Method for Assessing the Environmental and Social Risks of Unauthorized Landfill Sites

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Abstract. The problem of production and consumer waste generation is one of the main environmental issues of industrial society. However, the main method of waste disposal in Russia is still its landfilling at waste disposal facilities (landfill deposits, authorized and unauthorized dumps). A separate group of waste disposal facilities consists of illegal unauthorized landfill sites with solid municipal waste. The specificity of these waste disposal facilities is the complexity of monitoring of their formation and the difficulty of assessing their impact on the environment and public health. At present, there is no standard approved methodology for assessing the environmental and social risks of illegal unauthorized landfill sites. For that purpose, the authors have developed a method for assessing the hazards of unauthorized landfill sites, based on comparing the actual characteristics of landfills obtained during field surveys of urban areas with certain tabular values. Initial keeping track of landfill sites is fulfilled with the application of a web portal that implements geoinformational technologies. The use of the web portal for rapid detection of illegal unauthorized landfill sites, as well as the author's method and software that implements this method allows for rapid assessment of the environmental and social hazard of landfills based on data from field surveys of urban areas without laboratory measurements. The results obtained are intended for the classification of illegal landfill sites in order to develop plans for their elimination, taking into account the priorities of environmental policy.

1. Introduction

As it was noted by many scientists (M. Caniato, T. Tudor & M. Vaccari (2015), Daniel Hoornweg & Perinaz Bhada-Tata (2017), T. D. Farmer, P. J. Shaw & I. D. Williams (2015) and others) the problem of production and consumer waste generation is one of the main environmental concerns of industrial society at the present stage of its development [1-4]. Despite the fact that the world is aware of the need for competent waste management, excluding its accumulation in natural environment locations, in Russia, until now, the main method of waste disposal is its dumping at waste disposal facilities (further as the text goes WDF).

A separate group of WDF consists of illegal unauthorized landfills with solid municipal waste (further in the text SMW). The peculiarity of these WDF is the complexity of keeping track of their formation and the difficulty of assessing their impact on the environment and public health.

The impact of various substances generated during the decomposition of waste placed in landfill deposits and dumps on the environment and living organisms is presented in table 1.
### Table 1. Impact of waste decomposition products on the environment and living organisms

| Harmful substances | Main processes of harmful substances formation | Impact on the environment                  |
|--------------------|-----------------------------------------------|-------------------------------------------|
| Carbon monoxide (IV), carbon dioxide CO₂ | Waste incineration                            | Greenhouse effect                          |
| Carbon monoxide (II), carbon monoxide CO | Waste incineration                            | Disorder of atmosphere heat balance        |
| Lead and other heavy metals         | Landfill sites                                | Accumulation in organisms through food chains |
| Dioxins                  | Burning plastic material                       | Mutations of the organism                  |
| Mercury                  | Landfill sites                                | Accumulation in organisms through food chains |
| Methane                  | Decay                                         | Greenhouse effect                          |

Assessment of the negative impact of dumps and authorized landfills with SMW on the environment is carried out in the process of their monitoring.

The negative impact of dumps and authorized landfills on human health can be analyzed in the process of assessing the risk to public health due to exposure to chemicals that pollute the environment [5]. The features of risk assessment procedures of WDS negative impact on the environment and public health are considered in the studies of I. O. Kirilchuk, A. V. Besedin, G. P. Timofeev & A. V. Iordanova (2019) [6].

As has been noted by the authors in [7], at present, there is no standard approved methodology for assessing the environmental and social hazards of illegal unauthorized landfills. For that purpose, the authors have developed a method for rapid assessment of unauthorized landfills hazard, based on comparing the actual characteristics of dumps obtained during field surveys of urban areas with certain tabular values.

Approbation of the method has showed the occurrence of calculation abnormalities related to determining the hazard class by only one parameter. Therefore, it is necessary to develop an updated method, characterized by exacted calculation algorithm of environmental hazard class of unauthorized landfill sites, eliminating the occurrence of these calculation anomalies. This method should also take into account the evaluation of environmental damage to the earth's surface caused by unsanctioned landfill sites.

### 2. Materials and methods

An online resource is used for detection and initial keeping track of illegal unauthorized landfills being formed in the urban area. In the on-line mode it gives users the opportunity to put the location of SMW landfills on an interactive city map as point features. It is also possible to add the following attribute in-formation: waste landfill location, the approximate composition of landfills (paper, plastic containers, food waste, etc.), the size of a landfill, reasons for the formation of a waste landfill (undue removal of waste by specialized organizations, absence of trash enclosure or the insufficient number of containers, etc.), possible, according to the person who keeps track of the landfill, ways to solve this problem. The developed web resource is available in a user mode at http://dev.swsu.ru/. The interface of this web resource is shown in Figure 1.
The next step is to assess landfill hazard using plug-in external software modules that implement the author's algorithm for calculating a landfill environmental hazard class.

