



SUSTAINABILITY OF MSW FACILITIES IN CLIMATE CHANGES CONDITIONS

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Abstract

The article examines the problems of risk management of the adverse impacts of climate change, the risks of new or amplified existing factors affecting the municipal solid waste (MSW) management. Increased wind load, significant precipitation, unstable temperature conditions both in summer and winter, rising groundwater levels in urban areas, and others are the causes of risks of financial, technological, and legal instability, increasing the adverse impact on the urban environment in the activities of organizations managing housing, urban areas, and public utilities, supply of municipal resources, and municipal solid waste management. Special attention should be paid to the activities of regional environmental operators, taking into account new impact factors in the development and implementation of territorial schemes for the management of municipal solid waste. There have to be tools to manage such risks. Insurance is one of the most universal and widespread economic instruments. However, regulatory and methodological support does not always meet the prevailing conditions. Therefore, it is necessary to develop approaches to the insurance of production and consumption waste management facilities in the context of increased exposure to the negative effects of climate change.

Keywords: Municipal Solid Waste, MSW, Regional Environmental Operator, Climate Factors, Climate Vulnerabilities, Climate Exposure.

I. Introduction

For the near future, the Strategy of Environmental Safety of the Russian Federation considers the adverse effects of climate change to be the main challenges [VI]. In 2023 for the Russian Federation, the average annual air temperature anomaly (deviation from the average for 1991-2020) was +0.99°C. The part of the country's area occupied by abnormal temperature variations was 92% [VII]. There were a number of dangerous weather phenomena – 1,191, of which 448 were damaged [VIII]. This has had a major impact on MSW treatment facilities [V]. Despite some positive economic effects that have manifested themselves due to changing climatic conditions, for example, the expansion of the zone of sustainable agriculture, a decrease in the

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consumption of energy resources in urban areas, a relative increase in the duration of seasonal navigation on rivers and seas surrounding Russia and others, the overall situation is unstable and requires the development and application of tools that would ensure the stability of the functioning of the objects of economic activity.

Climate risk assessment is carried out in accordance with federal and regional legislation [IV].

II. Materials and methods

All municipal solid waste treatment facilities are objects of adverse impacts on the urban environment, which is enhanced by climatic factors. To select a risk management method effectively, it is necessary to determine the level of such impact, its nature, and limits (Table 1). The level of risk of adverse impacts on the environment also depends on the exposure of the MSW facility to climatic factors. Local conditions of MSW objects should be taken into account of MSW objects, including the traditional conditions of seasonal factors, for example, the direction of movement of air masses, precipitation levels, and temperature conditions.

Table 1: Analysis of the risks of adverse impact on the components of the natural environment at various stages of MSW management [I].

The risk of adverse impact of MSW on the urban environment	Accumulation of MSW	Transportation of MSW	Processing of MSW	Disposal of MSW
Components of the natural environment	Exposed	Exposed	Exposed	Exposed
Natural environmental systems			Exposed	Exposed
Natural landscapes			Exposed	Exposed
Natural and anthropogenic objects	Exposed	Exposed	Exposed	Exposed
Anthropogenic objects	Exposed	Exposed	Exposed	Exposed
Natural resources			Exposed	Exposed
Natural complexes			Exposed	Exposed

The risk assessment should identify the vulnerabilities of MSW facilities (Table 2). These properties of the facility may also be affected by the compliance of its design documentation and construction with regulatory requirements; the operation of the facility must comply with the provisions of environmental and industry legislation, and also loss prevention. In addition, it is necessary to carry out planned capital and routine repairs, as well as modernize the production process with the introduction of the best available technologies (BAT).

Table 2: Characteristics of vulnerabilities to the risks of adverse impact on the components of the natural environment at various stages of MSW management [III,IV].

