Population health risk assessment associated with air pollution in the area of natural chalk industrial processing complex influence

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Abstract. Increased air pollution in the areas where large mining complexes are located poses a risk to public health. The article examines harmful substances atmosphere emissions’ impact on the population health living near an industrial mining enterprise of the Kopanischensky natural chalk deposit in the Ostrogozhsky district of the Voronezh region. Environmental risks calculations showed that out of 36 chemical substances that pollute the atmosphere, 5 substances have a carcinogenic effect. The maximum values of the total carcinogenic risk do not exceed the dangerous threshold, however, they need to be carefully monitored. The main contributor to the total risk is carbon soot – 99.9%. Calculations results of non-carcinogenic risks due to inhalation exposure showed that the respiratory organs which are negatively affected by 8 out of 10 priority chemicals, are most potentially affected.

1. Introduction
Areas where large mining complexes are located pose risks to the environment and public health. Intensive quarrying leads to such negative consequences as changes in territory land forms; air pollution by gaseous and suspended substances emissions; withdrawal of land and water resources; pollution of the territory with the resulting wastes and wastewater; noise and vibration impact on the residential area; change in population social conditions [1-3].

Therefore, statistical relationships research and analysis in the system "technological impact sources – atmosphere" with priority indicators substantiation that determine environmental risks to the population health living in mining regions are highly relevant [4-6].

The aim of the work is to assess the carcinogenic and non-carcinogenic health risks of the population living in the villages of Luki and Peski-Kharkovskie, Ostrogozhsky district of the Voronezh region from sources of atmospheric air pollution located on the territory of an industrial mining enterprise of the Kopanischensky natural chalk open-pit mine. Initial data for risk assessment were provided by the Center for Hygiene and Epidemiology in the Voronezh Region.

2. Material and research methods
The Kopanischensky building material complex, located in the Ostrogozhsky district of the Voronezh region, specializes in the extraction of natural chalk from the Kopanishchensky deposit and its industrial...
processing with building lime release (quicklime), as well as raw and dry ground chalk. The technological process for the production of ground chalk includes extraction and transportation chalk processes, primary crushing, drying, grinding, packaging and transportation of finished product. Deposit development is carried out using open-pit method.

The enterprise is located on two industrial sites. Chalk extraction pits are located on two land plots and constitute an industrial site No. 1 with a total area of 151.8 hectares. The building materials complex occupies the third land plot with an area of 11.3 hectares, which is the industrial site No. 2.

All technological stages of chalk and quick lime production begin with chalk extraction in the enterprise quarry. At the present time, work on chalk development is being carried out in the central part of the quarry, which is located to the east of the production site of the complex. Mine face is located at a distance of 1.5 km from the complex.

During chalk development, a large amount of pollutants related to airborne industrial emissions enters the atmospheric air. The main emission sources of these pollutants are: excavation and loading and overburden operations, internal and external dumps, dumping operations which, under unfavorable conditions, lead to intense dust formation, depending on the type of material, particle size distribution and meteorological conditions.

Another important source of air pollution in the area of quarry influence and in the quarry itself is road construction equipment engines and vehicles operation that emit nitrogen dioxide, nitrogen oxide, gasoline, carbon monoxide, sulfur oxide and carbon soot.

Enterprise influence area is 3500 x 3630 m, covering surrounding residential area. Residential area, represented by the village. Luka, is located in the northern direction at a distance of 136 m, in the north-western, western directions – at a distance of 46 m, in the south-western direction – at a distance of 95 m from the enterprise. At a distance of 370 m to the north-east of the industrial site is the village Peski-Kharkovskie. On the territory of the complex sanitary protection zone there are educational institutions: MSOEI "Kopanischenskaya secondary school" for 120 students and MSOPEI "Kopanischenskaya kindergarten" for 45 places. In total, 823 people live in enterprise influence zone.

As a methodological basis for assessing environmental risks due to air pollution, we used the regulatory document R.2.1.10.1920-04 "Guidelines for assessing the risk to public health when exposed to chemicals that pollute the environment" [7].

There are 103 sources of atmospheric pollution on the territory of the enterprise, including 34 – organized and 69 – unorganized. As a result of the complex industrial activity, 36 types of polluting substance (PS) with a total volume of more than 3113 tons per year enter the atmospheric air, of which two pollutants belong to the 1st hazard class (benzopyrene and lead) and five – to the 2nd hazard class (manganese, sulfuric acid, hydrogen sulfide, benzene, ammonium biflouride). Their total share in the total amount of substances emitted into the atmosphere is 19.44%. The largest share (41.67%) falls on the substances of the 3rd hazard class. In this case, 5 substances (nitrogen dioxide, calcium carbonate, inorganic dust 70-20% SiO₂, sulfur dioxide and carbon oxide) are classified as pollutants, the total contribution of which to mining enterprise gross emission is 95% [8].

