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STUDYING THE IMPACT OF SINGLE BLASTS IN OPEN PITS ON THE AIR DUSTINESS IN THE CITY OF KRIVYI RIH

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Abstract. Great attention is paid worldwide to the ecology and ecological characteristics of the environment. Environmental safety is controlled in the mining regions and near the mining enterprises. To reduce dust emissions during single blasting in open pits, modern methods of dust control are used and new types of impulse explosives are applied. However, a problem of air pollution within the neighbouring territories is only being deteriorating. With this object in mind, more than 30 000 stations of air quality monitoring have been built all over the world. They record the indices of gases and fine-dispersed dust particles PM 2.5 and PM 10, which are the main factors of chronic disease risks.

The paper objective is to evaluate the nature of changes in air dustiness at the territory of mining Kryvyi Rih region taking into account the effect of single blasting in the open pits, meteorological conditions, and exogenous factors.

The paper represents the analysis of single blasting influence on the dust particle concentration in the atmosphere. The analysis involved both meteorological data and the data on the air quality obtained from 10 stations of automatic monitoring at the territory of the Kryvyi Rih region. Basing on the obtained data, graphs of temperature change, wind velocity and direction, relative air humidity, and dust particle concentration were developed. Interrelations between the meteorological conditions and dust particle concentration in the air were studied. It was identified that within the observation period single blasts in the open pits did not affect considerably the atmospheric dust pollution in the Kryvyi Rih region. The influences of the temperature inversion in dust concentration at night time were analyzed. It was specified that high temperature inversion was observed within the considered period of time.

Keywords: ecology, monitoring stations, dust concentration, fine-dispersed particles, single blast, open pit.

Introduction. Environmental safety of the industrial and mining regions is a topical problem for numerous countries of the world. Its solution requires that the industrial enterprises should control constantly their environmental impact. Consequently, the international standard ISO 14001:2015 has become widely used. The standard determines both implementation and functioning of the effective system of environmental management at an enterprise [1].

Technogenic air pollution with solid dust particles (PM) is the main factor of the chronic disease risks. In this case, solid dust particles PM 2.5 (with the diameter from 0.001 to 2.5 mcm) and PM 10 (with the diameter from 2.5 to 10 mcm) are considered. The PM 2.5 particles are the most dangerous ones [2] as they are fine-dispersed and can get deep into the lungs. According to the Worlds Health Organization, the average daily concentration of solid particles should be not more than [3] PM 2.5 – 0.025 mg/m^3 and PM 10 – 0.05 mg/m^3. The origin of solid fine-dispersed particle may be natural (ash of volcanic eruptions, fires), anthropogenic (exhaust gases, vapours, reagents), or technogenic (dust emissions of mining and processing facilities).

Currently, there are more than 30 000 stations of air quality monitoring; they are located in 132 countries to provide information on the air quality worldwide.

According to the project “World Air Quality Index” (AQI), more than 12 000 stations provide the data only concerning particles PM 2.5 and PM 10 [4]. Fig. 1 represents a typical flow-chart of such a station [5].

Stations of automatic air quality monitoring (Fig.1) make it possible to control concentrations of dust particles in the air including particles PM 2.5 and PM 10.

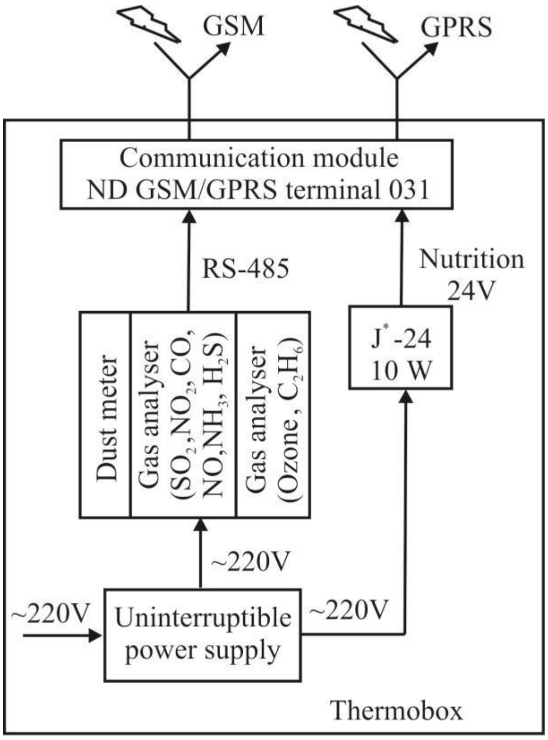


Figure 1 – Typical flow-chart of the automatic air quality monitoring station

Besides, the content of following gases is controlled:

nitrogen dioxide (NO_2); nitrogen oxide (NO); sulphur dioxide (SO_2); carbon oxide (CO); ammonia (NH_3); hydrogen sulphide (H_2S); ozone (O_3); ethylene (C_2H_4).

