of harmful chemicals (pollutants) into ambient air from stationary sources]. *GARANT: information and legal portal*. Available at: https://www.garant.ru/products/ipo/prime/doc/402674938/ (January 15, 2023) (in Russian).

nomic entity and a level of dust pollution created by it. At the same time, Rospotrebnadzor experts face the challenge to identify both a source and pollution created by it both during control and surveillance activities involving laboratory tests of ambient air and when analyzing social-hygienic monitoring data. Mandatory identification of sources that emit fine-dispersed dusts is fixed as a task to be solved by the WHO document [14].

Fine-dispersed particles are measured in ambient air by using several procedures: gravimetry[3], laser diffraction[4], nephelometric analysis and some others. Dust analyzers of DustTrak type (models 8530, 8533) are widely used in measuring; they are based on laser nephelometry. Some procedures involve using ATMAC devices that rely on piezoelectric measurement of a piezoelement frequency when aerosol particles are being deposited on its surface.

At the same time, it is still a vital task to perform simultaneous and interrelated measurements of fraction and chemical structure of dusts.

In this study, our aim was to develop and test new methodical, procedural and instrumental approaches to monitoring of solid particles, fine-dispersed included, within monitoring of ambient air quality.

Materials and methods. We have developed a two-stage scheme aimed at making monitoring of dust more effective. The scheme makes it possible to recognize airborne solid particles as per the coarse-to-fine principle [15, 16].

The first stage in the scheme involves rapid identification of the total PM levels using the SDS011 sensor, which employs laser diffraction to estimate PM_{10} and PM_{25} concentrations [17]. The best location for the second stage when more precise measurements are performed can be selected by identifying peak concentrations with this sensor.

The second stage in the scheme relies on using ‘computer vision’ that automates routine operations of object image recognition for calculating a percentage of a specific chemical in a sample. Airflow is sucked into the device by the sensor ventilator and dust particles are deposited partially on the slide while moving along the channel. Images of deposited particles made by the microscope contain all the relevant features of an analyzed scene in its numeric form. These data are analyzed by an imitation of a biological neural network performing a preset collection of calculations according to mathematical logic (model) [18, 19]. Microphotographs are taken with iMicro Q2 mini portable microscope with magnification x800. The microscope lens is connected to a camera, which is linked to nVidia Jetson Nano micro PC. The micro PC classifies analyzed particles and identifies their contours by using a neural network, that is, deals with image segmentation. As a result, a mass of each particle in a frame is calculated and relevant ROI (regions of interests) are cut from the initial frame. They contain images of all the identified particles that have also been classified as per a chemical they represent.

Monitoring data can be analyzed by using both cloud technologies applied, among other things, for the Internet of Things (IoT) and decentralized computations performed, for example, as per the EDGE-devices principle [18, 19].

Cloud technologies are able to provide centralized solutions to issues of segmentation and classification due to using centralized data processing by powerful servers available at a cloud platform. The servers process data flows generated by various devices with artificial intelligence methods and visualize them; the procedure requires a reliable channel for data transfer.

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[3] CSN EN 12341. Ambient air – Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass concentration of suspended particulate matter.

[4] MUK 4.1.3242-14. Izmerenie massovoi kontsentratsii melkodispersnykh chastits PM_{10} i $PM_{2.5}$ v atmosfernom vozdukhe s ispol'zovaniem metoda lazernoi difraktsii [Methodical guidelines MUK 4.1.3242-14. Measurement of mass concentrations of fine-dispersed particles PM_{10} and $PM_{2.5}$ in ambient air by suing laser diffraction]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200132738 (January 15, 2023) (in Russian).

On the other hand, a portable EDGE-device can implement multi-stage data processing within the coarse-to-fine paradigm in itself to solve monitoring tasks:

– continuous measurements of airborne $PM_{2.5}/PM_{10}$ levels (without morphology estimates and recognition of dust particles);

– morphological and component analysis of particles using optical object recognition and comparison of recognized particles to dust profiles of enterprises.