3. Results and Discussion
The environmental hazard class of a landfill site \( K \) is determined based on the analysis of certain parameters:

\[
K = K(S, C, L, Vf, T, D),
\]

where \( S \) – landfill area, m\(^2\);

\( C \) – approximate composition of landfilled waste;

\( L \) – distance from the places of human activity, reservoirs and special protected natural areas, m;

\( Vf \) – volume of the resulting filtrate, cub. m/year;

\( T \) – life cycle of a landfill, years;

\( D \) – amount of damage to soils as to a type of natural environment location, in thousand rubles.

Table 2 shows the correspondence of these parameters to the landfill hazard class.

| \( K \) | \( S \) | \( C \) | \( L \) | \( T \) | \( Vf \) | \( D \) |
|--------|--------|--------|--------|--------|--------|--------|
| I – extremely hazardous | >20 | Food waste, rubber, plastic | <50 | >2 | >15 | D>10 |
| II – highly hazardous | 15<\( S \)≤20 | Paper, metal | 50<\( L \)≤100 | 1,5<\( T \)≤2 | 10<\( Vf \)≤15 | 5<D≤10 |
| III – moderately hazardous | 10<\( S \)≤15 | Textiles, wool | 100<\( L \)≤200 | 1,5<\( T \)≤2 | 10<\( Vf \)≤15 | 2<D≤5 |
| IV – low hazard | 5<\( S \)≤10 | Wood, leather products | 200<\( L \)≤300 | 1<\( T \)≤1.5 | 5<\( Vf \)≤10 | 1<D≤2 |
| V – virtually non-hazardous | \( S \)≤5 | Brick /stone | \( L \)>300 | \( T \)≤1 | \( Vf \)≤5 | D≤1 |

The definition of the environmental hazard class of an unauthorized landfill is as follows: the actual values of a landfill are compared with the tabular ones in sequence. If three or more parameters from the actual values match the tabular ones in the first row, hazard class I is assigned. If there are no
matches with the values of the first row, the same comparison is made with the second row values, then with the third row values and subsequent ones. If two or more parameters match the second row values and one or two in the first row values, hazard class II is assigned. In the same way, all table rows are checked.

By considering the life cycle of the landfill (criterion T), indirect recording of biogas release is provided. Since the value of this parameter is determined by complex mathematical dependencies, it is sufficient to take into account the possibility of biogas formation in the landfill body for current classification of a landfill. The release of biogas only begins 2 years after the landfill occurrence.

A modified water balance equation can be used to find the volume of the resulting filtrate:

\[ V_f = (AP + WM + WWBR) - (E + MRC + SD + WB + WABR), \]

where \( V_f \) — filtrate volume;

\( AP \) — atmospheric precipitation at the landfill;

\( WM \) — wringing moisture;

\( WWBR \) — water weepage during biochemical reactions;

\( E \) — evaporation from the surface of the landfill site;

\( MRC \) — moisture consumed for the saturation of waste till full moisture-retaining capacity;

\( SD \) — surface discharge;

\( WB \) — loss of water due to biogas;

\( WABR \) — water absorption during biochemical reactions.

The extent of damage to soils as a natural environment location is calculated by the Method [8] and is expressed in cost form.

The extent of damage caused by unauthorized placement of production and consumer waste is calculated in the cost form using the following formula:

\[ D = \sum_{i=1}^{n} (M_i \cdot T_{ox} \cdot K_{land}), \]

where \( D \) — extent of damage, in rubles;

\( M_i \) — mass of waste with the same hazard class/ t;

\( T_{ox} \) — rates for calculating the extent of damage caused to soils as a natural environment location in case of soil degradation as a result of unauthorized placement of production and consumer waste;

\( K_{land} \) — parameter that is determined depending on the category of land and intended use on which the contaminated site is located.

Based on the proposed method, special software has been developed for calculating the environmental hazard class of an unauthorized landfill site.

### 4. Conclusion

Testing of the developed algorithm, method and special software has been carried out on the example of a real illegal unauthorized landfill site located on the territory of Kursk. Figure 2 shows the results of the environmental and social hazard assessment of this landfill.

Thus, the use of the web portal for effective detection of illegal unauthorized landfill sites, as well as the authors’ method and software that implement this method allows for rapid assessment of the environmental and social hazard of landfills based on data from field surveys of urban areas without laboratory measurements. The results obtained are intended for classification of unauthorized landfill sites in order to develop plans for their elimination, taking into account the priorities of environmental policy.
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