Component, Disperse and Morphological Composition of Ambient Air Dust Contamination in the Zones of Mining-Processing Enterprises

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Abstract. The article presents the results of complex studies of dust emissions of the mining and processing complex. The main technological processes and the sources operation that produce intense dust emissions are determined. It has been proved that dust emissions of the investigated enterprise contain fine dust dangerous for human health. The results of the studies allowed us to detect precisely the dispersed composition of dust emissions, with the separation of PM10 and PM2.5 fractions, the chemical composition of the dust, and the shape of the particles. Thus, operating with obtained data on dispersed composition of the dust emissions and the specified sedimentation coefficient, we were able to calculate the dispersion of all solid particles and separately the PM10 and PM2.5 at the location of the enterprise. The dust exposure of the population at the targeted zones has been also determined. The obtained concentration values were used for assess health risk level to population living at the border of sanitary protection zone of the enterprise. Due to the obtained results, the enterprise was provided with recommendations on the inclusion of fine particles PM 10 and PM 2.5 in the production control program. In the case of increasing its production capacity was recommended to introduce the environmental measures for the reduction of emission of the finely dispersed fractions PM10 and PM 2.5.

1. Introduction
Dusty mixtures, emitted by industrial enterprises of the mining and processing complex, contain chemical components – heavy metal oxides, nitrates, sulfates, soot, etc. Particular danger to human health is represented by dust emissions containing fine particles up to 10 microns. This danger is becoming more and more obvious. From 1990 to 2010, 3.1 million people died of the causes associated with PM2.5 particles. Another figure: particles PM2.5 reduce the expected life span by an average of 8.6 months. Totally 3% of deaths from cardiovascular and respiratory system diseases and 5% of deaths from lung cancer are associated with PM2.5 [1, 2].

The next important point in the study of fine particles is their volatility. Dust emissions from industrial enterprises contain particles of various sizes: large, medium, small, while large dust particles freely accumulate near the plant. Small particles PM 2.5 accumulate more slowly, it is more difficult for them to overcome the resistance of the environment and accumulate on the ground. For the smallest particles, the resistance is also caused by Brownian motion. Being in suspension, fine particles are carried over long distances, creating dangerous concentrations in the territory of the population residence [3].

2. Purpose of the Study
Due to the fact that numerous negative effects of PM10 and PM2.5 fine dusts on human health have been proved by numerous studies [4, 5], as well as the possibility of adsorption of toxic components, including heavy metals, on dust particles, the goal of the present study was to evaluate quantitatively the component and dispersed composition of dust pollution of the ambient air in the zones of location of the primary magnesium production complex, as well as to describe the features of dust particles’ morphology.

3. Object of the Study
The research object became a large mining and processing enterprise of the Perm Krai - the leader of the magnesium and rare metal industries of the Russian Federation, which accounts for almost 100% of REE, niobium and tantalum, more than 60% of commercial magnesium in the country [6].

4. Methods of Research
Sampling was carried out directly on the main sources of dust emission during the operation of process equipment, at a distance as close as possible to the source of dust emission. The distance depended on the specifics of the technological process. During the selection, filter materials were used to maximize the preservation of the fractional composition of the dust. The dispersion composition of the emissions was evaluated using a Microtrac S3500 laser particle analyzer (covered particle size range varied from 20 nm to 2000 μm); particle morphology and component composition were determined by electron microscopy using a high-resolution scanning microscope (magnification degree from 5 to 300 000 times) with a X-ray fluorescent attachment S3400N "HITACHI". The chemical composition was identified by X-ray phase analysis of the samples using an XRD-700 X-ray diffractometer "Shimadzu". To determine the level of dust pollution and to establish the emitting zones of influence of fine dust particles PM 10 and PM 2.5 and their comparison with the zones of influence of dust particle emissions without taking into account the dispersion, the model simulation of the dispersion of particulate pollutants’ emissions from the sources of the enterprise has been conducted. Dispersion calculations were carried out using a unified program for the calculation of air pollution, implementing the provisions of OND-86 [7]. The calculations were verified by instrumental research.

5. Results of the Study
The obtained results of the research have demonstrated, that the disperse structure of dusts in emissions of various technological processes is heterogeneous. The results of instrumental studies of the determination of the different fractions portion (%) in the dust particles are shown in Table 1.

| No s/p | Point of selection (Technological operation) | PM$_{2.5}$,% | PM$_{10}$,% | More than 10 micron |
|-------|---------------------------------------------|-------------|-------------|-------------------|
| 1     | Unloading of finished products               | 10.77       | 26.03       | 73.97             |
| 2     | Loading (steam hydrolysis section)           | 56.70       | 76.43       | 23.57             |
| 3     | Unloading (steam hydrolysis section)         | 13.69       | 16.69       | 83.31             |
| 4     | Unloading of finished products (precipitation of REM carbonates) | 20.34       | 85.60       | 14.40             |
| 5     | Preparation of soda solution                 | 1.63        | 9.88        | 90.12             |
| 6     | Mg refining, alloy preparation               | 0.00        | 0.56        | 99.44             |
| 7     | Grinding of flux                            | 2.14        | 19.96       | 80.04             |
| 8     | Grinding of sulfur                          | 3.33        | 18.79       | 81.21             |
Casting of metal on a foundry conveyor