Use of this scheme ensures that resource-consuming operations connected with optical image processing (Computer Vision) are accomplished only at those points where it is necessary and the results are extrapolated onto neighboring points. As a result, pollution maps are compared operatively in stream processing.

Particles are classified and their sized are identified using a neural network model trained on hundreds of examples attributed by experts. The network structure is one-directional (without feedbacks) and multi-layered. The network is trained by conventional backpropagation.

In this study, the neural network was trained using libraries with microphotos of dusts emitted at various productions and from various technological devices. Images on each microphoto were described with chemical, fraction and morphological structure of dusts. They were labeled with locations and contours of objects the neural network had to recognize.

Labels were made with Coco-annotator, web-based image annotation tool designed for versatility and to efficiently label images to create training data for image localization. The tool makes it possible to save the labeling results in CoCo format.

It is rather difficult to use microphotos in a portable device due to the necessity to focus a camera and to process several photos to get a qualitative image of one scene. In this study, we resorted to focus stacking to achieve greater depth of image sharpness by combining several images made from different focus lengths into one image with greater sharpness and definition of both front and background objects. The method uses several photos of the same scene obtained with different focus lengths and combines them into one definite image [18].

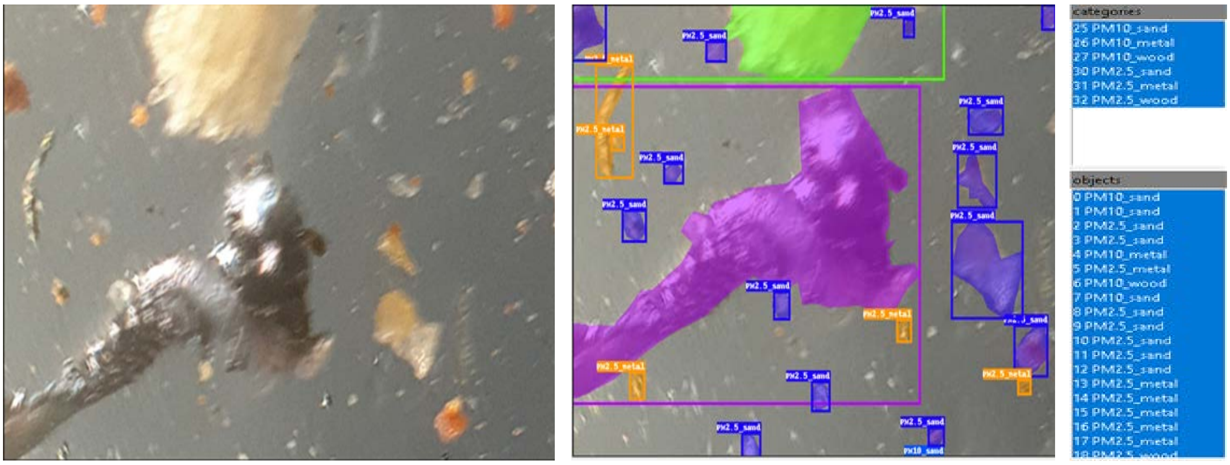
Hardware and software was tested by analyzing actual ambient air pollution in a zone influenced by a mining facility. The database with microphotos that was employed to train the neural network was created in 2020–2021.

Dust pollutions were simultaneously analyzed with conventional techniques in order to verify the results yielded by the new approaches. The disperse structure of analyzed dusts was identified with the Microtrac S3500 6 laser particle size analyzer. The component (chemical) structure of dust emissions was identified using a high-resolution scanning electronic microscope with thermal emission and S-3400N X-ray fluorescence device (HITACHI, Japan); air samples were also analyzed with X-ray diffraction (XRD) analysis using XRD-700 diffractometer (Shimadzu, Japan). X-ray photos were processed with XRD 6000/7000 Ver. 5.21 software. The phase structure of the analyzed samples was identified using ICDD PDF-4+ 2012 database at the Center for Collective Use of the Perm National Research Polytechnic University.

