Assessment of environmental risk of municipal solid waste Landfill (by example of the city of Belgorod)

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Abstract. The paper discusses current environmental problems associated with the accumulation and disposal of municipal solid waste in Russia by the example of the Belgorod region. It is shown that the existing rates of waste accumulation can lead to environmental emergencies in the region. The scenarios for the development of emergency situations at the landfill of Belgorod were considered. The analysis show that the most dangerous in terms of the social and environmental consequences of dangerous situations are scenarios related to the filtering of the contents of the map-ditches into the environment. Also, the high integral risk has a scenario with pollution of atmospheric air of polygon gases. Using the method of risk matrices by formalizing expert opinions, it is shown that a comprehensive method of disposal of solid waste minimizes anthropogenic pressure on the environment in the field of waste management.

1. Introduction

Currently, the problem of increasing the volume of industrial and municipal solid waste (MSW) generation is relevant for all regions of Russia According to the data provided in the Environmental Security Strategy of the Russian Federation for the period up to 2025, over 30000 million tons of waste has been accumulated as a result of past economic and other activities [1]. Currently, more than 14700 authorized waste disposal sites occupy an area of about 4 million hectares (which is comparable to the territory of Switzerland and the Netherlands), and 400,000 hectares of land are allocated annually for disposing of increasing volumes of MSW (40% more than Luxembourg’s territory) [1]. At present, the Government of the Russian Federation has begun large-scale reforms related to changing the order and methods of utilizing solid household waste.

Belgorod region is among the most successfully developing industrial-agrarian regions of Russia. The favorable economic and geographical position, the availability of natural resources and the developed infrastructure make the region attractive for investment projects and the promotion of innovative technologies. Belgorod Region has 1.1 percent of the country’s population, and produces up to 1 percent of the gross regional product in the Russian Federation, 1.5 percent of industrial goods, and about 4 percent of agricultural products [2]. High economic potential, growth in population size and population density cause the formation of significant volumes of various types of waste in the Belgorod region. In the Belgorod region, the volume of municipal solid waste is about 144 million tons annually.
To achieve risk reduction in the process of disposal of solid waste, the following tasks are required [4,5]:
1. To simulate scenarios of environmental risks of the landfill.
2. Analyze the possibility of using the integrated disposal of solid waste to reduce environmental risks.

2. Study area
In this study we consider the MSW landfill of the city of Belgorod. The study area is located in the Belgorod Region (Streletskeoe, 50°36′07.17″N, 36°27′40.40″E), western part of the Belgorod (Figure 1 and 2). The landfill is located on an area of 5 hectares. The distance from the center of city is about 9 km in the direction to the south-west; the distance from nearest living district is 1100 m. It is being used for disposal of mixed municipal waste. Every day, up to 38·10³ kg of waste is authorized for landfilling. The disposed waste includes: municipal solid waste, non-hazardous wastes and the material for landfill cover. Wastes may include scraps of paper, plastics and metals, packing, spent tires, textile products, building materials, ashes from municipal solid waste incinerators, polluted terrain from environment reclamation, etc.

![Figure 1. Location of Belgorod, Russian Federation.](image1)

![Figure 2. Belgorod city map and MSW Streletskeoe landfill location.](image2)

3. Results and discussion
Waste from residential buildings, public buildings and institutions, trade enterprises, public catering, street, landscape estimates, construction waste, solid industrial waste of 3–4 hazard classes for placement in ravine maps and for more than 20 years of operation are accepted at the landfill. It received 1.5 million tons of municipal solid and industrial waste.

On the basis of a detailed analysis of the impact of environmental factors on the environment and humans [6-12], the scenarios were taken as the baselines, as it shown in Table 1.

The numerical risk assessment at the MSW site of Belgorod was performed using the risk matrix method by formalizing expert opinions [13,14].

