Study of Soil in an Area Affected by a Solid Municipal Waste Landfill

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Abstract. The aim of this study is the detailed assessment of the impact of a solid municipal waste landfill on its adjacent land. The contents of heavy metals and some major components in soils at the SMW landfill boundary and in the sanitary protection zone were determined by potentiometry and atomic absorption spectroscopy. It was established that the actual concentration values in soil are significantly higher than the standard limits.

1. Introduction

One of the major problems related to Lake Baikal and its surrounding area is the waste management because the selective waste collection is not currently implemented. The Irkutsk region occupies one of the last places in Russia in terms of amount of waste recycling. The operated and reclaimed landfills and illegal dumps cause irreparable damage to the unique ecosystem of Lake Baikal. At the same time, there is a lack of appropriate monitoring system, thus, the technogenic load parameters and the environmental impact caused by the operation of solid municipal waste (SMW) landfills need special research to be assessed.

According to the Environmental Safety Strategy of the Russian Federation for the period to 2025, the total amount of waste that has been disposed by now all over the country is estimated at more than 30 bln tons. Each year, the amount of waste not involved in circular economy increases. Waste landfilling and dumping reduces the area of productive agricultural lands. After being taken from containers, waste is to be transported to a landfill [1-2].

The Irkutsk region is divided into 2 zones. The Zone 1 (NORTH) covers 11 districts and municipal areas with the total population of 689,900 people; its area is 42.9 mln ha, the yearly waste output is 287,000 tons; the regional waste management operator is JSC Bratsk SMW Landfill. The Zone 2 (SOUTH) covers 31 districts and municipal areas with the total population of 1,724,700 people; its area is 36.3 mln ha; the yearly waste output is 977,100 tons; the regional waste management operator is JSC RT NEO Irkutsk [3]. There are 23 landfills in the region, 70% (16 facilities) characterized by medium and high degree of filling. Another eight landfills are located in the natural territory near Lake Baikal. Altogether, these sites for authorized deposition cover 35.7% of regional needs [4]. According to the Ministry of Natural Resources and Environment of the Irkutsk region, about 40 facilities more are needed to manage the total amount of waste. In the nearest years, sorting facilities of the total capacity of 500,000 tons are planned to be constructed [3-5].
The aims of this study are, first, to determine the landfill soil composition in terms of heavy metals and other components and, second, to assess the environmental impact of a landfill. The results of this study can be used by environmental scientists, decision-makers, and environmental activists to accelerate the implementation of selective collection and recycling of municipal waste.

2. Research part

The Marata SMW landfill in the city of Irkutsk launched in 1963 is located at the 5th km of the Aleksandrovsky highway and has the area of 42 ha. The landfill has been many times expanded by tens of hectares to prolong its lifetime. Currently, it is more than 90% full. Every day, the landfill receives 1,500 m$^3$ of waste. The total amount of waste currently disposed at the landfill site is over 10 mln tons [4].

Soils around the landfill are polluted via atmospheric transfer and subsequent precipitation of pollutants and via surface watercourses that interact with the landfill. As a rule, the pollution affected area of soil is similar to that of ground water. The soil pollution was assessed based on the following parameters: the pollution affected area, the maximum distance to pollution front, and the pollution composition. The sampling points were chosen considering the geochemical migration of elements at an autonomous location, on gentle slopes of the water divide, high and low on the floodplain, and in superaquatic landscapes. As a result of the sample analysis, the geochemical barriers can be determined and the distribution of pollutants in soil can be registered [6]. Thus, soil samples were collected at the SMW landfill boundary and at the distance of 500 m from it in the sanitary protection zone. Soils were sampled in September 2019 on four sides of the landfill considering prevailing winds, landscape, and water level [7-9]. Also, the coordinates of sampling points were registered, and the photo and video recording was performed. Sampling points were not chosen randomly. The studies of the physicochemical properties and the determination of the pollution degree of landfill soil in 2014 showed that the lead, arsenic, cobalt, nickel, and copper contents were hundreds and thousands of times higher than their limits [10-15]. Thus, it was decided to continue the research of the landfill-affected area to measure the parameters that exceeded the limits in 2014 (Fig.1, 2).

![SMW landfill of the Irkutsk city. Sampling points.](image)

**Figure 1.** SMW landfill of the Irkutsk city. Sampling points.
1,2 - western slope, 3,4 - northern slope, 5,6 - eastern slope, 7,8 - southern slope.
The compliance with the quality standards for the soil layer was assessed using the hygiene standard SanPiN 1.2.3685-21 [16]. Threshold limit values (TLVs) of chemical substances in soil. In the case of leachate pollution of the soil layer, it leaks into upper aquifers, thus, pollutants are eventually carried into the Angara river, which is a fishery waterbody. Soil samples were studied by atomic absorption spectroscopy. The preparation and storage of soil samples were performed in compliance with the standard techniques. The results of the study are charted in Tables 1 and 2.

