Reduction of individual carcinogenic and non-carcinogenic risks on impact area resulted from operation of construction industry enterprises

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Abstract. The article presents the assessment of carcinogenic and non-carcinogenic risks to the human health resulted from the work of the construction industry enterprises. It is shown that the level of risks to the human health causes concern. It is established that while assessing carcinogenic and non-carcinogenic risks to the human health the construction enterprises don’t take into account the emission of mercury compounds in cement production. Both the sources of mercury emission into the atmosphere and the methods for reducing mercury emission in cement production technique are shown. It’s stated that to improve the environment, it is necessary to define impact areas, provide a sanitary protective barrier between the industrial territory and the residential area by creating additional green belts that provide shielding, assimilation and filtration of air pollutants which make the microclimate better. It is suggested that monitoring of atmospheric emission of mercury should be included in the production control program and pollution control for mercury emissions should be introduced into Maximum Permissible Emissions (MPEs) projects.

1. Introduction
It is necessary to mention that reducing the risk of the population morbidity from harmful substances emitted by industrial enterprises is the urgent task for increasing the life expectancy of the population not only in the Russian Federation, but throughout the world [1-5]. Assessment of the risk to human health from air pollution produced by stationary and mobile sources of construction enterprises contributes to the identification of priority pollutants. Identified pollutants represent the greatest danger to human health. As the result plans of action to minimize their negative impact on human health can be developed in future [6-8].

2. Materials and methods issue
In the given research work risk assessments were used as a basic technique in accordance with the “Guidelines for assessing the risk to human health when exposed to chemicals that pollute the environment” P.2.1.10.1920-04, approved by The Head Sanitarian of the Russian Federation [9].

The main stages of the risk assessment procedure are the following [10]:

- hazard identification that identifies all potential sources of air pollution. Selection of priority factors to be studied thoroughly during the risk assessment process;
• identification of impact areas or zones of influence of enterprises, as the greatest of two distances X1, X2: $X_1 = 10X_{\text{max}}$; $X_2 = 0.05\text{MPC}$ (Maximum Permissible Concentration), where $X_{\text{max}}$ is the distance at which maximum pollution is observed, m

• exposure assessment, which includes the characteristics of levels, duration, frequency and the ways of impact of the pollutants under study. Identification of a potentially exposed population;

• assessment of the dose-response relationship, as the determination of the quantitative characteristics of the relationship between concentration, the exposure of the substance under study and the harmful factors caused by it;

• risk profile, which includes determining the sources and severity of risks to human health with a view to subsequent use at the risk managing stage.

3. Results and discussion

The main sources of the cement production harmful substances emission are clinker burning kilns and grinding mills. The kilns account for up to 85% of all emissions from cement plants [11]. The amount of dust emission from the kilns depends on the clinker production method, the size and design of the kilns, the firing process mode, the type of fuel used, the presence of heat exchangers in the kiln and their structures, and the characteristics of the raw mix. According to [12-13], for each ton of clinker there are 2500-7500 m$^3$ of flue gases with dust content before treatment of 8.5-70 g / m$^3$. The dust of kilns is usually polydisperse, with a high content (up to 30-70%) of particles less than 10 microns in size. Dust is characterized by high sorption capacity with respect to heavy metals. Sources of emission are also mills for dry grinding of raw materials, drying drums, crushing units, places of transportation and storage of cement and raw materials.

As a result of the production activities enterprises producing cement emit 40-50 items of pollutants into the atmosphere. Pollutants are distributed by hazard into the hazard classes in the total amount of gross emissions as follows, %: 1 hazard class up to 0.00006; 2 hazard class up to 0.028; 3 hazard class up to 74; 4 hazard class - the rest (about 25%). For example, taking into account the MPD project data of Belgorod Cement CJSC, the lists of pollutants priority from 45 substances emitted by the enterprise into the atmosphere were determined. Potential chemical carcinogens belonging to groups 1, 2A, 2B according to IARC classification have been identified. It was found out that out of the 45 pollutants, 7 have a carcinogenic effect: Petrol, Benzene, Soot, Lead, Formaldehyde, Chromium (VI), Ethylbenzene.