The control stations collect data from a meteorological station on the atmospheric pressure, wind velocity and direction, air temperature and humidity.

While open-cast mining, environmental task of the production is to provide safe dust and gas concentrations both within the worked-out space of the open pits and in the atmospheric layer above the neighbouring territories.

Violation of the technological requirements and ventilation modes as well as unfavourable meteorological conditions results in the increasing concentration of hazardous substances in the air. Moreover, increased air pollution in the open pit space takes place while single blasting.

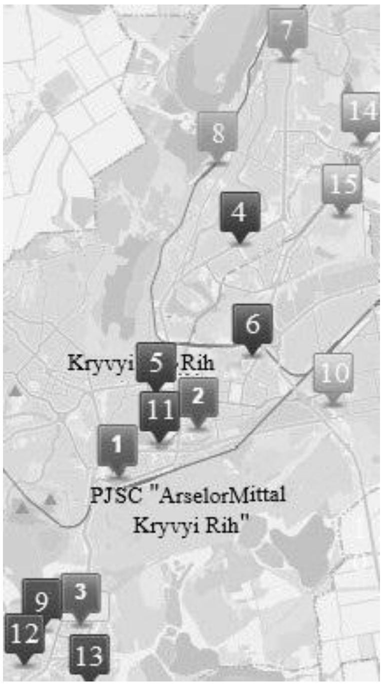
Air quality monitoring in the open pits and at the boundary of sanitary-protective zones helps evaluate the efficiency of measures aimed at reduction of air pollution. Thus, studying the influence of open-pit mining on the nature of air pollution is rather a topical environmental task.

Methods. The purpose of the research is to evaluate the nature of changes in air dustiness at the territory of mining Kryvyi Rih region taking into consideration the effect of single blasting in the open pits, meteorological conditions, and exogenous factors.

The Kryvyi Rih region is one of the world largest ones in terms of iron ore reserves. The deposits are being developed by surface and underground mining.

Modern methods of dust control and impulse explosives are used to reduce dust emissions while single blasting in the open pits. However, there is a problem of emissions of hazardous dust particles PM 2.5 and PM 10.

The territory of this region includes 33 stations of air quality monitoring (MS). The monitoring is provided for 5 municipal and 28 industrial enterprises [5]. Fig.2 shows a scheme of location of the automatic air quality monitoring stations [5].



1, 2,…, 15 – numbers of the monitoring stations*

Figure 2 – Location of the automatic air quality monitoring stations
(* to simplify the data analysis, other numbers are assigned for the monitoring stations)

The stations of automatic air quality monitoring (Fig. 2) belong to the following enterprises [5]: # 1, # 2, # 3 (“ArcelorMittal Kryvyi Rih” PJSC); # 4, # 5, # 6, # 11 (municipal stations); # 7, # 8 (“Kryvbaszalizrudkom” JSC); # 10 (Kryvyi Rih Cement PJSC); # 9, # 12, # 13 (JSC Southern GZK); and # 14, # 15 (METINVEST-KMRP LLC).

The current paper studies the effects of blasting operations performed on 14.01.2021 (12 p.m.) at open pits # 2-bis and # 3 of the mining enterprise “ArcelorMittal Kryvyi Rih” PJSC on the air quality of neighbouring territories within the city of Kryvyi Rih. The air pollution was being analyzed from 13.01.2021 (12 am) till 15.01.2021 (11 pm).

To study the obtained results, a wind rose for the region of Kryvyi Rih was developed basing on the meteorological data [5] (Fig.3).

Analysis of the meteorological data (Fig.3) represents the priority wind directions and ranges of the wind velocity variations. During the period under consideration, the southern-western wind prevailed. A wind velocity varied within the range of 0.4 – 2.8 m/s.