The value of risk was calculated by the formula:

\[ R = K_i \cdot K_s \cdot W \cdot S \]  \hspace{1cm} (1)

where \(R\) is the risk (Table 1); \(W\) – probability of the accident realization (\(W\) takes values 1 – 6): 1 – The onset of an accident is unlikely, or the probability of its occurrence is no more than \(10^{-3} – 10^{-2}\) times a year (no more than once in 100 years); 2 – The onset of the accident is not likely enough, or the probability of its occurrence is \(2 \cdot 10^{-2} – 10^{-1}\) times a year (no more than 1 time in 10 – 50 years); 3 – The onset of the accident is likely, or the probability of its occurrence is \(2 \cdot 10^{-1} – 10^{-0}\) times a year (no more than 1 time in 4 – 10 years); 4 – The onset of the accident is very likely, or the probability of its occurrence is \(10^{-0} – 2.5 \cdot 10^{0}\) times a year (no more than 1 time in the period 1 – 4 years); 5 – The occurrence of an accident is extremely likely, or the probability of its occurrence is \(3 \cdot 10^{-1} – 10^{0}\) times a year (no more than 1 time in the period 1 year); 6 – The occurrence of an accident is certain, or the probability of its occurrence is \(10^{0} – 10^{1}\) times a year (it will occur in the period 1 – 4 years)
times a year (no more than 1 time in 1–3 years); 6 – The onset of the accident is inevitable, or the probability of its occurrence is $10^0 - 10^1$ times a year (1 or more times a year);

**Table 1.** Types of accidents.

| Scenario number and risk $R_i$ | Types of accidents |
|--------------------------------|-------------------|
| 1 ($R_1$)                      | Failure of embankment dams and waste disposal maps (overflow, destruction of the dam body) |
| 2 ($R_2$)                      | Imperfection of underground clay massif due to neotectonic phenomena |
| 3 ($R_3$)                      | Filtration of polluted wastewater through drainage channels and through the near-surface soil layer into the environment |
| 4 ($R_4$)                      | Atmospheric transfer from waste treatment facilities |
| 5 ($R_5$)                      | Air pollution caused by ignition on the waste disposal map |
| 6 ($R_6$)                      | Soil pollution with heavy metals |
| 7 ($R_7$)                      | Emission of pollutants as a result of extreme natural phenomena (tornadoes, hurricanes, earthquakes) or man-made events (plane crash, terrorist act) |
| 8 ($R_8$)                      | Accidents in the implementation of recycling processes |
| 9 ($R_9$)                      | Damage to human health as a result of outbreaks of infectious diseases at landfills |

$S$ – damage magnitude (Table 2); 

**Table 2.** Magnitude $S$ of the factor assessing the consequences of catastrophic accidents (scale 1 – 5).

| $S$ | Description of the consequences of the accident depending on the magnitude |
|-----|------------------------------------------------------------------------|
| 1   | The consequences are insignificant, can be eliminated by the management of the landfill in the organization of current costs up to 1 month |
| 2   | The consequences are limited; they can be eliminated at the expense of the internal reserves of the landfill management company or the attraction of borrowed funds. The cost of eliminating the consequences will not lead to the bankruptcy of the management company. The term of elimination of consequences is up to 1 year. |
| 3   | Major damage, elimination of the consequences requires the support of the federal center or international organizations. Term of elimination of consequences – 3 years or more |
| 4   | Big damage, elimination of the consequences requires the support of the federal center or international organizations. Term of elimination of consequences – 3 years or more |
| 5   | Irreparable damage, consequences can be minimized for a long time. |

$K_1$ – ranking of the time factor of the impact of the primary subject of exposure to risk objects (correction factor $K_1$ takes values from 1.1 to 1.7): 1.1 – Impact of the factor is absent; 1.2 – Impact of the factor is of a pulse nature (less than 1 hour); 1.3 – The impact factor is small (1 – 12 hours); 1.4 – The impact of a factor of short duration (12 – 24 hours); 1.5 – Exposure to a factor of average duration (24 – 96 hours); 1.6 – The impact of the factor is very long (5 – 30 days); 1.7 – The impact of the factor is extremely long (more than 30 days) or is permanent; 

$K_2$ – factor of seasonal distribution of hazardous phenomena and processes (correction factor $K_2$ takes values from 1.1 to 1.4): 1.1 – Seasonal conditions have little or no effect on the course of an emergency situation; 1.2 – Seasonal conditions may partially complicate an emergency situation; 1.3 – Seasonal conditions can significantly complicate the course of an emergency situation; 1.4 – Seasonal
conditions, coupled with the most threatened period of the year, may unpredictably complicate an emergency situation.