Basic results. The study established that dust pollution near an industrial facility with intensive emissions of solid particles into ambient air had a complex component and dispersed structure. Dusts, which were identified as 'particulate matter' at Rosgidromet monitoring posts, contained salts and oxides of iron, silicon, magnesium, manganese, aluminum, and some other metals. Similar results were obtained by using the new suggested approaches.

The employed neural network brought some good results concerning image recognitions. The method made it possible to identify contours of separate particles and each particle was identified and classified. As a result, a table with data on identified chemicals was created for each sample; percentage of each chemical was calculated as per the number of its particles; statistical characteristics were also obtained (Figure 1).

Table 1 provides both data obtained by conventional procedures and the new suggested method.



a *b* *c*

Figure 1. Initial image of dust particles (*a*) and results of particle recognition (*b*, *c*)

Table 1

Identified quantitative and qualitative indicators of the dust component

Chemical	Level in the analyzed sample, mg/m^3		Validity of differences	
	Conventional procedures	Image recognition	t-test	P (the level of significance)
Fe_2O_3	19.49 ± 0.2	17.25 ± 0.29	6.36	0.00
SiO_2	31.04 ± 12.98	27.16 ± 13.68	0.21	0.84
Al_2O_3	22.22 ± 2.75	21.03 ± 4.58	0.22	0.82
NaCl	1.3 ± 3.85	1.9 ± 1.53	0.14	0.88
CaO	20.12 ± 2.67	18.86 ± 3.74	0.27	0.78
MgO	4.21 ± 0.75	4.01 ± 1.26	0.14	0.89
KCl	1.62 ± 0.19	0.85 ± 0.97	0.78	0.44
$MnSO_4$	0.05 ± 3.62	0.00 ± 0.00	0.01	0.99
$AlCl_3$	0.85 ± 1.58	0.1 ± 0.04	0.47	0.64
Others	2.38 ± 0.63	4.89 ± 6.68	0.37	0.71
PM_{10}	74.28 ± 15.3	72.75 ± 12.92	0.08	0.94
$PM_{2.5}$	21.3 ± 1.16	19.49 ± 4.54	0.39	0.70

Obviously, similarity between the measurements can be considered quite satisfactory. The qualitative database with microphotos of dust samples created at previous stages in this research has made a substantial contribution to the quality of the results [20–22].

The suggested approach to measuring dusts within social-hygienic monitoring has an obvious advantage. It is a possibility to identify dispersed and component structure of dusts quite operatively as opposed to conventional procedures when it takes several days or even several weeks to identify and quantify chemical structure of a dust component in ambient air pollution.

The obtained data can give grounds for identifying a contribution made by a specific economic entity to ambient air pollution and, which is no less significant, to public health risks. It is vital to identify such contributions correctly, both for an economic entity itself (an emission source) and a surveillance authority. The approach was tested when assessing a sanitary-hygienic situation near an industrial site of a large facility dealing with potassium salts mining. Inventory of emission sources located at the facility involved component analysis of solid particles in dusts, creation of a 'dust emission profile' and taking microphotos of particles.

We analyzed the chemical structure of emissions and dust components in them at the boundary of the sanitary protection zone (SPZ) (1 km away from the boundary of the industrial site) and established significant differences between taken air samples (Table 2). Marker chemicals typical for the facility occurred in dusts sampled at the boundary of the sanitary protection zone and described emission sources. However, contributions of these chemicals into the total emission mass were approximately 5.9 % (4.6–7.2 %) in the analyzed samples. Even though some chemicals occurred in levels reaching 4.2 single maximum MPC at the boundary, which meant the hygienic standards were violated, the economic entity was able to prove that it did not create excessive levels of pollution and did not have those chemicals in emissions, which accounted for the bulk of dusts identified at the boundary of the sanitary protection zone.