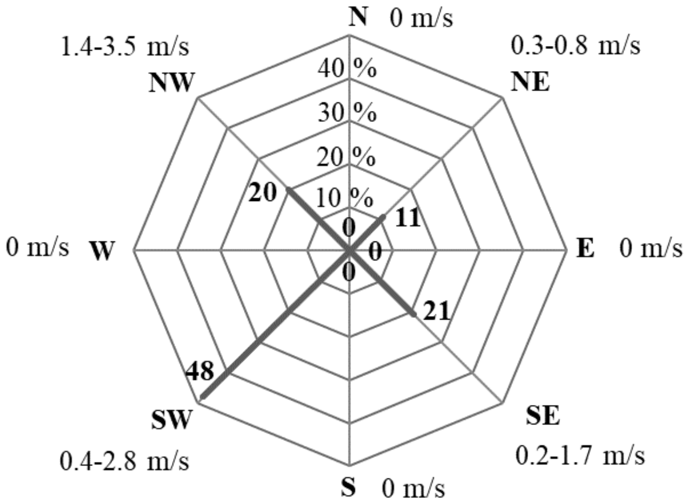


Figure 3 – Wind rose

Processing of the monitoring station data [5] requires the results with the priority wind directions, which represent a relative value $P_i = n_i \cdot (\Sigma\, n_i)^{-1} \cdot 100$ %, where n_i is the number of days with similar wind directions.

The second necessary condition of the air dustiness analysis is the control of changes in temperature and relative air humidity. The results of meteorological data [5] within the period under consideration are represented in Fig.4.

Analysis of the graphic representation of a temperature mode in the atmosphere (Fig.4) shows that the maximum air temperature T_{max} = 273.8 K was observed at 3 pm 14.01.2021; its minimum T_{min} = 261.4 K was recorded at 4 am 15.01.2021. In this context, the greatest temperature decrease was observed from 3 pm 14.01.2021 till 4 am 15.01.2021.

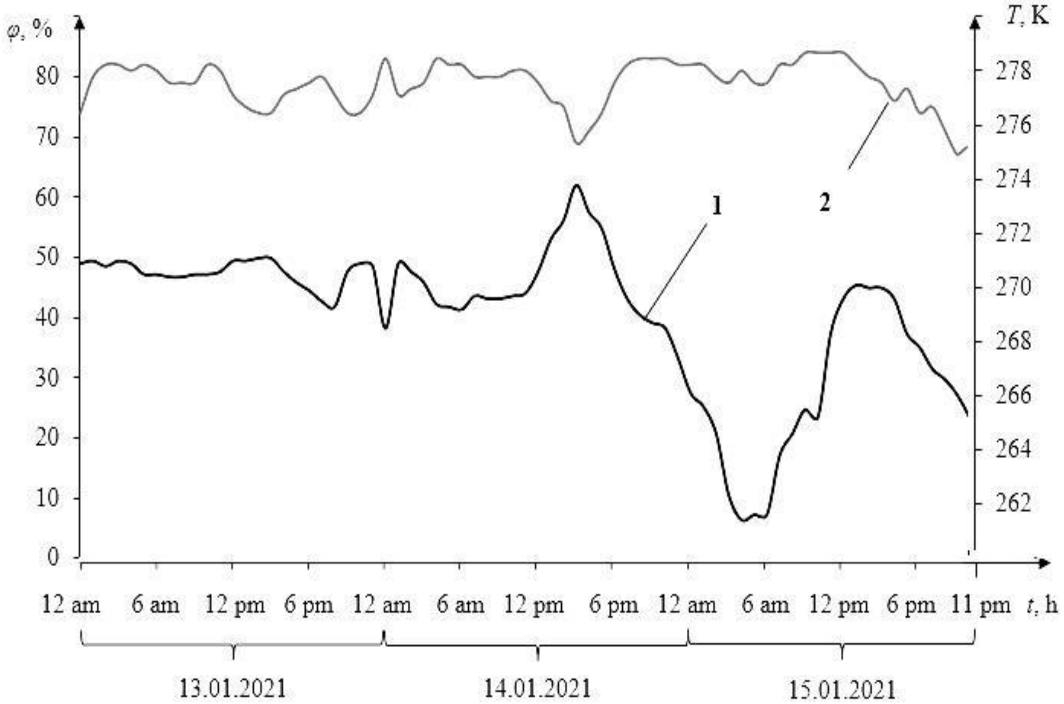
Analysis of the graphic representation of relative humidity in the atmospheric air (Fig.4) demonstrates that the value of relative humidity within the observation period varies from 67 to 84% on average.