Vulnerabilities to the risks of negative impact of MSW on the urban environment	Accumulation MSW	Transportation MSW	Treatment MSW	Disposal MSW
Components of the natural environment	Exposed	Exposed	Exposed	Exposed
Natural environmental systems			Exposed	Exposed
Natural landscapes			Exposed	Exposed
Natural and anthropogenic objects	Exposed		Exposed	Exposed
Anthropogenic objects	Exposed		Exposed	Exposed
Natural resources			Exposed	Exposed
Natural complexes			Exposed	Exposed

Due to the high level of regulation of activities in the solid municipal waste management industry – licensing activities, classifying MSW facilities as objects of the 1st or 2nd category of adverse environmental impact, it is necessary to increase the level of training of industry workers, as well as the use of BAT in the field of MSW collection. Separate collection should be implemented already at the household level. This will allow for more efficient use of MSW as a secondary material resource, and the organization of separate collection should also be considered as loss prevention at the creation of targeted insurance products.

In recent years, the vulnerability of MSW treatment facilities has increased significantly due to changes in the nature, intensity of exposure, duration, and other qualities of climatic factors (Table 3). In this regard, the sustainability of their activities has also decreased. For example, in areas where municipal solid waste disposal facilities for MSW are located, cases of complaints from local residents about the spread of odors, as a result of the release of landfill gases, and the weathering of light MSW fragments outside the sanitary protection zone have become more frequent. As a result of changes in the nature and volume of precipitation, MSW landfill treatment facilities cannot cope with the formation of landfill filtrate. All this leads to complaints to regulatory authorities, lawsuits against facility operators, and the diversion of forces and funds to settle them.

Table 3. Increased vulnerabilities to the risks of the adverse impact of MSW treatment facilities on the components of the natural environment under the influence of climatic factors [III, IV].

Hydrometeorological indicators, their critical values, consequences for MSW treatment facilities	Accumulation of MSW	Transportation-MSW	Processing of MSW	Disposal of MSW
Squally wind				
An increase in wind loads on buildings and equipment of MSW treatment facilities.	Exposed		Exposed	Exposed
Weathering of light MSW fragments.	Exposed	Exposed	Exposed	Exposed
Removal of pollutants from the territory of MSW facilities	Exposed	Exposed	Exposed	Exposed
The spread of unpleasant odors of municipal solid waste	Exposed	Exposed	Exposed	Exposed
Heavy snowfall, ice formation				
The cost of cleaning the territory and buildings of MSW facilities from snow.	Exposed		Exposed	Exposed
Formation of ice on the equipment of MSW facilities.	Exposed		Exposed	Exposed
Freezing of MSW volumes makes it difficult to process and sort.	Exposed	Exposed	Exposed	Exposed
Heavy rainfall				
Flooding of the territory of MSW facilities	Exposed		Exposed	Exposed
Causing damage to the technological equipment of MSW facilities	Exposed		Exposed	Exposed
Significant temperature fluctuations.				
In the daytime, the temperature is above zero degrees Celsius; in the evening and at night, below zero degrees.	Exposed		Exposed	Exposed

Hydrometeorological indicators, their critical values, consequences for MSW treatment facilities	Accumulation of MSW	Transportation-MSW	Processing of MSW	Disposal of MSW
Stimulation of chemical reactions in the mass of MSW	Exposed		Exposed	Exposed
Impact on the equipment and infrastructure of the energy supply of MSW facilities.	Exposed		Exposed	Exposed

The main purpose of the MSW treatment facilities adaptation plans is production sustainability in difficult, rapidly changing atmospheric conditions.

The negative impact of external conditions on the waste management industry can manifest itself in the following ways:

- the need for expenditures on engineering and environmental surveys and remediation of polluted lands (see the table below);
- risks of the contractual obligations of regional environmental operators to waste generators for the organization of primary accumulation of municipal solid waste at container sites, transportation to MSW treatment and sorting points (see the table below);
- the need for insurance costs against damage to property (see the table below);
- the need to incur expenses for accident and health insurance (see the table below)

[VIII]

Table 4. Risk insurance of harm to the components of the natural environment, life, and health of individuals as a result of the adverse impact of MSW treatment facilities on the environment [X].