In order to identify the hazard of chemicals polluting the atmosphere, in accordance with R.2.1.10.1920-04 [7], potential chemical carcinogens have been identified according to the classification of the International Agency on Research for Cancer (IARC). 5 substances have a carcinogenic effect:

- to the 1st category of hazard, i.e. with proven carcinogenicity for humans include: benzopyrene, benzene, carbon soot (black carbon);
- to category 2B hazard, i.e. are possible human carcinogens, include: lead and ethylbenzene.

The list of priority pollutants for assessing non-carcinogenic risk includes 10 pollutants, including: nitrogen dioxide, nitrogen oxide, calcium carbonate, calcium oxide (quicklime), kerosene, manganese, inorganic dust 20-70% SiO₂, carbon soot, sulfur dioxide and carbon oxide.
Thus, at the stage of hazard identification by assessing the risk to public health, the preliminary list of priority chemicals included 14 air pollutants contained in the emissions of the chalk processing complex.

3. Results and discussion

Analysis of the toxicological characteristics of 14 chemical substances-atmospheric pollutants, selected for further research, showed:

- 5 substances have a *carcinogenic effect* (development of malignant neoplasms): benzene, benzopyrene, lead, carbon soot and ethylbenzene;
- *embryotropic action* (accompanied by embryo death) possesses 9 substances: nitrogen dioxide, nitrogen oxide, benzopyrene, benzene, manganese and its compounds, lead and its compounds, sulfur dioxide, carbon oxide, ethylbenzene;
- 9 substances have *gonadotropic action* (accompanied by miscarriage, weakening of sexual potency and men and women infertility): nitrogen dioxide, nitrogen oxide, benzopyrene, benzene, manganese and its compounds, lead and its compounds, sulfur dioxide, carbon oxide, ethylbenzene;
- *teratogenic action* (i.e. the action of chemicals on the body of mother, father or fetus) is possessed by 8 substances: nitrogen dioxide, nitrogen oxide, benzopyrene, benzene, lead and its compounds, sulfur dioxide, carbon oxide, ethylbenzene;
- 6 substances have a *mutagenic effect* (the ability of chemicals to cause changes at the genetic level): benzopyrene, benzene, lead and its compounds, sulfur dioxide, carbon oxide, ethylbenzene.

The industrial site of the enterprise is located in an area of moderate meteorological pollution potential. Flat terrain does not significantly affect the dispersion of pollutants in the atmosphere. Mainly the southwest wind direction dominates.

The population sensitivity to the effects of pollution depends on a large number of factors (for example, gender, age, general state of human health; meteorological conditions: temperature, humidity, etc.). Smokers with asthma and chronic bronchitis, as well as children and the elderly people are considered more vulnerable, and the main entry way of polluted air into the human body is inhalational, i.e. breathing in [9].

Taking into account the fact that the enterprise does not carry out atmospheric air quality observations in the residential area with average daily samples selection, to determine the contribution to the level of atmospheric pollution formation the method of mathematical modeling of atmospheric pollutants dispersion was used using the UPAPE "Ecolog 4.0”.

Average annual concentrations of each priority air pollutant substance are calculated in the affected area at 242 impact points / control points on the territory of residential development, including: twp. Luki – in 221 points, twp. Peski – Kharkovskie – at 21 points.

823 people live in the zone of influence of the enterprise, including the twp. Luki – 732 people, twp. Peski-Kharkovskie – 91 people. Pollutants exposure time on human body at the control points of residential buildings in the influence zone of the enterprise was chosen 24 hours a day, exposure way was inhalation. For each of the 14 pollutants in residential buildings under their influence, the minimum and maximum concentrations were selected. The calculated concentrations of pollutants entering the atmospheric air are below the maximum hygienic standards.

The individual carcinogenic risk was assessed from exposure to 5 substances: lead, carbon soot, benzopyrene, benzene, ethylbenzene. The data obtained indicate that the maximum levels of individual *carcinogenic risk* at the control points of residential buildings located in the influence zone of the enterprise are $1.96 \times 10^{-5}$ from carbon soot exposure; from other carcinogenic substances – less than $1 \times 10^{-6}$ and correspond to the values: benzene – $6.61 \times 10^{-6}$, benzopyrene – $9.01 \times 10^{-10}$, lead – $4.83 \times 10^{-11}$, ethylbenzene – $2.36 \times 10^{-11}$. These risks are typical for the *twp. Luki*. 
In the influence zone of the enterprise on the territory of residential development of twp. Peski-Kharkovskie, the maximum levels of individual carcinogenic risk from carbon soot exposure – $1.9 \times 10^{-6}$, benzene – $1.56 \times 10^{-10}$, benzopyrene – $9.08 \times 10^{-11}$, lead – $9.98 \times 10^{-13}$, ethylbenzene – $5.57 \times 10^{-13}$.

It should be noted that the maximum individual carcinogenic risks are slightly higher in twp. Luki than in twp. Peski-Kharkovskie.

Thus, the highest values of individual carcinogenic risk are observed in the influence zone of the enterprise from carbon soot exposure, the main contribution to the total risk of which is 99.9%. In accordance with the acceptance criteria, these individual risks belong to the second range (individual risk throughout life more than $1 \times 10^{-4}$, but less than $1 \times 10^{-6}$), corresponds to the maximum permissible risk. These levels are subject to constant monitoring.