According to the results of the evaluation of the components of the object under study, relationships are constructed explaining the relationship between the psycholinguistic operators and the quantitative measures assigned to them (Table 3) [15-20].

| Scenario number | Scenario                                                                 | Parameters of R | The level of risk | Actions                                                                 |
|-----------------|--------------------------------------------------------------------------|-----------------|------------------|-------------------------------------------------------------------------|
| 1 (R₁)          | Failure of embankment dams and waste disposal maps (overflow, destruction of the dam body) | W = 4, K₁ = 1.2, K₂ = 1, S = 4, R₁ = 27 | Average          | In the framework of the perspective activity of the enterprise, planning of measures is carried out to reduce the risk with the reservation of a special budget |
| 2 (R₂)          | Imperfection of underground clay massif due to neotectonic phenomena     | W = 2, K₁ = 1.5, K₂ = 1.1, S = 4, R₁ = 13 | Low              | Special events are not required at the moment, the risk can be neglected before obtaining data indicating an increase of risk. |
| 3 (R₃)          | Filtration of polluted wastewater through drainage channels and through the near-surface soil layer into the environment | W = 6, K₁ = 1.7, K₂ = 1.3, S = 4, R₁ = 53 | Very low         | The development and implementation of a special large-scale action plan with the involvement of outside experts with the involvement of large volumes of third-party funding is required. |
| 4 (R₄)          | Atmospheric transfer from waste treatment facilities                     | W = 6, K₁ = 1.4, K₂ = 1.2, S = 3, R₁ = 30 | High             | Requires the development and implementation of a list of special measures to reduce the risk of attracting additional funding from internal or external sources |
| 5 (R₅)          | Air pollution caused by ignition on the waste disposal map               | W = 4, K₁ = 1.3, K₂ = 1.2, S = 3, R₁ = 19 | Low              | Special events are not required at the moment, the risk can be neglected before obtaining data indicating an increase of risk. |
| 6 (R₆)          | Soil pollution with heavy metals                                       | W = 5, K₁ = 1.2, K₂ = 1.3, S = 3, R₁ = 23 | Average          | In the framework of the perspective activity of the enterprise, planning of measures is carried out to reduce the risk with the reservation of a special budget |
| 7 (R₇)          | Emission of pollutants as a result of extreme natural phenomena or man-made events | W = 1, K₁ = 1.2, K₂ = 1.3, S = 3, R₁ = 5 | Very low         | No special events are required.                                           |
| 8 (R₈)          | Accidents in the implementation of recycling processes                  | W = 2, K₁ = 1.2, K₂ = 1.3, S = 3, R₁ = 9 | Very low         | No special events are required.                                           |
| 9 (R₉)          | Damage to human health as a result of outbreaks of infectious diseases at landfills | W = 3, K₁ = 1.6, K₂ = 1.2, S = 2, R₁ = 12 | Low              | Special events are not required at the moment, the risk can be neglected before obtaining data indicating an increase of risk. |
The analysis shows that the most dangerous in terms of the social and environmental consequences of dangerous situations are scenarios related to the filtering of the contents of the card-trenches into the environment, and the danger is represented by both existing and old filled maps. Also, the high integral risk has a scenario with pollution of atmospheric air of polygon gases. In order to reduce the environmental risks of these two situations, it is advisable to use complex methods for the disposal of solid waste: sorting, composting (Table 4).

**Table 4. Risk assessment of complex solid waste disposal methods.**

| Scenario number | Scenario | Parameter of $R$ | The level of risk | Actions |
|----------------|----------|------------------|------------------|---------|
| 1 (R₁)         | Failure of embankment dams and waste disposal maps (overflow, destruction of the dam body) | $W = 5$ | Average | In the framework of the perspective activity of the enterprise, planning of measures is carried out to reduce the risk with the reservation of a special budget |
|                |          | $K₁ = 1.6$       |                  |         |
|                |          | $K₂ = 1.2$       |                  |         |
|                |          | $S = 3$          |                  |         |
|                |          | $R₁ = 23$        |                  |         |
| 2 (R₂)         | Imperfection of underground clay massif due to neotectonic phenomena | $W = 5$ | Low | Special events are not required at the moment, the risk can be neglected before obtaining data indicating an increase of risk. |
|                |          | $K₁ = 1.3$       |                  |         |
|                |          | $K₂ = 1.2$       |                  |         |
|                |          | $S = 2$          |                  |         |
|                |          | $R₁ = 16$        |                  |         |

4. Conclusion

The analysis showed that the most dangerous in terms of the social and environmental consequences of dangerous situations are scenarios related to the filtering of the contents of the map-ditches into the environment. Also, the high integral risk has a scenario with pollution of atmospheric air of polygon gases. Thus, the method of risk matrices through the formalization of expert conclusions has shown that a comprehensive method of disposal of solid waste minimizes the anthropogenic burden on the environment in the field of waste management.

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