In terms of 15 monitoring stations, representing their data on fine-dispersed dust particles, the data concerning 10 stations ## 1 – 10 were studied and processed (Fig. 2).

Fig.5 shows the results of the processing of monitoring data [5] concerning dust particle concentration in the air.

Results and discussion. The results of dust particle monitoring at the stations (Fig.5) were studied by superimposing the data on wind direction and strength, temperature, and humidity.

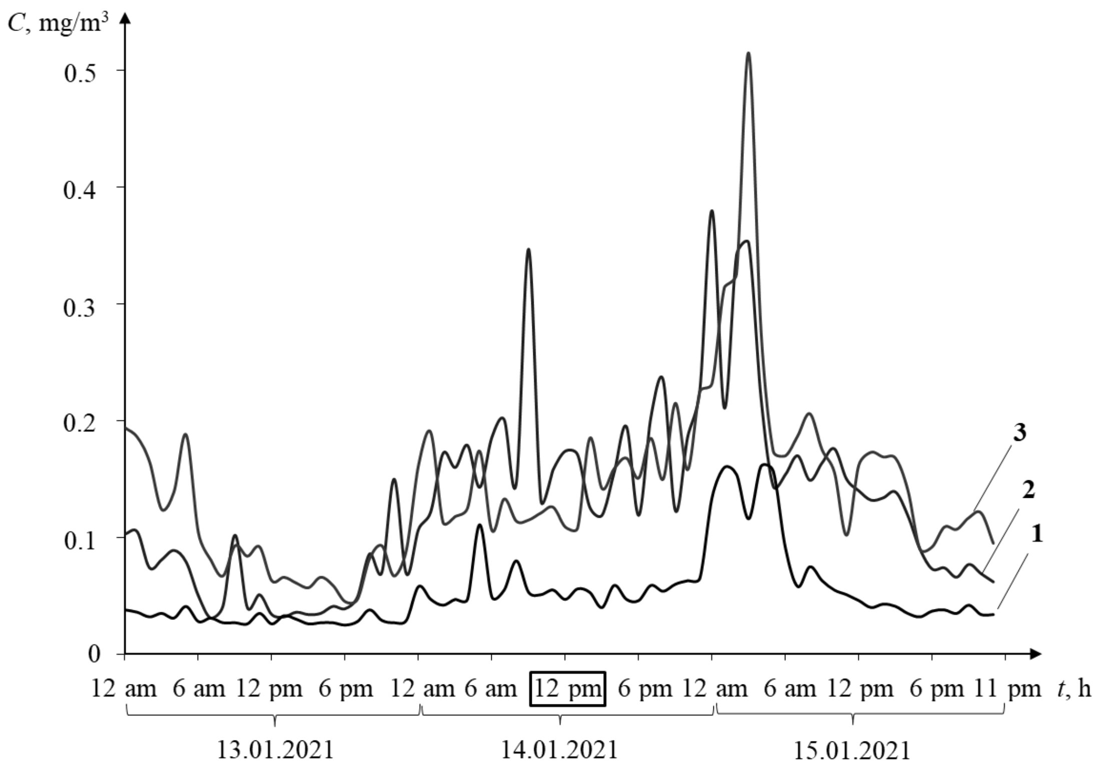
First of all, changes in data variations at stations ## 1, 2, and 3 of “ArcelorMittal Kryvyi Rih” PJSC (Fig.5, *a*) were analyzed as they were maximally close to the single blast location. Stations #1, 2 are near the metallurgical integrated works of the company at the distances of 1000 m and 3000 m, respectively; station #3 is located near the mining-and-processing integrated works at the distance of 1900 m from the potential dust source. Graphic representation in Fig.5, *a* demonstrates that an insignificant growth in dust concentration is recorded after the single blast.