Table 1. Contents of metals in soil samples.

| №  | Ni     | Cu     | Pb     | Cd     | Mn     | Fe     |
|----|--------|--------|--------|--------|--------|--------|
| 1  | 9,22±2,77 | 9,48±2,84 | 8,05±2,42 | 0,071±0,021 | 18,76±5,63 | 1610±241 |
| 2  | 19,88±5,96 | 6,99±2,1 | 6,53±1,96 | 0,03±0,009 | 19,19±5,76 | 391±58  |
| 3  | 22,32±6,7 | 14,43±4,33 | 6,79±2,04 | 0,096±0,029 | 19,25±5,78 | 1060±159 |
| 4  | 13,06±3,92 | 7,64±2,29 | 6,47±1,94 | 0,047±0,014 | 19,26±5,78 | 579±86  |
| 5  | 11,97±3,59 | 10,22±3,07 | 7,57±2,27 | 0,145±0,043 | 19,59±5,88 | 115±17  |
| 6  | 34,28±10,28 | 10,78±3,23 | 2,44±0,73 | 0,027±0,008 | 19,31±5,79 | 282±42  |
| 7  | 29,15±8,75 | 5,18±1,55 | 8,21±2,46 | 0,053±0,016 | 19,23±5,77 | 420±63  |
| 8  | 24,40±7,32 | 9,4±2,82 | 6,34±1,9 | 0,092±0,028 | 19,53±5,86 | 141±21  |
| TLV| 4      | 3      | 6      | -      | 1500   | -      |

As can be seen from the presented data for copper, nickel, and lead, in samples collected at the landfill boundary, their concentrations are several times higher than their TLVs. In samples collected in the sanitary protection zone, TLVs for these metals are also violated.

Figure 2. Sampling point No. 8 on the border of the landfill and the sanitary protection zone.
Table 2. Testing results for soil samples.

| Sample | Water pH, pH units | Total nitrogen, % | Exchangeable ammonium nitrogen, mln^{-1} | Nitrate nitrogen, mln^{-1} | Nitrite nitrogen, mg/kg | Phosphate ions, mg/kg |
|--------|--------------------|-------------------|------------------------------------------|---------------------------|-------------------------|-----------------------|
| 1      | 8,5±0,1            | 0,11±0,02         | 7,2±1,1                                  | 0,95±0,3                  | 0,3±0,12                | 45±11                 |
| 2      | 6,5±0,1            | 0,29±0,04         | 10±1                                     | 0,61±0,19                 | 0,47±0,19               | 46±12                 |
| 3      | 8,8±0,1            | 0,067±0,016       | 2,4±0,4                                  | 1,0±0,3                   | 0,32±0,13               | 36±9                  |
| 4      | 4,8±0,1            | 0,83±0,1          | 17±2                                     | 2,7±0,9                   | 0,17±0,07               | 375±56                |
| 5      | 5,8±0,1            | 0,53±0,07         | 39±3                                     | 4,0±1,3                   | 0,17±0,07               | >500 (1034)           |
| 6      | 6,8±0,1            | 0,028±0,012       | 1,3±0,2                                  | 1,0±0,3                   | 0,16±0,06               | 34±9                  |
| 7      | 5,8±0,1            | 0,043±0,013       | 6,3±0,9                                  | 0,30±0,1                 | 0,16±0,06               | 43±11                 |
| 8      | 5,8±0,1            | 0,051±0,07        | 31±2                                     | 2,6±0,8                   | 0,22±0,09               | 421±63                |
| ND     | GOST 26423-85      | 26107-84          | 26489-85                                 | 16.1:2.2:2.3:            | 16.1:2.2.2:2:3.         | 67-10                 |
|        |                    |                   |                                          |                           |                         | 3.51-10               | 52-08                 |

The most probable reason of the high heavy metal contents in soils sampled at the landfill boundary and in the sanitary protection zone is burial of hazardous wastes (e.g., medical waste, mercury-containing waste including thermometers and mercury lamps, and spent batteries and accumulators) in the landfill [17-19]. The highest hazard is associated with leachate, which is formed by atmospheric precipitation at the landfill [20-21]. Penetrating into the landfill body, precipitates cause leaching of metals and, thus, soil contamination around the landfill and can penetrate into the major aquifers, which are the sources of drinking water for the Karluk and Glazunovo villages. The heavy metal contents in soils are also affected by the nearby automobile highway.

3. Conclusions
The soil samples collected at the landfill boundary and in the sanitary protection zone were studied. The physicochemical parameters were determined by potentiometric analysis and atomic absorption spectroscopy.

It was established that the studied samples contain heavy metals in high concentrations. The soil pollution is caused by the water migration of chemical substances including heavy metals that are occur in the landfill body after waste burial and the location of the landfill near an automobile highway.

The environmental assessment of the landfill was performed. It was concluded that the SMW landfill of the Irkutsk city is now close to its end-of-life stage, and it is urgent that the waste management development strategy were elaborated for the Irkutsk region in cooperation with the regional waste management operator, which would decrease the technogenic load on the environment of Baikalia. The manufacturing supervision of the SMW landfill should include the constant observation of the soil, water, and air condition in the landfill-affected area. It is also important to implement the selective waste collection and recycling as soon as possible to reduce the environmental impact of the landfill.

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