Environmental monitoring of ecological safety during construction works

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Abstract. Environmental monitoring of the construction works must consists of the modern scientific methods and techniques of physical, chemical, and biological measurements for monitoring the construction sites intermittently or continuously. It determines the pollutant factors and makes the right environmental quality assessment.

During the construction period the environmental monitoring subjects are the construction waste water and the sanitary sewage, the surface water around construction site, the noises around the site and from the construction site engines (if the construction period has continuous operations, the monitoring takes place 24 hours a day) and the dust. Particular attention should be paid to monitor the concentration of fine dust particles, due to the negative impact on human health.

In order to get the effective data about the PM₂.₅ and PM₁₀ fine dust particles concentration in the air during the construction operations a slightly polluted area was studied according to the map of the dust emission. This area is located in Zheleznodorozhnny district of Rostov-on-Don up to the Seversky Donets River. The large residential development «Ekaterininsky» is under construction there.

The environmental monitoring of this fine dust polluted area included the study of three subjects.

The results of local dust emission showed the significant amount of fine dust from any height levels where construction works are carried out.

This article describes the results of environmental monitoring of dust pollution in Rostov-on-Don and environmental requirement and measures which should be designed in the Construction method statements and the Work performance projects for reducing the environmental impact during construction operations.

1 Introduction

Environmental monitoring of construction works must consists of the modern scientific methods and techniques of physical, chemical, and biological measurements for monitoring the construction sites intermittently or continuously. It determines the pollutant factors and makes the right environmental quality assessment.

All the stages of construction production need the environmental monitoring, due to the different purposes of monitoring.
During the construction period, the environmental monitoring can identify accurately and fairly the construction operations’ influence on the site and surrounding area and provide the scientific data for environmental management. The continuous monitoring can obtain the monitoring results in real time, in order to help the environmental management team to check the environmental quality of the site timely and to be able to assume the corrective measures.

During the construction period the environmental monitoring subjects are the construction waste water and the sanitary sewage, the surface water around construction site, the noise around the site and from the construction site engines (if the construction period has continuous operations, the monitoring takes place 24 hours a day) and the dust. Particular attention should be paid to monitoring the concentration of fine dust particles, due to the negative impact on human health.

PM is a generic term for a variety of solids or liquid droplets over a wide range of sizes. Two mechanisms are accounted for the presence of atmospheric PM: primary emission and secondary formation. Primary particles are emitted directly into the air as a solid or liquid particle. Secondary particles form in the atmosphere sulfate, ammonia, and nitrate species as a result of chemical reactions among precursors. Airborne PM with a nominal aerodynamic diameter of 2.5 µm or less is considered to be fine PM or PM$_{2.5}$. Both primary emission and secondary formations are significant contributors to atmospheric PM$_{2.5}$.

The works of V.N. Azarov, [7-10], N.V. Menzelintseva [11], M.V. Trokhimchuk, [9], T.V. Solovyeva [12], I.V. Stefanenko [13] and many others are devoted to the study of the dust emission and the evaluation of influence on the environment.

During the monitoring, the construction site engines must operate normally, the construction operations must be performed also normally.

The environmental quality standards during the construction period are:
1. Federal law no.7-FL (R.E. from 29.07.2018) Environmental Protection Act, Russia. 2002. [1]
2. Federal law no.96-FL (R.E. from 28.12.2017) Ambient Air Protection Act, Russia. 1999. [2]
3. Health standards 2.2.5.1313-03 Exposure limits. Russia. 2003. [3]
4. Sanitary Rules and Regulations 2.1.6.1032-01 Hygienic Requirements for Atmospheric Air Protection in Populated Areas. Russia. 2001. [4]
5. Rules of construction 51.13330.2011. Noise protection. Russia. 2011. [5]

2. The environment monitoring
2.1 The environment monitoring mythology
The number of monitor factors and the monitoring frequency are selected according to the curtain construction characters of the project.

The air quality factors, as TSP or PM$_{10}$ concentration, the sampling points of the monitoring will vary with the wind direction. The data will be taken from three sampling points: the 1$^{st}$ one is the upwind and others are the downwind. The current monitoring points will be determined according to the wind direction on that day.

It is recommended to install the associated monitoring equipment on the construction site for the well-timed monitoring.