1 – temperature; 2 – relative humidity

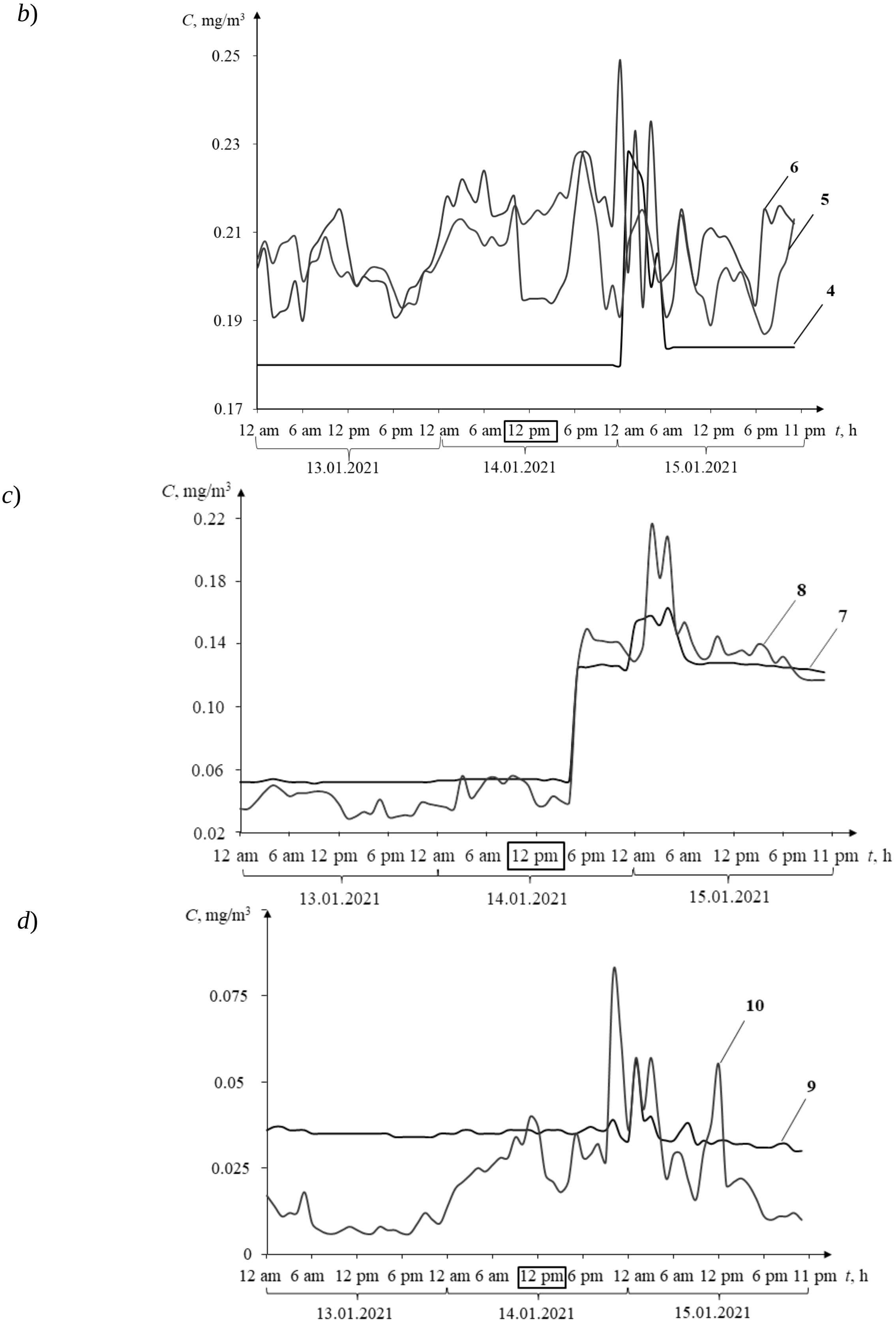
Figure 4 – Changes in air temperature and relative humidity

a)



1, 2,…, 10 – numbers of the monitoring stations; 12 pm – time of single blasting in terms of open pits # 2-bis and # 3 of "ArcelorMittal Kryvyi Rih" PJSC

Figure 5 – Measuring the dust particle concentration in the air at the monitoring stations of "ArcelorMittal Kryvyi Rih" PJSC (*a*),



1, 2,…, 10 – numbers of the monitoring stations; 12 pm – time of single blasting in terms of open pits # 2-bis and # 3 of "ArcelorMittal Kryvyi Rih" PJSC

Figure 5 – Measuring the dust particle concentration in the air at the monitoring stations of municipal stations (*b*), "Kryvbaszalizrudkom" JSC (*c*), # 9 (JSC Southern GZK), and # 10 (Kryvyi Rih Cement PJSC) (*d*)

The results of dust particle monitoring at the stations (Fig.5) were studied by superimposing the data on wind direction and strength, temperature, and humidity.

