Special aspects of assessing hazard to public health while monitoring the negative impact of solid municipal waste landfills

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Abstract. The present study considers the negative impact of solid municipal waste landfills on the environment and public health. It also assesses hazard to public health caused by the impact of solid municipal waste landfill emissions (by the example of a solid household landfill in the city of Kursk). We have carried out four interrelated stages of research work during the implementation of public health hazard assessment of the municipal waste landfill under study: hazard identification, assessment of dose-response relationship, exposure assessment, and risk characterization. At each stage, we assessed uncertainties that might affect the completeness and accuracy of final conclusions and recommendations. A particular attention was paid to some specific uncertainties that are due to the peculiarities of waste landfills’ operation. These uncertainties can have a significant impact on the results of the study, especially in terms of emissions’ quantitative composition. Thus, despite the fact that the risk level of the solid municipal waste landfill under study was assessed as low, the authors propose the introduction of a degassing system at the solid municipal waste landfill in Kursk. The application of this system will eliminate the release of biogas into the atmosphere, reduce the load on the air and reliably decrease hazard to public health caused by the impact of the landfill.

1. Introduction
Currently, the problem of solid municipal waste formation and disposal is one of the main environmental objectives in ensuring ecological safety in the Russian Federation and abroad. Every year the amount of solid municipal waste (hereinafter referred to as SMW) is steadily increasing. In Russia, about 130 million m$^3$ of SMW is formed annually [1].

At present, the first place among the methods of waste disposal belongs to solid municipal waste landfills. About 90-95% of waste is deposited at these landfills. In Russia, the problem of landfill depositing is not paid due attention to. Most SMW landfills do not meet sanitary standards [2]. Existing SMW landfills can pose a significant environmental hazard which will exist for decades. In this regard, hazard assessment of landfill impact on the environment and public health comes to the fore [3].

Nowadays, in almost all world countries and international organizations the concept of hazard assessment is considered as the main mechanism for the development and management decision-making at the international, national or regional levels, and at the level of individual production or other potential source of environmental pollution [4].

2. Materials and methods
At present, the task of assessing hazard to public health caused by the negative impact of pollutants
released from the body of SMW landfill is particularly relevant [5]. The complete (basic) scheme of health hazard assessment provides for four interrelated stages: hazard identification, dose-response relationship assessment, exposure assessment, risk characterization [6]. At each stage, uncertainties affecting the completeness and validity of final conclusions and recommendations are assessed.

In estimating hazard to public health when being exposed to chemicals which pollute the environment, most of the uncertainties are related to various aspects of such substances’ impact on human health. However, uncertainties related to the nature of environmental pollution sources such as SMW landfills might be critical.

Within this study, we consider the procedure for assessing hazard to public health from the impact of SMW landfill’s emissions (by the example of a solid domestic waste landfill in Kursk) with the identification of specific uncertainties due to the peculiarities of the waste land-fill operation as a source of negative impact.

3. Results and discussion
In order to substantiate the list of chemicals for the subsequent assessment of health risk to the population, the ranking of emitted pollutants by the indices of comparative non-carcinogenic and carcinogenic danger was carried out. When ranking chemicals we have taken the population living in the affected area of landfill emissions. The total number is 160 people.

The greatest contribution to the comparative carcinogenic and non-carcinogenic hazard indices was made by the following substances: formaldehyde, ethyl benzene, ammonia, methane, xylene, hydrogen sulfide, nitrogen dioxide, and toluene.

Based on the results of calculations, a list of chemicals has been formed which includes all carcinogenic substances and substances with the highest rank of comparative non-carcinogenic hazard index. There are also substances included in the list of priority substances for the Russian Federation. These substances: Formaldehyde, Ethyl benzene, Soot, Benzapyrene, Ammonia, Methane, Xylene, Hydrogen sulfide, Nitrogen dioxide, Toluene, Sulfur dioxide, Carbon monoxide.

As part of the dose-response relationship assessment, the hygienic and toxicological specification of chemical substances emitted by the Kursk solid domestic waste landfill under study has been performed. The analysis has showed that the respiratory system is adversely affected by 7 substances: sulfur dioxide, nitrogen dioxide, ammonia, xylene, formaldehyde, hydrogen sulfide, soot. The development is influenced by 3 substances: carbon monoxide, ethyl benzene, benzapyrene.

The immune system is negatively affected by 3 substances: formaldehyde, benzapyrene, sulfur dioxide. The change in blood composition can be influenced by 2 substances: nitrogen dioxide, carbon monoxide. Carbon monoxide and sulfur dioxide have a negative impact on the cardiovascular system; xylene, ethylbenzene and toluene have a negative influence on kidneys and liver. Soot has systemic effect and a negative impact on teeth, and formaldehyde has an effect on eyes. Ethylbenzene has a negative impact on the endocrine system.

Thus, respiratory organs, central nervous system, blood, development, cardiovascular system, immune system, kidneys, liver, endocrine system, teeth, eyes are expected to be vulnerable to the impact of emissions from the landfill under study.