The obtained results were also confirmed by comparing microphotos of particles taken at the emission sources of the facility and at the boundary of the sanitary protection zone (Figure 2). Most particles emitted by the facility had a similar crystal-like shape typical for salts. Solid particles identified at the boundary of the sanitary protection zone had fundamentally different shapes.

On the one hand, these results ensure no incorrect administrative measures will be taken as regards the economic entity; on the other hand, they pose a new challenge, which is to identify actual sources of ambient air pollution.

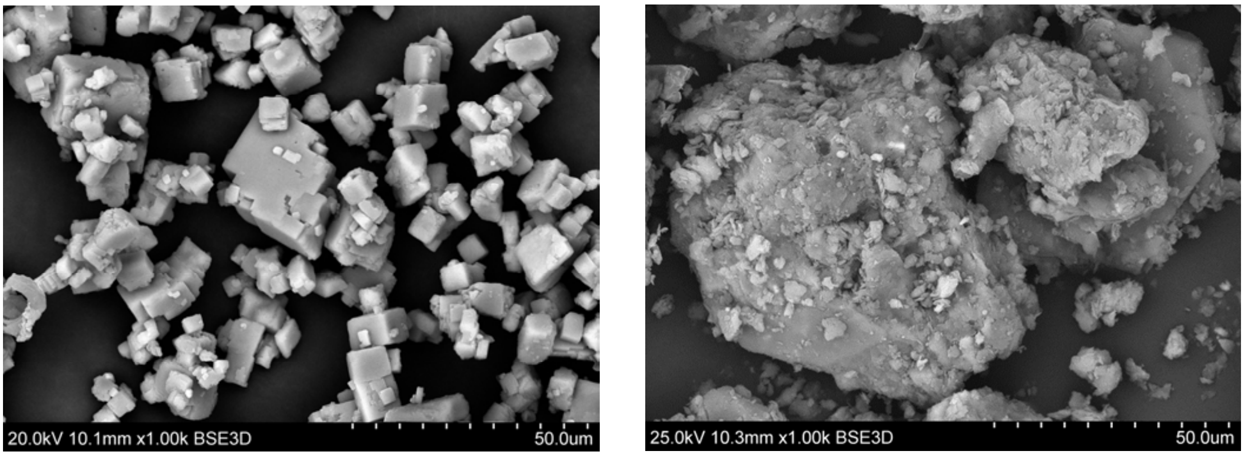
Another positive aspect of creating dust profiles is a possibility to correctly assess public health risks. Dusts that are declared by economic entities in their emission inventories as ‘particulate matter’ or, for example, as a ‘dust containing less than 20 % of SiO_2’ often contain salts and/or oxides of heavy metals. Such chemicals cause much greater health hazards than simple particulate matter. Some examples are provided in Table 3. Thus, emissions of processing machinery are declared by an economic entity as ‘particulate matter’ (RfC^5 = 0.075 mg/m^3); in reality, they are a complex mixture of iron, magnesium, and aluminum salts and oxides. It is noteworthy that reference levels of each component are lower than those of unidentified particulate matter. In addition, fine-dispersed PM_{10} and $PM_{2.5}$ are identified in emissions and they are much more harmful for health than the total solid particles.