First of all, changes in data variations at stations ## 1, 2, and 3 of "ArcelorMittal Kryvyi Rih" PJSC (Fig.5, *a*) were analyzed as they were maximally close to the single blast location. Stations #1, 2 are near the metallurgical integrated works of the company at the distances of 1000 m and 3000 m, respectively; station #3 is located near the mining-and-processing integrated works at the distance of 1900 m from the potential dust source. Graphic representation in Fig.5, *a* demonstrates that an insignificant growth in dust concentration is recorded after the single blast.

A drastic increase in the fine-dispersed dust concentration at stations ## 1, 2, and 3 took place at night being explained by great influence of temperature inversion.

In case of station #1 (Fig. 5, *a*), a distinct increase in concentration was observed in 11 hours (11 pm 14.01.2021) after the single blasting in terms of the northern-western wind with reaching its maximum in 2 hours (1 am 15.01.2021). After that, an insignificant fluctuation of the concentration was observed. An evident decrease in the concentration with its further stabilization started at 7 am 15.01.2021 (in 6 hours after reaching the peak) in terms of the southern-eastern wind.

At station #2 (Fig. 5, *a*), a clear local growth of concentration was observed in 9 hours (9 pm 14.01.2021) after the single blasting in terms of the southern-eastern wind. A distinct reduction of the concentration after reaching its maximum was observed in 6 hours (3 am 15.01.2021) in terms of the northern-eastern wind.

In case of station #3 (Fig. 5, *a*), a clear local increase in the dust concentration was observed in 10 hours (10 pm 14.01.2021) after the single blasting at southern-western wind with reaching its maximum in 5 hours (3 am 15.01.2021). Then, the concentration starts its decreasing in terms of the northern-eastern wind.

Fig. 5, *b* shows that within the period under consideration at station #4 one could observe a marked local growth of dust concentration during the night time (12 am 15.01.2021) in terms of the southern-eastern wind with the concentration decrease for the next 6 hours at the northern-eastern wind down to some constant value.

At stations # 5 and # 6 (Fig. 5, *b*), a periodic growth and reduction of dust concentration took place before and after the blasting operations. In this context, the greatest increase was recorded in the late evening (11 pm 14.01.2021) in terms of the northern-eastern wind. A concentration increase was observed within an hour. After that, its reduction was recorded in terms of the same wind direction.

Analysis of the graphs in Fig 5, *c* demonstrates that at stations # 7 and # 8 of "Kryvbaszalizrudkom" JSC, which are located at the distances of 4800 and 3750 m respectively from the integrated works, one can detect a clearly defined growth of dust concentration in 4 hours (4 pm 14.01.2021) after the single blasting in terms of the southern-eastern wind. After that, the concentration value at station # 7 increases additionally in 7 hours (11 pm 14.01.2021) up to its maximum at the northern-eastern wind. In case of station # 8, one can observe similar increase in 8 hours (12 am 15.01.2021) at the same wind direction. Further, the concentration value at the indicated stations goes down in terms of the same wind direction and takes on average some constant value. In this context, the concentration value in the process of stabilization exceeds its initial value before single blasting by more than 2 times. However, temperature reversion is evident at stations # 7 and # 8 (Fig. 5, *c*) at night.

Analysis of the graphs in Fig. 5, *d* demonstrates that at station # 9 of JSC Southern GZK, that is located at the distance of 500 m from the integrated works, one can observe locally increased dust concentration in 12 hours (12 am 15.01.2021) after the single blasting in the neighbouring open pit (at the northern-eastern wind). However, location of this station relative to the potential source of dust generation (Fig. 2) and current wind direction make it impossible to establish certain connection between the dust concentration growth and intensity of the considered source. A dust concentration at station # 9 is growing within an hour. Next, at the same wind direction, the concentration decreases returning on average its initial value. Apart from the indicated time period, the dust concentration experiences practically no changes.

At station # 9 (Fig. 5, *d*), the effect of temperature inversion is manifested inconsiderably.

In case of station # 10 of Kryvyi Rih Cement PJSC (Fig. 5, *d*) located at the distance of 3100 m from the enterprise, a distinct local growth of duct concentration was observed during the evening and night time (9 pm 14.01.2021) in 9 hours after the single blasting. A concentration increase was taking place within an hour in terms of the southern-eastern wind. In this context, local bursts of concentration were also observed before the single blasting. As for this station, the effect of temperature inversion on the fine-dispersed dust concentration was observed in the evening of 14.01.2021.