Risks group	Contents of risk groups	Tools of MSW management	
		Operator's liability insurance for handling MSW for environmental damage	Liability insurance of the owner or operator of the MSW facility
Risks of harm to the environment, life, and health of individuals	1) Risk of claims for damages resulting from damage to the environment, life, and health of individual persons as a result of the spread of pollutants to the site adjacent to the MSW object;	■	

Risks group	Contents of risk groups	Tools of MSW management	
		Operator's liability insurance for handling MSW for environmental damage	Liability insurance of the owner or operator of the MSW facility
	2) The risk of filing claims for damages due to damage to the environment, life, and health of individuals as a result of contamination of the MSW facility site		■

Depending on the purpose of the municipal solid waste treatment facility, the design of a liability insurance policy or a property insurance policy may vary. For example, for landfills for the disposal of MSW, the insurance policy must also guarantee funds for the remediation of the landfill after its closure. The life of a MSW landfill is long, and it happens that operators or owners who own or operate landfills cease their activities as a result of bankruptcy before the start of landfill reclamation. As a result, the authorized bodies cannot demand that they pay for the work. For example, the cost of reclamation of a MSW landfill with a total area of 50 hectares and a landfill body height of about 50 m may amount to 4 billion rubles. The work is carried out at the expense of the regional budget. A specially designed policy will allow you to accumulate funds for these works on special accounts [X].

The dangerous weather phenomena are accompanied by an increased risk of negative consequences. These climatic factors are having an increasing impact on the housing and communal services and waste management industry in the regions. The use of insurance products can increase the resilience of operators and waste management facilities to the adverse effects of extreme meteorological events. The benefits and advantages that the solid municipal waste management industry will receive in the emerging conditions may look like this:

- insurance coverage can provide compensation for damage to property because of meteorological events, for example, compensation for liability claims in the event of an accident or incident at the facility;
- insurers play an important role in the assessment of insurance risks and show policyholders the probability of an insured event, taking into account the amount of possible damage through the use of discounts, deductibles, and differentiated terms of insurance payments, as well as a special design of the insurance policy;
- the loss prevention is aimed at reducing the likelihood of an insured event [II].

Table 5. Risk insurance of damage to property and real estate as a result of the adverse impact of MSW facilities on the environment [III].

Risks group	Contents of risk groups	Tools of MSW management	
		Operator's liability insurance for handling MSW for environmental damage	Liability insurance of the owner or operator of the MSW facility
liability insurance risks of deterioration of the consumer value of property, real estate	1) Damages due to damage to property, real estate located on a neighboring site.	■	■
	2) The risk of lawsuits due to the reduced liquidity of neighboring properties.		■

III. Results

Ensuring the sustainability of MSW treatment facilities through insurance is a process of creating insurance coverage, which includes risk identification and analysis, with careful consideration of climatic vulnerabilities and the facility's exposure to climatic factors (Tables 1, Tables 3). This main stage in the development of insurance products is shown in the block diagram (Fig. 1). Where, at the first level, the impact of the adverse impact of climatic factors on the financial stability of the facility is demonstrated, and at the second level, the impact of the vulnerability of the facility and its exposure to the influence of climatic factors on the content of risks and their assessment. Risk assessment is one of the main steps in ensuring resilience to the negative effects of climate change (Fig. 1).