If the values of the factors tend to certain limits during the analyzing and comparison the results of the monitoring, it is necessary to appropriate corrective measures. It helps to prevent environmental factors exceeding the standard. When environmental monitoring results achieve the grade of “alert value” (refer with: Table 1), corrective measures need to be taken immediately. After that, it is necessary to monitor the environmental factors again, in order to verify the improved effects.

2.2 Ecological situation in Rostov-on-Don
The significant sources of the air pollution in Rostov-on-Don are the mobile and stationary ones. According to statistics of 2018 in the Rostov region, the emissions of pollutants into the atmosphere of the city amounted up to 130.999 thousand tons. The most of pollution is from mobile sources – 121.427 thousand tons, and the other ones are from stationary sources – 9.572 thousand tons. If we
compare this data with the previous year, the total amount of the emissions into the atmosphere is decreased by 21,267 thousand tons. The main sources of air pollution of Rostov-on-Don are motor vehicle emissions (over 70% of the total amount), emissions from construction operations, plants and factories emissions, etc.

| Item no | Monitoring items | Level | Daily average          |
|---------|------------------|-------|------------------------|
| 1       | TSP              | Low level | Average before construction |
|         |                  | Alert level | 130% larger than low level |
|         |                  | Rated level | 500 [mg/m³] |
| 2       | PM10             | Low level | Average before construction |
|         |                  | Alert level | 130% more than the low level |
|         |                  | Rated level | 95 [mg/m³] |
| 3       | Sound level      | Low level | Average before construction |
|         |                  | Alert level | Dayshift: 120% more than the low level |
|         |                  |           | Nightshift: 110% more than the low level |
|         |                  | Rated level | Dayshift: 70 [dB] |
|         |                  |           | Nightshift: 60 [dB] |

At this moment the dust emissions are also becoming the primary pollutants that should be taken into account during the environment monitoring management. The dust pollution monitoring of the air environment is the complex present-day task for realization. This type of monitoring determines the actual data of air quality, the dust concentration, the health hazard degree evaluation.

The most important factor for the health hazard degree evaluation of the dust influence is determining the size of its particles. Particular attention should be paid to the concentration of small size particles (less than 10µm). This kind of dust is a characteristic of dust generation in cities. Its development is a result of construction operations, the work of the industrial enterprises (dusty producing operations), and the motor vehicle emissions. Therefore, today one of the research priorities must be in controlling the concentration of the fine dust particles in the air pollution of the urban environment.

At the same time, it is very important to apply the interdisciplinary approach for the determining the local concentration and dispersion of the dust in the air during construction operations. Thus, it is necessary to determine the air sampling points, taking into account the areas where the dust production is highly intensive. The development of methods for determining the level of the fine dust concentration, as well as methods of possible prediction of dust levels, depending on various factors is also very important.

One of the essential methods for determining the air pollution with fine dust is the gravimetric method. The gravimetric method is used to determine the massive emission of pollutants according to the data on the fuel and feed compositions, the production conditions, the efficiency of gas cleaning by gas-dusting equipment, etc. It calculates the empirical dependencies or specific emissions of harmful substances per unit of output, used raw materials, fuel and generated energy.

Airplanes and helicopters, as well as satellite systems, are used to control the air quality at high altitudes. The automatic monitoring systems with large coverage capacity are also used. The air
pollution monitoring systems are established and operated in a number of countries. There are many methods for monitoring air pollution; among them are the methods based on the use of lasers of the higher status.

In addition to the monitoring the air pollution methods level, the indirect methods are also used. They are the samplings of the atmospheric precipitation, the determination of the concentration of harmful substances in snow, soil and vegetation.

According to the map of dust emission in Rostov-on-Don (Figure 1), the most polluted areas in Rostov-on-Don are: Leventsovskiy and Chkalovskiy districts, the central part of the city. Much less pollution is in Zheleznodorozhniy district of Rostov-on-Don up to the Seversky Donets River. The construction production of the large residential development «Ekaterininsky» in the Zheleznodorozhniy district near the Kumzhenskaya grove pollutes the atmospheric air with fine dust from 2.5 to 10µm, among all other pollutants.