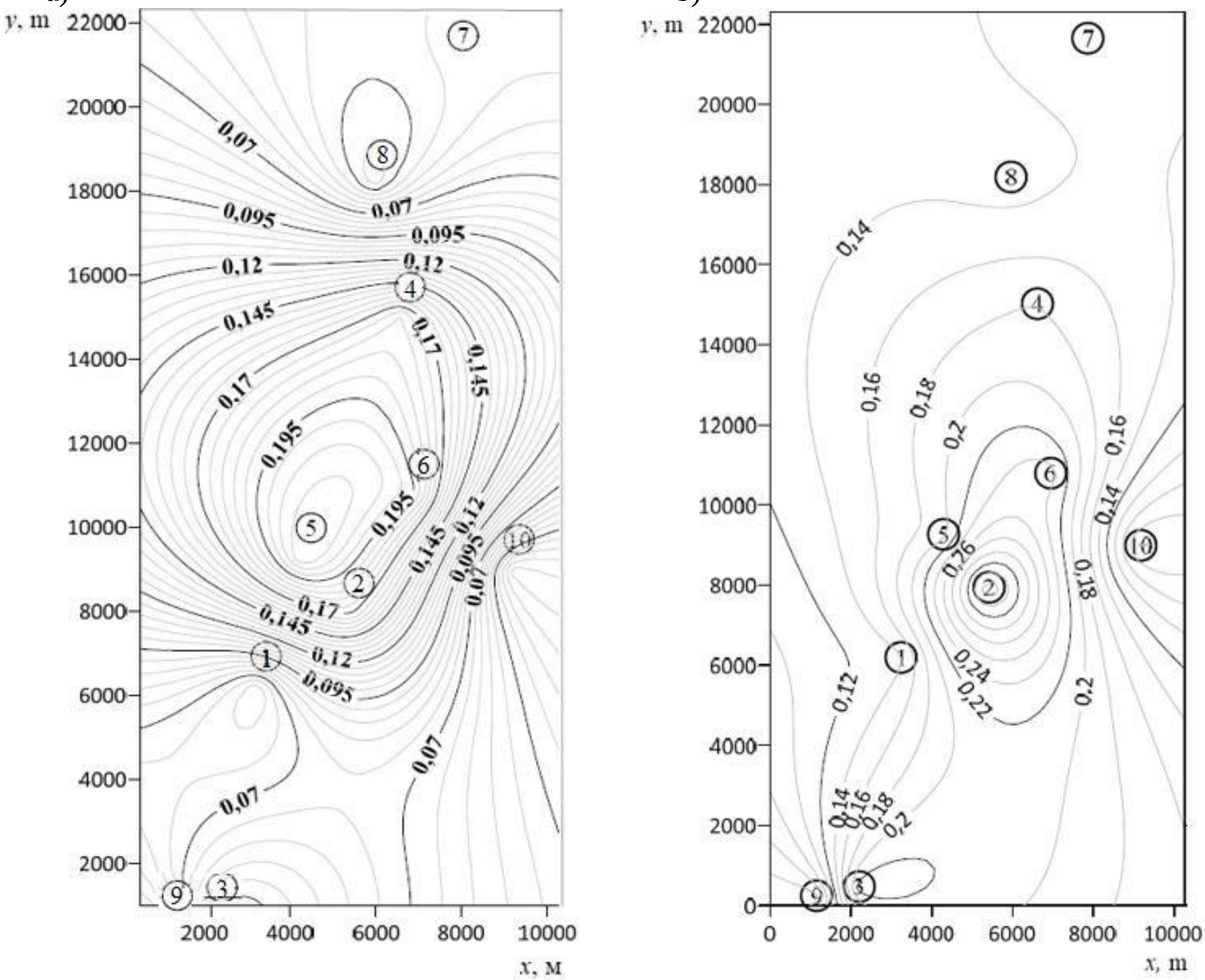
Analysis of the meteorological data within the period under study and consideration of the location of open pits and industrial objects of the Kryvyi Rih region [6] as well as the data on duct concentration changes at the monitoring stations (Fig. 5) does not allow identifying the unambiguous connection between the wind direction and dust concentration value.