Pollutants, the total amount of which in the gross emission is more than 95% are presented in Table 1.

| №  | The name of the substance                  | CAS       | Hazard Class | Emission of substance, tons / year | Specific Weight,% |
|----|------------------------------------------|-----------|--------------|----------------------------------|------------------|
| 1  | Nitrogen (IV) oxide                      | 10102-44-0| 1            | 2796                             | 33               |
| 2  | Inorganic dust <20% SiO2                 |           | 3            | 2209                             | 26               |
| 3  | Carbon oxide                             | 630-08-0  | 4            | 2110                             | 25               |
| 4  | Inorganic dust 70-20% SiO2               |           | 3            | 807                              | 9,6              |
| 5  | Nitrogen (II) oxide                      | 10102-43-9| 2            | 443                              | 5,2              |

Calculation of carcinogenic risk was carried out using the data on the magnitude of exposure and the values of factors of carcinogenic potential [1]: $CR = \text{LADD.SF}$, where LADD is the average daily...
dose for life, mg / (kg. per day); SF - factor of inclination, (mg / kg./per day) -1. The results of the calculation of individual carcinogenic risk in the impact area are presented in Table 2.

| №  | Code | The name of the substance     | CAS          | Individual carcinogenic risk |
|----|------|-------------------------------|--------------|------------------------------|
| 1  | 184  | Lead and its compounds        | 7439-92-1    | 1,9E-08                      |
| 2  | 203  | Chromium (VI) oxide           | 18540-29-9   | 6,7E-06                      |
| 3  | 602  | Benzene                       | 71-43-2      | 1,6E-06                      |
| 4  | 627  | Ethylbenzene                  | 100-41-4     | 5,7E-09                      |
| 5  | 1325 | Formaldehyde                  | 50-00-0      | 9,0E-07                      |
|    |      | Total HI                      |              | 9,2E-06                      |

The calculations of the individual cancerogenic risk on the impact area polluted with benzene and chromium (VI) oxide which were carried out in accordance with the items 7.6.2., 7.6.3 of The Guideline to Risk Assessment for Human Health under the Influence of the Chemicals Polluting the Environment correspond to the risk which causes concern.

Non-cancerogenic risk was quantitatively estimated on the basis of calculation of hazard coefficient HQ: HQ = Ci/RfC, where HQ – hazard coefficient; Ci – average concentration for the environmental air, mg/m³, RfC – reference concentration, mg/m³. The results of the calculation of the non-cancerogenic risk on the impact area are presented in Table 3.

| №  | Code | The name of the substance          | CAS          | Hazard coefficient |
|----|------|-----------------------------------|--------------|--------------------|
| 1  | 143  | Manganese compounds               | 7439-96-5    | 0,6                |
| 2  | 184  | Lead, compounds                   | 7439-92-1    | 0,003              |
| 3  | 203  | Chromium (VI) oxide               | 18540-29-9   | 0,006              |
| 4  | 301  | Nitrogen (IV) oxide               | 10102-44-0   | 0,05               |
| 5  | 303  | Ammonia                           | 7664-41-7    | 0,01               |
| 6  | 304  | Nitrogen (II) oxide (nitrogen oxide) | 10102-43-9 | 0,01               |
| 7  | 337  | Carbon oxide                      | 630-08-0     | 0,02               |
| 8  | 342  | Gaseous fluorides                 | 7664-39-3    | 0,0007             |
| 9  | 616  | Xylene (mixture of isomers)       | 1330-20-7    | 0,002              |
| 10 | 621  | Toluene (methylbenzene)           | 108-88-3     | 0,004              |
| 11 | 1061 | Ethanol                           | 64-17-5      | 0,00001            |
| 12 | 1071 | Phenol                            | 108-95-2     | 0,005              |
| 13 | 1325 | Formaldehyde                      | 50-00-0      | 0,02               |
| 14 | 2732 | Kerosene                          | 8008-20-6    | 0,02               |
| 15 | 2907 | Inorganic dust: more than 70% SiO₂ |             | 0,07               |
| 16 | 2908 | Inorganic dust 70- 20% SiO₂       |             | 0,07               |
| 17 | 2909 | Inorganic dust < 20 % SiO₂        |             | 0,05               |
|    |      | Total HQ                          |             | 0,9                |
According to the criteria the non-carcinogenic risk is considered acceptable, not causing concern, if HQ is <0.8. If HQ is from 0.8 to 1.0, the risk is the maximum permissible, causing concern. If HQ> 1, the risk is dangerous. Thus, the total risk value for non-carcinogenic effects is of concern (Table 3).