![Figure 1. The map of the dust emission in Rostov-on-Don](image)

At present, a number of countries, including Russia, have the permissible levels of pollution for particles of size not exceeding 2.5µm (PM$_{2.5}$) and 10µm (PM$_{10}$), since the dust particles of small size
are the most dangerous, they are able to penetrate the human lungs. However, it is typical to consider the concentration of the suspended substances without taking into account their particles’ size.

Most researchers monitor the amount of suspended substances near highways without taking into account the fractional composition of dust. Recently, the number of diseases which are typical in the construction industry among the residents of many cities has increased. The reason for this situation is the lack of control over the dustiness of residential areas of populated areas.

In studies conducted to date, the lower threshold level of air pollution of fine dust, below which PM\(_{10}\) does not affect the human body, could not be determined. However, the WHO working group believes that the threshold concentration of PM\(_{10}\) is in the lower part of the range of concentrations of PM\(_{10}\) in the European Region. The standards of air quality (Table 2) in Russian Federation, EU, and WHO shows the threshold levels of air pollution.

**Table 2.** Air quality standards: RF, EU, WHO

| Polluting substance | The averaging time | Concentration, [\(\mu g/m^3\)] |
|---------------------|--------------------|---------------------------------|
| Suspended substance, the particles of size <10[\(\mu m\)] (PM\(_{10}\)) | 24 hours, year | RF  | EU  | WHO |
|                     |                   | 60  | 50  | 50  |
| Suspended substance, the particles of size <2,5[\(\mu m\)] (PM\(_{2.5}\)) | 24 hours, year | RF  | EU  | WHO |
|                     |                   | 35  | -   | 20  |
| Suspended substance (overall concentration) | 24 hours (daily mean), 20 minutes | RF  | EU  | WHO |
|                     |                   | 500 | -   | -   |
|                     |                   | 15000 | -   | -   |

The total amount of pollutants (refer with Figure 2) shows the current ecological situation in Rostov-on-Don.

**Figure 2.** The total amount of pollutants in Rostov-on-Don

The sources of these emissions are the motor vehicle and road-building machinery emissions. During their operation the combustion products of diesel fuel are emitted into the atmospheric air.

The air pollution of Rostov-on-Don consists of the vehicle emissions mainly (more than 70% of the total), as well as emissions from heat and power engineering facilities, construction operations, engineering enterprises. The construction operations take the 3rd place for air pollution. Over the past 3 years, air pollution in this sector has increased in 150%.
The most appropriate method for controlling the air pollution is the display method, which is based on the use of selective indicator elements. They change their color depending on the concentration of atmospheric contaminant in the emissions.

In order to get the effective data about the PM$_{2.5}$ and PM$_{10}$ fine dust particles concentration in the air during the construction operations a slightly polluted area was studied according to the map of dust emission. This area is located in Zheleznodorozhniy district of Rostov-on-Don up to the Seversky Donets River. The large residential development «Ekaterininsky» is under construction there.

2.3 The results of the ecological monitoring of the construction sites in Rostov-on-Don

The environmental monitoring of this fine dust polluted area included the study of three subjects:

1. Construction site at the moment of earthwork operations.
2. The apartment building put into operation, inhabited and located at a radial distance of 200-300m from the construction site.
3. The apartment building has been put into operation recently, where the repair and construction works are being carried out. The fine dust concentration sampling was carried out by height along; sampling took place at 5 points at different heights. The results of the researching showed the significant PM$_{2.5}$, PM$_{10}$ emissions there.

The analysis of the air pollution of a residential building with the repair and construction works carried out showed these result values.

The variation range of the dust particles size of dust in the residential building with the repair works is from 0.5μm to 10μm, the value of the median diameter (d50) ranges from 6.3μm on the 6th floor to 8.2μm on the 20th floor. The most common dust size (from 70% to 90%) is from 8μm to 10μm. The maximum value of the dust with a size of 10μm is on the 6th floor. The maximum value of the dust with a size up to 2.5μm is on the 11th floor. Also, it is worth noting that on the 20th floor the value of the dust with a size from 5 μm to 10μm is less than on the other floors.

The analysis of the air pollution of a residential inhabited building showed these result values.