Table 2

Contributions made by emission sources at the mining facility to dust pollution in ambient air at the boundary of the sanitary protection zone

Chemical	Dust profile, mg/m^3		A contribution made by the facility at the SPZ boundary, %		Background pollution	
	Emissions from the facility	At the measuring point	To a chemical concentration, %	To total dust pollution	mg/m^3	% of the total
KCl	0.0383	0.0383	100.0	1.47	0	0
NaCl	0.0296	0.0296	100.0	1.13	0	0
$AlCl_3$	0.002	0.006	33.3	0.08	0.0040	0.15
$MgSO_4$	0.0029	0.0118	24.6	0.11	0.0089	0.34
SiO_2	0.0284	0.7762	3.66	1.09	0.7478	28.64
MgO	0.0015	0.0535	2.80	0.06	0.0520	1.99
Al_2O_3	0.009	0.4133	2.18	0.34	0.4043	15.48
CaO	0.0014	0.1989	0.70	0.05	0.1975	7.56
Fe_2O_3	0.0033	0.9589	0.34	0.13	0.9556	36.60
$MnSO_4$	0.000	0.0135	0.00	0.00	0.0135	0.52
Others	0.0377	0.111	33.96	1.44	0.0733	2.81
Total:	**0.1541**	**2.6110**		**5.90**	**2.4569**	**94.10**

5 *RfC*, reference concentration is an average daily concentration of a chemical; it is established considering all the available research data and, probably, does not create unacceptable health risks for sensitive population groups (the Guide R 2.1.10.1920-04).



a *b*

Figure 2. Dust particle shapes: *a*) in emissions from the facility (magnification x1000); *b*) in ambient air at the SPZ boundary (magnification x1000)

Table 3

Example coding and an inventory list of chemicals as per data of calculations and research results

Emission source	Coded by a facility		Dust components identified by research		
	Chemical	*RfC*, mg/m^3	Identified structure	*RfC*, mg/m^3	% in dusts
Mechanical processing of metals (cutting)	Particulate matter	0.075	Iron sulfate	0.007–	30.58
			Silicon dioxide	0.05	20.07
			Iron oxide	0.04–	19.67
			Magnesium oxide	0.05–	16.81
			Aluminum oxide	0.005	3.23
			Others (not identified)	0.075	9.43
			PM_{10}	0.05	33.0
			$PM_{2.5}$	0.015	7.1
Mechanical processing of metals (drilling)	Particulate matter	0.075	Iron oxide	0.04–	97.35
			Mn and its compounds	0.00005	1.15
			Chromium (recalculated as per chromium (VI) oxide)	0.000008	0.99
			Other chemicals	0.15/0.075	0.40
			Aluminum oxide	0.005	0.11
			PM_{10}	0.04	13.00
			$PM_{2.5}$	0.015	7.00
Turnery	Particulate matter	0.075	Iron oxide	0.04	98.19
			Mn and its compounds	0.00005	1.07
			Others (not identified)	0.075	0.41
			Chromium	0.000008	0.33
			PM_{10}	0.05	12.00
			$PM_{2.5}$	0.015	0.40

Both toxic elements in the dust structure and a considerable share of fine-dispersed particles allow assuming that potential health risks in a zone influenced by the analyzed facility might be substantially underestimated with the existing system of chemical identification.

The last assertion was also confirmed by analyzing a sanitary-hygienic situation in a zone influenced by emissions from a primary aluminum production at a production facility in Krasnoyarsk. Emissions were coded as inorganic dusts (the reference concentration taken as per TSP is 0.075 mg/m^3) whereas aluminum oxide (Al_2O_3) was identified as a primary chemical in the dust fraction accounting for 84–87 % (the safe reference concentration equals 0.005 mg/m^3).

A ground-level dust concentration measured at the boundary of the sanitary protection zone around the analyzed facility equaled 0.035 mg/m^3. The data provided by the facility indicate that health risks are acceptable for people in the closest residential area since the hazard quotient (*HQ*[6]) is below 0.47, its permissible levels being 1.0. The facility is not given any tasks to reduce emissions or take any other actions aimed at minimizing public health risks.

Considering that 85 % of dust particles are aluminum oxide with its ground-level concentration being approximately 0.030 mg/m^3, health risks reach 7.0 HQ and this rate is 'high'[7]. A zone under harmful influence of the facility grows substantially in such a situation. Harmful exposure ($HQ > 1.0$) affects people living in 10 residential buildings, children attending pre-school children facilities and owners of more than 60 land spots with country houses. The situation is considered unfavorable and requires immediate measures to be taken to reduce aluminum oxide emissions.