|   |                                                                 |     |     |     |
|---|-----------------------------------------------------------------|-----|-----|-----|
| 9 | Draining of SHES from the scrap crucible into the process box  | 4.55| 15.53| 84.47|
| 10| Filter cleaning (chlorine after electrolysis)                    | 0.00| 0.514| 99.49|
| 11| Lifting and filling of supply bins                              | 11.66| 38.63| 61.37|
| 12| Unloading into the hopper (lime for neutralization of chlorine)  | 0.00| 0.00 | 100.00|
| 13| Lime after roasting                                             | 5.97| 30.13| 69.87|
| 14| Loading of CaF2                                                 | 3.35| 30.98| 69.02|
| 15| Distillation of carnallite dust from in / ovens                 | 9.75| 44.48| 55.52|
| 16| Loading of chlorators with charge                               | 9.02| 28.99| 71.01|
| 17| Transportation of carnallite to the KS furnace                  | 15.31| 27.60| 72.40|
| 18| Transportation of carnallite from the KS furnace                | 8.04| 41.05| 58.95|

The fraction of particles up to 2.5 μm in size (PM 2.5) inclusive was from 0.00 to 56.70%; Particles of less than 10 μm in size (PM 10) inclusive - 0.00 - 85.60%; Particles with sizes more than 10 microns - 14.40 -100.00%. Under microscopic study, the presence of nano-sized particles was established.

The distribution of the dispersed composition of dust emissions of the dust particles studied in the ejection structure is presented in the form of histograms in figure 1.

![Image](image_url)

**Figure 1.** Percentage of suspended particles in industrial emissions.

In the course of the study, the component composition of the dust emissions of the selected samples was studied. The main share of the component composition of emissions consists of impurities distinctive for this production: magnesium, potassium, calcium, chlorine, silicon and metal oxides: iron, aluminum, lead, copper, manganese, zinc, chromium. Figure 2 shows the spectrograms of the emission components from the operation of the technological equipment of the investigated enterprise.
Figure 2. Spectrograms of the component composition of dust emissions of the investigated enterprises.

The studied morphological features of the selected samples allowed us to identify the shapes of fine particles emitted into the atmospheric air. It is determined that the dust particles have a rounded, irregular, cubic and composite shape. Images of dust particles of different shapes are shown in figure 3. Based on the obtained results of the disperse composition and morphological features, model calculations of the dispersion of dust emissions were carried out and zones of distribution of fine dust PM 10 and PM 2.5 over the territory were established and compared with the zones of influence of dust particle emissions without allowance for dispersion.

As initial data, the inventory data the pollutant sources of the investigated enterprise were used. The calculation took into account the emissions of solid pollutants and finely dispersed dusts PM10 and
PM 2.5. For each release of solid pollutants and finely dispersed dusts PM10 and PM 2.5, the settling coefficient (sedimentation) was refined [8]. Calculation of dispersion was carried out at the areas on the border of the sanitary protection zone of the enterprise and on a regular grid covering the territory of the enterprise and the outskirts including the territory of the population habitation.

Figure 3. Forms of fine particles of the mining and processing complex.

Figure 4. Isolation of dispersion of magnesium oxide (without taking into account the dispersed composition).
Figure 5. Isolation of dispersion of PM 10.

Figure 6. Isolation of dispersion of PM 2.5.
Calculation of the dispersion of dust emissions without taking into account the dispersed composition, according to the substances specific for the given production, established concentrations in the population's living areas for magnesium oxide - 0.37 MPC m, for calcium oxide - 0.14 MPC m.

Taking into account the dust emissions of finely divided fractions separately for PM10 and PM2.5, the calculated concentrations of finely divided fractions at the population residential areas were established for RM 10 - 0.54 MPC m, for RM 2.5 - 0.31 MPC m. Which indicates a higher level of air pollution. More than 200 people will live in the zone of the established exposition at the moment, including about 20 children.

In general, the situation should be assessed as a safe one, the normative quality of atmospheric air is observed at the border of residential areas.

Areas of distribution of solid dust emissions without taking into account the dispersed composition and fine particles in the form of isolines of dispersion are presented in figures 4-6.

Analysis of indicators of the health risk of the population [9] at the population residential areas determined that the maximum value of the coefficient characterizing the acute inhalation effect for fine particles is PM10 - 1.07 HQ, PM 2.5 – 0.77 HQ, which allows to assume risks of the formation of respiratory functions disorders in the population permanently residing near the enterprise, as well as other deviations in the state of health, characteristic for the action of finely dispersed particles.

The availability of up-to-date data on the dispersed composition of dust emissions made it possible to establish exposure levels to such hazardous components as PM 10 and PM 2.5, as well as to more accurately assess the health risks for the population.

Based on the results of the conducted studies, the enterprise was recommended to include in the production control program finely dispersed particles of PM 10 and PM 2.5 at the areas of population residence. In case of increasing production capacity, the introduction of environmental measures to reduce emissions of finely dispersed fractions of PM10 and PM 2.5.

6. Conclusions
- It is established that the technological processes of the mining and processing complex are accompanied by intense dust emission;
- it is proved that majority of the sources of the investigated enterprise contain emissions of fine particles dangerous for human health. Dust emissions into the atmosphere contain PM10 to 85.60%, PM2.5 to 56.70%;
- according to the study, it is clear that the probability of the presence of hazardous small particles in the air in the zones of influence of production facilities is quite high. The population living in the area of the enterprise is under the influence of dust factor;
- availability of actual information on dust emissions - component composition, dispersed composition, particle shapes, allow more accurate assessment of the exposure level at specified areas and apply the methodology for assessing the health risk for the population.

7. List of References
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