Analyzing the data provided by enterprises (form 2-TP “air”), it can be concluded that the cement industry does not control and take into account mercury emission which is a particularly dangerous substance. For the first time the scientists of BSTU named after V.G. Shukhov turned their minds to the importance of mercury emission control in 1990 [14]. It was noted in subsequent studies [15-18] that a similar situation is typical for all enterprises in cement industry of Russia. In general, the emission of mercury into the atmosphere by cement plants in Russia is presented in Table 4.

Table 4. The emission of mercury into the atmosphere in cement production technique, the area of the impact zone, environmental and economic damage in rubles at the exchange rate of 2018.

| Federal District | Total cement production thousand tons / year | Emission of mercury to the atmosphere, t / year | Area of impact, km² | Environmental and economic damage million rubles / year |
|------------------|--------------------------------------------|-----------------------------------------------|---------------------|---------------------------------------------------------|
| Central          | 12525                                      | 1,078                                         | 300                 | 199                                                     |
| Northwestern     | 2087                                       | 0,180                                         | 54                  | 40                                                      |
| Southern         | 5316                                       | 0,457                                         | 137                 | 91                                                      |
| Volga            | 6918                                       | 0,595                                         | 179                 | 118                                                     |
| Ural             | 3878                                       | 0,333                                         | 100                 | 66                                                      |
| Siberian         | 3634                                       | 0,313                                         | 94                  | 62                                                      |
| Far East         | 1317                                       | 0,112                                         | 34                  | 22                                                      |
| Total            | 35673                                      | ~3,1                                          | 898                 | 598                                                     |

The impact area for the federal districts of Russia lies within 34-300 km², and the total impact area exposed to mercury reaches 898 km², Table 4.

Mercury is not classified as a carcinogen, but the substance and its compounds are particularly dangerous [19]. For the working area, the maximum permissible concentration (MPC) is 0.01 mg / m³; for residential areas the MPC is 0.0003 mg / m³. The hazard coefficient for mercury is 83101, therefore, mercury emissions are characterized by large values of the given masses, despite the relatively small annual emissions, Table 4. According to the technique, the equivalent mass of annual emission M₁ was calculated using the formulas presented in [20].

For an overall assessment of non-carcinogenic effects it is important to take into account mercury emission. Thus, when mercury emission is not taken into account, the calculated HQ can be <1.0 and the non-carcinogenic risk in this case is considered acceptable. But when mercury emission to impact areas (area of enterprise influence) is taken into account, the total non-carcinogenic risk can become dangerous when HQ> 1.

To reduce the total non-carcinogenic risk, it is important to reduce the release of mercury into the atmosphere. Monitoring of this problem is partially defined in [14]. Thus, at enterprises where such carbonate rocks as marl which is suitable for Portland cement production is used according to their cement production technique, mercury compounds impurities emit directly from raw materials.

While using the cement production technique based on chalk with clay additives and pyrite cinders, it appeared that the main way of mercury compounds emission into the atmosphere was due to the use of pyrite cinders, in which a high content of mercury was observed. Therefore, replacing pyrite cinder with other additives free of mercury, it is possible to reduce significantly the environmental burden on the impact area.

Another factor increasing non-cancer risk is the use of electrostatic precipitators dust [21-22]. The point is that the dust of electrostatic precipitators in the cement production is used as a fertilizer for liming sour soils in agriculture [21]. It should be noted that the mercury content in the electrostatic precipitators dust exceeds the permissible levels a hundred times [14].
4. Conclusion:

1. Individual carcinogenic risk on the impact areas within the zone of influence of a cement production enterprise causes concern.
2. For a general assessment of non-carcinogenic effects, monitoring of mercury emissions on impact areas is necessary, since the total non-carcinogenic risk can be dangerous when HQ> 1.
3. In order to reduce the risk to human health from atmospheric emission from the sources of pollution, the following organizational and technical measures should be taken:
   - To include monitoring the content of mercury emission in the air into the production control program. To introduce the calculation of pollution for mercury emission into MPEs (maximum permissible emissions) project;
   - To introduce mercury level control in the dust of electric precipitators during its processing and alternative use;
   - To provide a sanitary protection barrier between the territory of the enterprise and the residential area by creating additional green belts that can ensure shielding, assimilation and filtration of air pollutants and increase the microclimate comfort.

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