Discussion. Dust pollution poses serious threats and health hazards. Managerial decisions concerning its level are usually made based on hygienic assessments including health risk assessment and characteristics. Given that, it is especially vital to correctly estimate dispersed and component structures of airborne dusts.

The major goal of social and hygienic monitoring is to establish reasons for violations of environmental safety and cause-effect relations within the 'environment – health' system. This activity requires advanced techniques for dust quantification and differentiation.

The suggested approaches based on such advanced techniques can be useful for continuous observations performed by Rospotrebnadzor experts. It is important that the method and its hardware support make it possible to identify and establish quantitative characteristics of both component and dispersed structure of dusts. This provides a solution to a whole set of tasks that may arise within monitoring activities or control of ambient air quality. Thus, actual levels of hazardous chemicals can be identified in ambient air (including heavy metal compounds etc.); contributions made by specific sources to pollution can be provided with solid evidence; population exposures can be estimated more precisely and adequately etc.

Undoubtedly, implementation of the suggested approaches largely depends on availability of libraries that contain attributed (annotated) microphotos. Such libraries (databases) ensure proper training of a neural network and subsequent recognition of sampled dust particles. At the same time, dust emissions are being examined widely enough at the moment [23–25]. This makes it possible to constantly accumulate and expand available data. In addition, many parties seem to have considerable interest in creation of such libraries. Surveillance authorities can rely on operative identification of marker chemicals to prove objectivity of administrative measures taken in a situation when some violations have been detected. Economic entities can both perform self-assessment within production control and defend their interests in difficult situations in case violations of hygienic standards have been detected during control and surveillance activities.

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[6] *HQ*, hazard quotient is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected (reference concentration) (the Guide R.2.1.10.1920-04).

[7] MR 2.1.10.0156-19. 2.1.10. Gigiena. Kommunal'naya gigiena. Sostoyanie zdorov'ya naseleniya v svyazi s sostoyaniem okruzhayushchei sredy i usloviyami prozhivaniya naseleniya. Otsenka kachestva atmosfernogo vozdukha i analiz riska zdorov'yu naseleniya v tselyakh prinyatiya obosnovannykh upravlencheskikh reshenii v sfere obespecheniya kachestva atmosfernogo vozdukha i sanitarno-epidemiologicheskogo blagopoluchiya naseleniya [The Methodical guidelines 2.1.10.0156-19. 2.1.10. Hygiene. Communal hygiene. Public health associated with quality of the environment and living conditions. Assessment of ambient air quality and public health risk analysis in order to make well-grounded managerial decisions concerning provision of ambient air quality and sanitary-epidemiological wellbeing of the population]. *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_415503/ (January 15, 2023) (in Russian).

Conclusions. In this study, we have described a new method to identify and quantify chemical and fraction structures of airborne dusts. The method is based on sampling and taking microphotos of dusts and subsequent analysis of the solid component in them using a neural network that has been trained relying on previously collected data about dust structure and their dispersed composition. Several technical decisions are suggested for image processing in order to raise an image quality and achieve more adequate results.

The suggested approaches can be useful for continuous observations performed by Rospotrebnadzor experts.

The method requires further adjusting and testing on a wider range of various types and levels of dust pollution. At the same time, the study results indicate the method offers wide opportunities that make it possible to:

– rapidly identify component and dispersed structure of dusts in ambient air;

– create a dust pollution profile;

– comparatively analyze and estimate contributions made by different sources to ambient air pollution;

– rely on obtained results to ensure more correct and precise health risk assessment.

Implementation of the suggested approaches largely depends on availability of libraries that contain attributed microphotos of dusts with various qualitative and disperse structure. Creation of such databases (libraries), data renewal and acquisition in them and their use in solving practical tasks can be a promising trend in further development of social and hygienic monitoring.