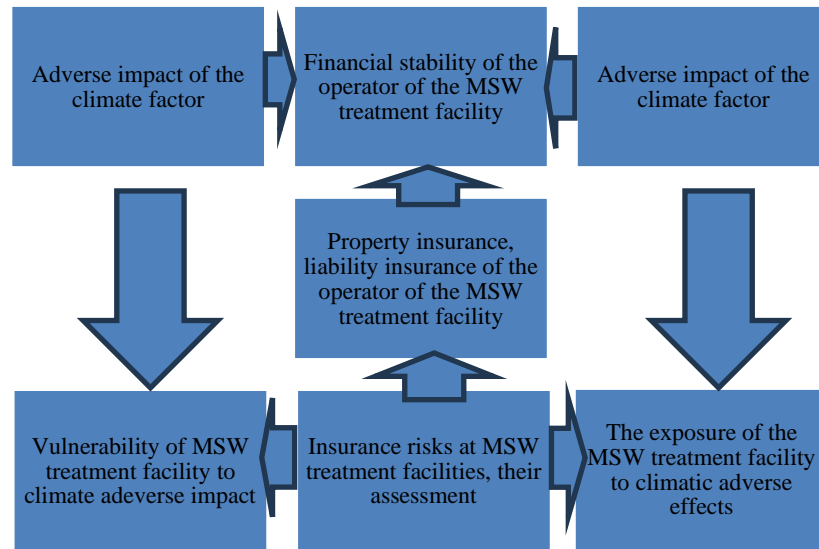


Fig. 1. The impact of insurance on the sustainability of municipal solid waste management

The consequences of the use of insurance instruments and preventive measures on the sustainability of the solid municipal waste treatment facility can be demonstrated as follows:

$$K_{smw} = \frac{K_{rt} \cdot C_{rm} - Inscov}{K_d \cdot B_v + C_{pm}} \quad (1)$$

where:

K_{smw} – the stability coefficient of the MSW facility;

C_{rt} - efficiency coefficient of restorative technologies;

C_{rm} -estimated cost of restoration measures;

$Inscov$ - the amount of insurance coverage;

B_v - the book value of the municipal solid waste (MSW) treatment facility;

K_d - the depreciation coefficient reflects the change in the value of fixed assets, the impact of environmental protection measures on the condition of the facility over the period of the insurance policy;

C_{pm} - the cost of preventive protection environmental measures [XI].

It can be seen from the equation that if we consider the cost of restoration measures and the book value of the facility as constant values, then the lower the value of C_{so} , the higher the sustainability of the municipal solid waste treatment facility.

IV. Discussion

This paper presents generalized approaches to the selection of insurance products at various stages of waste management in conditions of increasing vulnerability of MSW facilities under the influence of climatic factors. Algorithms for the selection of insurance conditions and insurance products are presented in the form

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of matrices that can serve as a basis for their development by including new indicators. The sustainability coefficient of the MSW facility, C_{sf} , is proposed as an estimated indicator that allows demonstrating the impact of the amount of insurance coverage and the amount of preventive measures taken at the municipal solid waste treatment facility on the sustainability of its production activities. At the same time, when developing plans for adaptation to the negative effects of climate change in the field of MSW management, it is necessary to provide:

- the use of stochastic models, including generalized distributions of extreme values for extremes, in predicting negative impacts on technical facilities [III];
- to take into account the dependence of the level of economic losses on the intensity of dangerous meteorological phenomena [III];
- analysis of the dependencies of the limiting state of technical facilities and the influence of random variables on them (changes in climatic indicators, behavior of materials and equipment in difficult weather conditions) [III];
- predicting the probability of failures using random phenomenon analysis methods;
- dependence of the stability of a technical facility on the composition and quality of preventive measures [VIII];
- the use of risk assessment methods in the design of insurance coverage, which makes it possible to assess how random changes in input parameters affect the output parameters of a technical facility [VIII];
- analysis of the impact on the terms of insurance coverage of preventive measures at the facility aimed at reducing the impact of the negative effects of climate change on the operational characteristics of the facility [VIII].

V. Conclusion

To reduce the level of exposure and vulnerability of waste management facilities to the adverse effects of climate change, it is necessary.

For insured:

- in order to increase financial stability, the development of standard approaches for planning and conducting preventive measures at MSW facilities. At the same time, information and technical reference books on best available technologies (BAT) or other standardization documents, such as national standards, should be used;

for insurers:

- monitor the impact of climate risks on insurance companies' balance sheets;
- to develop methodological bases for determining insurance volumes, coverage, premiums, and reserve sizes;
- to develop methods for assessing damage caused as a result of the negative impact of climatic factors, including for the purposes of forecasting the possible development of the situation and planning preventive measures.

Conflict of Interest:

The authors declare that there is no conflict of interest regarding this article.

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