Fig. 6 shows isolines of the dust particle concentrations in the air obtained while processing data from the monitoring stations.

Analysis of the graphs (Fig. 6) indicates that the highest concentrations of dust particles in the air were observed at nights (Fig. 6, *b*), which is connected with the temperature inversion effect. Meanwhile, in the daytime (Fig. 6, *a*) one can see the nonuniform distribution of concentrations, which is connected with the increased intensity of turbulence. Besides, Fig.6 shows that the single blasting in open pits (12 pm 14.01.2021) did not influence considerably the dust particle concentrations at the monitoring stations.

The abovementioned results show that the concentration of fine-dispersed dust particles in the air is much higher at nights than in the day time [6-9]. From the scientific viewpoint, this phenomenon can be explained by the following. Firstly, warm air at night captures the cool air. The air temperature falls with the emerging inversion. As a result, the contaminating substances and emissions, having been captured by the atmosphere during a day, are dissipated with their further sedimentation closer to the ground. However, during the night hours the effect of inversion arises with the resulting deteriorated air quality. Secondly, high air humidity influences its pollution [10, 11]. The authors studied this fact in their article [6] where relatively high coefficients of correlations between the levels of average index of air quality of polluting substances and humidity were obtained. Consequently, clear sky, no rains, and slow wind velocities within the period under study confirm the fact that the concentration of solid particles at night time becomes much higher comparing with the day hours.

a) b)



1, 2,…, 10 – numbers of the monitoring stations

Figure 6 – Isolines of the dust particle concentrations in the air at 1 pm 14.01.2021 (*a*) and at 12 am 15.01.2021 (*b*)

Conclusions.

1. Single blasting in the open pits # 2-bis and # 3 of “ArcelorMittal Kryvyi Rih” PJSC have not resulted in the increased air dustiness within the region.

2. It has been determined that the influence of temperature inversion at night time results in a drastic increase in the fine-dispersed dust particle concentration at the monitoring stations located near the metallurgical and mining-and-processing integrated works “ArcelorMittal Kryvyi Rih” PJSC. In this context, wind velocity varied from 0.2 to 3.5 m/s, and air humidity was within the range of 67-84 %.

3. Fluctuations of dust concentrations are caused mostly by the changing intensity of the dust generation sources and air flow turbulence.

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ДОСЛІДЖЕННЯ ВПЛИВУ МАСОВИХ ВИБУХІВ У КАР'ЄРАХ НА ЗАПИЛЕНІСТЬ ПОВІТРЯ МІСТА КРИВИЙ РІГ

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Анотація. У всьому світі приділяється увага екології та екологічним характеристикам навколишнього середовища. У гірничодобувних регіонах та біля переробних підприємств контролюється екологічна безпека. У кар'єрах для зниження викидів пилу при масових вибухах використовуються сучасні методи пилоподавлення і застосовуються нові типи імпульсних вибухових речовин. Проте проблема забруднення повітря на прилеглих територіях лише посилюється. З цією метою по всьому світу збудовано понад 30 000 станцій моніторингу якості повітря. На них фіксуються показники газів та дрібних частинок пилу PM 2,5 та PM 10, які є основним фактором ризику хронічних захворювань.

Метою роботи є оцінка характеру зміни запиленості повітря на території гірничодобувного Криворізького району з урахуванням впливу масових вибухів у кар'єрах, метеорологічних умов та екзогенного фактору.

У статті здійснено аналіз впливу масових вибухів на концентрацію частинок пилу в атмосфері. При аналізі використовувалися метеорологічні дані та дані щодо якості повітря, отримані з 10 станцій автоматичного моніторингу на території Криворізького регіону. На базі отриманих даних побудовано графіки зміни температури, швидкості та напрямку вітру, відносної вологості повітря та концентрації частинок пилу. Досліджено взаємозв'язок між метеорологічними умовами та концентрацією частинок пилу в повітрі. Встановлено, що за період спостережень, масові вибухи в кар'єрах не вплинули на пилове забруднення атмосферного повітря в Криворізькому регіоні. Проведено аналіз впливу температурної інверсії на концентрацію пилу у нічний час. Виявлено, що у період часу спостерігалася висока температурна інверсія.

Ключові слова: екологія, станції моніторингу, концентрація пилу, тонкодисперсні частки, масовий вибух, кар'єр.

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