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Competing interests. The authors declare no competing interests.

References

1. Curtis L., Rea W., Smith-Willis P., Fenyves E., Pan Y. Adverse health effects of outdoor air pollutants. *Environ. Int.*, 2006, vol. 32, no. 6, pp. 815–830. DOI: 10.1016/j.envint.2006.03.012

2. Treskova Yu.V. Otsenka stepeni opasnosti melkodispersnykh chastits v atmosfernom vozdukhe i tselesoobraznost' ikh normirovaniya [Assessment of the degree of danger of fine particles in the atmospheric air and the feasibility of their regulation]. *Molodoi uchenyi*, 2016, no. 7 (111), pp. 291–294 (in Russian).

3. Health effects of particulate matter final. *WHO*, 2013. Available at: https://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf (December 27, 2023).

4. Health effects of dust. *Government of Western Australia, Department of Health*. Available at: https://www.healthywa.wa.gov.au/Articles/F_I/Health-effects-of-dust (December 27, 2023).

5. Revich B.A. Fine suspended particulates in ambient air and their health effects in megalopolises. *Problemy ekologicheskogo monitoringa i modelirovaniya ekosistem*, 2018, vol. 29, no. 3, pp. 53–78. DOI: 10.21513/0207-2564-2018-3-53-78 (in Russian).

6. Liao Z., Nie J., Sun P. The impact of particulate matter (PM2.5) on skin barrier revealed by transcriptome analysis: Focusing on cholesterol metabolism. *Toxicol. Rep.*, 2019, vol. 7, pp. 1–9. DOI: 10.1016/j.toxrep.2019.11.014

7. Magnani N.D., Muresan X.M., Belmonte G., Cervellati F., Sticozzi C., Pecorelli A., Miracco C., Marchini T. [et al.]. Skin Damage Mechanisms Related to Airborne Particulate Matter Exposure. *Toxicol. Sci.*, 2016, vol. 149, no. 1, pp. 227–236. DOI: 10.1093/toxsci/kfv230

8. Peters R., Ee N., Peters J., Booth A., Mudway I., Anstey K.J. Air Pollution and Dementia: A Systematic Review. *J. Alzheimers Dis.*, 2019, vol. 70, no. s1, pp. S145–S163. DOI: 10.3233/JAD-180631

9. Choi H., Kim S.H. Air Pollution and Dementia. *Dement. Neurocogn. Disord.*, 2019, vol. 18, no. 4, pp. 109–112. DOI: 10.12779/dnd.2019.18.4.109

10. Lee M., Schwartz J., Wang Y., Dominici F., Zanobetti A. Long-term effect of fine particulate matter on hospitalization with dementia. *Environmental Pollution*, 2019, vol. 254, pt A, pp. 112926. DOI: 10.1016/j.envpol.2019.07.094

11. Cserbik D., Chen J.-C., McConnell R., Berhane K., Sowell E.R., Schwartz J., Hackman D.A., Kan E. Fine particulate matter exposure during childhood relates to hemispheric-specific differences in brain structure. *Environ. Int.*, 2020, vol. 143, pp. 105933. DOI: 10.1016/j.envint.2020.105933

12. Katoto P.D.M.C., Brand A.S., Bakan B., Obadia P.M., Kuhangana C., Kayembe-Kitenge T., Kitenge J.P., Nkulu C.B.L. [et al.]. Acute and chronic exposure to air pollution in relation with incidence, prevalence, severity and mortality of COVID-19: a rapid systematic review. *Environ. Health*, 2021, vol. 20, no. 1, pp. 41. DOI: 10.1186/s12940-021-00714-1

13. Comunian S., Dongo D., Milani C., Palestini P. Air Pollution and COVID-19: The Role of Particulate Matter in the Spread and Increase of COVID-19's Morbidity and Mortality. *Int. J. Environ. Res. Public. Health*, 2020, vol. 17, no. 12, pp. 4487. DOI: 10.3390/ijerph17124487

14. Baumann R., Krzyzanowski M., Chicherin S. Framework plan for the development of monitoring of particulate matter in EECCA. Bonn, WHO European Centre for Environment and Health, 2006. Available at: https://www.euro.who.int/__data/assets/pdf_file/0019/130762/E88565.pdf (December 27, 2022).