The variation range of the dust particles size of a residential building next to the construction site is from 0.5μm to 10μm, the value of the median diameter (d50) ranges from 7.5μm on the 25th floor to 8.4μm on the 2nd floor. 60-75% of dust value is dust with a size from 8.3μm to 10μm. The largest dust size of 10μm is on the 25th floor. The maximum value of the dust particles with the size up to 2.5μm is also located on the 25th floor. It is worth noting that on the 2nd floor, dust of the size as high as 2.5μm is less than on the other floors.

The analysis of the overall concentrations of the dust pollution at the sampling points of the construction site showed these result values.

The variation range of the dust particles size around the perimeter of the building construction site is from 0.5μm to 10μm. The median diameter value (d50) is 7μm for the 4th point, 7.3μm for points #1 and #3, and 9.4μm for the 2nd point. The most common dust size (70-80%) is from 9 μm to 10μm at all points, except the 2nd one. The maximum value of dust with a size of 10μm is at the point #4. The maximum value of the dust with a size up to 2.5μm is at point #1. Also, it is worth noting that at the 2nd point the value of the dust with a size from 5μm to 10μm is minimum than at the rest ones.

3 Summary

During the construction period of the large residential development, the significant PM$_{2.5}$ and PM$_{10}$ dust emission is observed.

The results of the local dust emission in residential buildings under construction researching showed the significant amount of fine dust from any height levels where construction works are being carried out.

It was determined that the level of the fine dust concentration from 2.5μm to 10μm exceeds the permissible level of pollution during the construction operations and PM$_{2.5}$ is concentrated at higher levels then PM$_{10}$.
The development of methods aimed at reducing the harmful effect on the atmospheric air is based on the finding the way of improvement construction technologies and operations.

Environmental monitoring of the construction industry should include:

1. Environmental monitoring and assessment of potential environmental impacts of the local air pollution from the harmful effects of the construction works.
2. Interpretation of analysis results and impact assessment depending on the purpose of the study.

It should be noted that the received data can be used for a general compromise solution. For example, the kinds of materials better to be used in the construction operations such as plastering, painting and other finishing works can be determined.

It is necessary to get the conditions when process technologies with the significant dust emission follow the equation:

\[ G = mg = \sum_{i=1}^{n} F_i \times \sum_{i=1}^{n} F_i \times \sum_{i=1}^{n} F_i \times \sum_{i=1}^{n} F_i, \]  

(1)

Where \( G \) - gravity force, \( m \) - mass of a particle (kg), \( n \) – number of contacts of a particle with compounds, \( F_i \) - cohesive strength between particles.

It is necessary to try to get \( G \rightarrow \text{const} \).

Then it will be possible to make any decisions to ensure even minimal air pollution.

There were three subjects for researching where the sampling took place during the local construction operations.

The hand-held particle counter Handheld 3016 was used for sampling. The results of the research showed that locally dust was concentrated at the place of the construction and repair works. Then it is spread in all directions including upstairs. The coarse particles are precipitated faster.

The fine dust rises to higher levels and spreads from building to building.

The results of the analysis also showed that the excess of the lower threshold level of the air pollution is more approximately in 20 times. The construction of the large residential developments is cost-effectively, so there is a tendency to build them, that’s why the lower threshold level of dust pollution can be increased in several times.

The environmental requirements for the residential construction can be divided into main levels of local pollution with PM\(_{2.5}\) and PM\(_{10}\):

1. The requirement of environmental safety in the design of buildings;
2. The environmental safety control during the certain elements of buildings production and the use of the construction materials in the construction operations;
3. The period of special environmental safety control during the construction of buildings and their commissioning.

All these measures are designed at the stage of the construction method statement development, and then at the stage of the work performance project development in accordance with the rules of construction 48.13330.2011 organization of construction [6].

Their goal is the minimum impact on the ecosystem of the environment at the location of the building or the construction site. The technogenic ecosystem is changed under the influence of building technological processes, creating in particular the mechanism of the biosphere destruction.

Reducing of this impact means reducing of their destructive intensity. Such security is ensured by outturn costs in environmental protection measures.

All technological constructions affecting the environmental safety should be designed in the construction method statement and the work performance project with mandatory scheduling of the timing of these processes and the use of the protective measures against the local pollution of the air environment with PM\(_{2.5}\) and PM\(_{10}\) particles during this period.

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