Individual risks from exposure to benzene, benzopyrene, lead, ethylbenzene, in accordance with the risk acceptance criteria, belong to the first range (individual risk throughout life equal to or less than $1 \times 10^{-6}$), and are characterized as negligible, not distinguished from the usual, everyday risks. Such risks do not require any additional measures to reduce them, and their levels are subject only to periodic monitoring.

Based on the hazard ratios calculation, the risk of non-carcinogenic effects was assessed. The pollutants ranking according to the hazard coefficients average values rate showed that, in general, in the residential area of influence zone of CJSC "KBMC", the first ranking place is occupied by sulfur dioxide (HQ average = 0.38); the second – nitrogen dioxide and kerosene (HQ average = 0.18), the third – inorganic dust: 70-20% SiO$_2$ (HQ average = 0.14). For other substances, the average hazard factors are less than 0.1.

The analysis of calculated hazard coefficients (HQ average) for individual settlements located in the influence zone of the enterprise shows that in twp. Luki the average hazard coefficient for sulfur dioxide highest rates are also mentioned – 0.41; nitrogen dioxide and kerosene – 0.2, inorganic dust: 70-20% SiO$_2$ – 0.15. For other substances, the average hazard ratios do not exceed 0.1. In twp. Peski-Kharkovskie for one pollutant, the average hazard coefficient is higher than 0.1: sulfur dioxide – 0.23 (first rank place).

In all territories, the lowest average hazard ratios are observed when exposed to manganese and carbon oxide.

Analysis of the maximum values of the calculated hazard factors (HQ max) in residential buildings located in the influence zone of the enterprise showed that in the influence zone of emissions in general, including twp. Luki, the non-carcinogenic risk will be: from kerosene – 0.69, sulfur dioxide – 0.67, nitrogen dioxide – 0.66, calcium oxide – 0.34, calcium carbonate – 0.25, inorganic dust: 70-20% SiO$_2$ – 0.24; for other pollutants, hazard ratios at maximum exposure will not exceed 0.1. In twp. Peski-Kharkovskie maximum level of non-carcinogenic risk will be 0.25 from sulfur dioxide exposure, inorganic dust: 70-20% SiO$_2$ – 0.1, from other priority pollutants – less than 0.1.

Thus, the obtained values of non-carcinogenic risk from each priority substances do not exceed the permissible level (1).

As a result of data analysis from 10 pollutants of non-carcinogenic effects development for chronic inhalation exposure, it was established that the priority chemicals in the residential area of twp. Peski-Kharkovskie and Luki, which is under the influence of emissions from KBMC, have a unidirectional combined effect on the respiratory system (8 substances), the hematopoietic system (3 substances), the central nervous system (2 pollutants), developmental processes, cardiovascular system, liver, nervous system, immune system, teeth, cause premature mortality, systemic effects (1 priority pollutant). Moreover, the most affected are the respiratory organs, which are influenced by 8 out of 10 priority chemicals [7].

The assessment of non-carcinogenic risk, taking into account the impact on critical organs and systems, showed that the maximum total hazard indexes (HI max) when exposed to the respiratory system are 1.96 (which exceeds the permissible level – 1), on the hematopoietic system – 0.74, the central nervous system – less than 0.1 (Luki). In Peski-Kharkovskie at the maximum exposure, the total
non-carcinogenic risks of developing adverse effects on the respiratory system will be 0.49, blood – 0.077, central nervous system – 0.004. Except for Luki, these levels of risk can be considered as acceptable.

4. Conclusion
Thus, the assessment of carcinogenic and non-carcinogenic risks to the population health of two provinces, Peski-Kharkovskie and Luki, under the influence of chemicals that pollute the atmospheric air with emissions of the enterprise stationary and mobile sources, made it possible to draw the following conclusions.

- The maximum values of the total carcinogenic risk are somewhat higher in the residential area of two provinces, Luki (1.96 * 10^-5) than in two provinces, Peski-Kharkovskie (1.91 * 10^-6). The main contributor to the total risk is carbon soot – 99.9%.
- These levels are subject to constant monitoring.
- Pollutants ranking according to the average values rate of the hazard coefficients showed that, in general, in the residential area of two provinces, Luki and Peski-Kharkovskie influence zones of the enterprise, the first rank place is taken by sulfur dioxide, the second – nitrogen dioxide and kerosene, the third – inorganic dust.
- Analysis of pollutants on non-carcinogenic effects development for chronic inhalation exposure showed that the respiratory organs, which are affected by 8 out of 10 priority chemicals, are most affected. And in two provinces, Luki recorded the maximum total hazard indexes (HI max = 1.96) when exposed to the respiratory system, which exceed the permissible level (HI = 1).

Thus, the mining enterprise "Kopanishchensky building materials complex" is a potential source of atmospheric pollution and can have a negative impact on the population health of surrounding territories living near the industrial zone of Kopanishchensky natural chalk deposit quarry mining.

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