Exposure assessment characterizes levels, duration, frequency and methods of factors’ impact on the estimated population. Taking into consideration the purpose of our study, the residential area scenario was adopted as the basis of the exposure scenario, which considers chronic (lifetime) exposure.

On the basis of findings made in the hazard identification, atmospheric air was considered as the analyzed environment, and inhalation root was a priority one. At the same time, surface air concentrations of the relevant chemicals at the locations under consideration are required to characterize the risks.

The calculation of both maximum one-time and average concentrations has been carried out using computer programs that created computer simulation of aerial effluents dispersion on the basis of special mathematical dependencies. As a result of simulation, the values of maximum annual concentrations of priority substances obtained are significantly lower than the established Russian maximum allowable
concentrations for these substances.

Risk characterization is the final stage of public health hazard assessment. At this stage the results of the previous three stages are summarized, the risks and their comparative characteristics are calculated, and all the uncertainties are analyzed that can affect the validity and reliability of final conclusions and recommendations being necessary for risk management.

The probability of carcinogenic effects for the population living in the affected area of the landfill (CR) was estimated as a result of formaldehyde, ethylbenzene, soot and benzapyrene impact (Table 1).

The analysis has shown that on the border of the estimated sanitary protection zone of the landfill, in the territory of residential development and in the territory of garden plots in the zone of the landfill’s emissions impact, the levels of individual carcinogenic risk without regard to the background from the effects of formaldehyde, ethylbenzene, soot and benzapyrene correspond to the first risk range (minimum level). Such risks do not require any additional measures to reduce them and their levels are subject only to periodic control. The total carcinogenic risk also corresponds to the first risk range.

**Table 1.** Carcinogenic health hazard due to the impact of substances emitted by the landfill

| No. | Code | Substance        | CAS       | CR       |
|-----|------|-----------------|-----------|----------|
|     |      |                 |           | min      | max      | average |
|     |      | estimated sanitary protection zone of the landfill |           |          |          |          |
| 1   | 1325 | Formaldehyde    | 50-00-0   | 9.77E-07 | 3.25E-06 | 2.19E-06 |
| 2   | 627  | Ethyl benzene   | 100-41-4  | 8.09E-08 | 2.69E-07 | 1.81E-07 |
| 3   | 328  | Soot            |           | 8.13E-09 | 1.21E-07 | 3.69E-08 |
| 4   | 703  | Benzapyrene     | 50-32-8   | 2.01E-13 | 5.46E-13 | 3.68E-13 |
| Total |      |                 |           | 1.07E-06 | 3.64E-06 | 2.41E-06 |
|     |      | residential space in the affected area |           |          |          |          |
| 1   | 1325 | Formaldehyde    | 50-00-0   | 1.01E-06 | 2.61E-06 | 1.50E-06 |
| 2   | 627  | Ethyl benzene   | 100-41-4  | 8.38E-08 | 2.16E-07 | 1.24E-07 |
| 3   | 328  | Soot            |           | 6.68E-09 | 6.42E-08 | 1.42E-08 |
| 4   | 703  | Benzapyrene     | 50-32-8   | 1.67E-13 | 4.01E-13 | 2.51E-13 |
| Total |      |                 |           | 1.10E-06 | 2.89E-06 | 1.64E-06 |
|     |      | garden plots in the affected area |           |          |          |          |
| 1   | 1325 | Formaldehyde    | 50-00-0   | 9.33E-07 | 3.31E-06 | 1.82E-06 |
| 2   | 627  | Ethyl benzene   | 100-41-4  | 7.70E-08 | 2.75E-07 | 1.51E-07 |
| 3   | 328  | Soot            |           | 5.34E-09 | 1.19E-07 | 2.36E-08 |
| 4   | 703  | Benzapyrene     | 50-32-8   | 1.78E-13 | 6.35E-13 | 3.38E-13 |
| Total |      |                 |           | 1.02E-06 | 3.70E-06 | 1.99E-06 |

The results of ranking the levels of non-carcinogenic health hazard have showed that substances with the strongest non-carcinogenic effects are: formaldehyde, hydrogen sulfide, ammonia, xylene. The values of danger coefficients (HQ) excluding the background at all points of impact/receptor points are significantly below acceptable (less than 1).

This level of risk is assessed as low one, as shown in Table 2. The maximum concentrations of the priority substances do not exceed 0.0661 in the residential area and 0.0825 at the boundary of the estimated sanitary protection zone.

The total impact of pollutant emissions on critical organs and systems is presented in Table 3.

**Table 2.** Non-carcinogenic risks from landfill emissions without regard to the background
The data obtained indicate that at the boundaries of the estimated sanitary protection territories of the landfill, in the residential space and in the territory of garden plots located in the zone of the landfill’s influence with the joint action of chemicals by their non-carcinogenic effects (HI), the negative impact on the respiratory system, development, central nervous system, blood, heart vascular system, immune system, kidneys and liver due to the landfill’s emissions excluding the background are at an acceptable level.