15. Kokoulin A.N., Kokoulin R.A. The Hierarchical Approach for Image Processing in Objects Recognition System. *Proceedings of the 2022 Conference of Russian Young Researchers in Electrical and Electronic Engineering (ElConRus)*, 2022, pp. 340–344.

16. Wang W., Chang F. A Multi-focus Image Fusion Method Based on Laplacian Pyramid. *Journal of Computers*, 2011, vol. 6, no. 12, pp. 2559–2566. DOI: 10.4304/jcp.6.12.2559-2566

17. Kokoulin A.N., Yuzhakov A.A., Kokoulin R.A. Multiscale Optical PM2.5 Particles Recognition and Sorting System in Dust Probes. *2020 5th International Conference on Smart and Sustainable Technologies (SpliTech)*. Croatia, 2020, pp. 1–6. DOI: 10.23919/SpliTech49282.2020.9243759

18. Lai W.-S., Huang J.-B., Ahuja N., Yang M.-H. Fast and Accurate Image Super-Resolution with Deep Laplacian Pyr-amid Networks. Available at: https://arxiv.org/abs/1710.01992 (February 10, 2023).

19. Wronski B., Garcia-Dorado I., Ernst M., Kelly D., Krainin M., Liang C.-K., Levoy M., Milanfar P. Handheld Multi-Frame Super-Resolution. *ACM Transactions on Graphics*, vol. 38, no. 4, pp. 1–18. DOI: 10.1145/3306346.3323024

20. Sysoeva E.V., Gel'manova M.O. Issledovanie zagryazneniya raiona Moskvy melkodispersnymi chastitsami pyli vblizi avtomobil'nykh dorog [Study of pollution of the Moscow region with fine dust particles near highways]. *Aktual'nye problemy stroitel'noi otrasli i obrazovaniya: Sbornik dokladov Pervoi Natsional'noi konferentsii*. Moscow, Natsional'nyi issledovatel'skii Moskovskii gosudarstvennyi stroitel'nyi universitet Publ., 2020, pp. 566–571 (in Russian).

21. Volodina D.A., Talovskaya A.V., Yazikov E.G., Devyatova A.Yu., Edelev A.V. Assessment of dust and aerosol pollution in the zone of influence of the cement plant based on the study of snow cover (Novosibirsk region). *Izvestiya Tomskogo politekhnicheskogo universiteta. Inzhiniring georesursov*, 2022, vol. 333, no. 10, pp. 69–85. DOI: 10.18799/24131830/2022/10/3704 (in Russian).

22. Budaeva Yu.S. Ecological and geochemical assessment of the territory of Yurga according to the data of studying the snow cover (Kemerovo region). *Aktual'nye problemy nedropol'zovaniya: tezisy dokladov XVIII Mezhdunarodnogo foruma-konkursa studentov i molodykh uchenykh*, Saint Petersburg, 2022, pp. 172–175 (in Russian).

23. Methodology for monitoring dust concentrations in ambient air and analysis of collected measurements. *CEE Bankwatch Network*. Available at: https://bankwatch.org/wp-content/uploads/2020/07/Methodology-EDM-164.pdf (January 13, 2023).

Kokoulin A.N., May I.V., Zagorodnov S.Yu., Yuzhakov A.A. On new methods for measuring and identifying dust microparticles in ambient air. Health Risk Analysis, 2023, no. 1, pp. 36–45. DOI: 10.21668/health.risk/2023.1.04.eng

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