4. Conclusion

At each stage of hazard assessment, some uncertainties were identified. Also, each stage has determined how these uncertainties affected the completeness and validity of final conclusions and whether any adjustments to the study were required. Some of the identified uncertainties can be attributed to almost any study objects – the lack of Roshydromet (Federal Service of Russia on Hydrometeorology and Environmental Monitoring) data on the background average annual concentrations at the site where study was being undertaken, the suitability of techniques for modeling chemical substances’ dispersion in the atmosphere in order to assess hazard, etc. However, in the course of the work, special attention was paid to some specific uncertainties that are due to the peculiarities of the waste landfill operation under study:

1. An uncertainty concerning the volume of waste deposited at the landfill. Information on the amount of waste is usually provided by the owner of the landfill according to accounting data, which is not always true.
2. The volume of released biogas largely depends on compositional analysis of solid municipal wastes. Such analysis has never been undertaken in Kursk.
3. The components of the landfill body wastes can significantly vary over time depending on some factors, for example, from the combustion of waste at the landfill, which has been repeatedly revealed at the Kursk SMW landfill.

These uncertainties can significantly influence the results of the study, especially in terms of quantitative composition of emissions. Thus, despite the fact that the level of non-carcinogenic risk was assessed as low, and the total carcinogenic risk was attributed to the first risk range (minimum level), we propose the introduction of a degassing system at the landfill in Kursk, in which biogas released from the landfill body is to be collected and used to generate heat or electricity [7]. The use of a degassing system will make it possible almost completely to eliminate biogas release into the atmosphere, decrease load on the air and reliably reduce the level of hazard to public health from the impact of SMW landfill to minimum values.
Table 3. Total hazard indices with simultaneous input of chemical substances depending on their influence on critical organs and systems excluding the background

| territories                                      | organs                        | substances                                      | HI min   | HI max   |
|-------------------------------------------------|-------------------------------|-------------------------------------------------|----------|----------|
| estimated sanitary protection zone of industrial site | breathing organs             | ammonia, xylene, nitrogen dioxide, formaldehyde, sulfur dioxide, hydrogen sulfide, soot | 4.78E-02 | 1.66E-01 |
|                                                 | development                   | carbon monoxide, ethyl benzene, benzapyrene     | 1.50E-04 | 6.20E-04 |
|                                                 | central nervous system        | toluene, xylene, carbon monoxide                | 4.91E-03 | 1.65E-02 |
|                                                 | blood                         | carbon monoxide, nitrogen dioxide               | 2.64E-03 | 1.37E-02 |
|                                                 | immune system                 | formaldehyde, benzapyrene, sulfur dioxide       | 2.76E-02 | 9.38E-02 |
|                                                 | kidneys                       | xylene, ethyl benzene, toluene                 | 3.62E-03 | 1.20E-02 |
|                                                 | liver                         | xylene, ethyl benzene, toluene                 | 3.62E-03 | 1.20E-02 |
|                                                 | heart vascular system         | carbon monoxide, sulfur dioxide                 | 2.93E-03 | 1.17E-02 |
|                                                 | HI total                      |                                                 | 9.33E-02 | 3.26E-01 |
| residential space in the affected area          | breathing organs             | ammonia, xylene, nitrogen dioxide, formaldehyde, sulfur dioxide, hydrogen sulfide, soot | 4.95E-02 | 1.31E-01 |
|                                                 | development                   | carbon monoxide, ethyl benzene, benzapyrene     | 1.52E-04 | 4.53E-04 |
|                                                 | central nervous system        | toluene, xylene, carbon monoxide                | 5.08E-03 | 1.31E-02 |
|                                                 | blood                         | carbon monoxide, nitrogen dioxide               | 2.64E-03 | 9.27E-03 |
|                                                 | immune system                 | formaldehyde, benzapyrene, sulfur dioxide       | 2.87E-02 | 7.46E-02 |
|                                                 | kidneys                       | xylene, ethyl benzene, toluene                 | 3.75E-03 | 9.65E-03 |
|                                                 | liver                         | xylene, ethyl benzene, toluene                 | 3.75E-03 | 9.65E-03 |
|                                                 | heart vascular system         | carbon monoxide, sulfur dioxide                 | 3.03E-03 | 8.71E-03 |
Table 3. Continuation

|                  | HI total          |
|------------------|-------------------|
| breathing organs | ammonia, xylene,  |
|                  | nitrogen          |
|                  | dioxide, formaldehyde, sulfur dioxide, hydrogen sulfide, soot | 4.55E-02 | 1.68E-01 |
| development      | carbon monoxide, ethyl benzene, benzapyrene | 1.39E-04 | 6.09E-04 |
| central nervous system | toluene, xylene, carbon monoxide | 4.68E-03 | 1.67E-02 |
| garden plots     | carbon monoxide, nitrogen dioxide | 2.39E-03 | 1.35E-02 |
| blood            | formaldehyde, benzapyrene, sulfur dioxide | 2.63E-02 | 9.52E-02 |
| immune system    | xylene, ethyl benzene, toluene | 3.45E-03 | 1.23E-02 |
| kidneys          | xylene, ethyl benzene, toluene | 3.45E-03 | 1.23E-02 |
| heart vascular system | carbon monoxide, sulfur dioxide | 2.77E-03 | 1.15E-02 |

| HI total          | 8.87E-02 | 3.30E-01 |

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