Adaptation of construction and demolition waste management towards climate change

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Abstract: According to the results of observations of Federal agency Roshydromet, the specific signs of recent decades are climate changes caused by global warming. Their features are an increase in the average annual temperature, frequency and intensity of dangerous hydrometeorological phenomena, an increase in the amount of precipitation, spatial and seasonal heterogeneity. The territories of Russia are in the area of observed and predicted climate changes, and their consequences have an increasing impact on the socio-economic development of the country, the living conditions and health of people, as well as on the state of economic sectors and objects of economic activity. The article examines measures to adapt the sphere of management of construction and demolition waste (CDW) to the negative consequences of climate change.

Keywords: adaptation measures, construction and demolition waste (CDW), climate change, negative consequences, factors and objects of impact.

1 Introduction

The consequences of climate change are attributed to the challenges in the Environmental Security Strategy of the Russian Federation for the period up to 2025, approved by Decree of the President of the Russian Federation No. 176 dated 04/19/2017 [1]. According to the state report "On the State and Environmental Protection of the Russian Federation in 2020" prepared by the Ministry of Natural Resources of Russia, the average annual air temperature near the Earth's surface in the territory of the Russian Federation has been growing by an average of 0.47 °C over 10 years since the mid-1970s, which is 2.5 times higher than the growth rate of the average global temperature air temperature (0,18 °C for 10 years) [2].

According to the state report of the Federal Service for Hydrometeorology and Environmental Monitoring "On climate features in the territory of the Russian Federation for 2021" in 2021, 612 cases of occurrence of dangerous meteorological phenomena (DMP) and complexes of meteorological phenomena, the combination of which forms DMP, were

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registered on the territory of Russia. Statistics show that only in 2021 the number of dangerous meteorological phenomena increased by 30% compared to 2020. The frequency of heavy precipitation, strong and hurricane-force winds, frosts and complexes of meteorological phenomena (CMP) is high. The latter account for more than 65% of all dangerous meteorological phenomena. The dangerous phenomena that are part of the CMP individually often did not reach the criteria of dangerous, but in combination with each other greatly hindered the economic activity of the regions [3].

In recent decades, the strengthening of the destructive effect of temperature and humidity deformations on buildings, structures and housing and communal services facilities has become a problem for the branches of urban economy and housing and communal complex, which is associated with an increase in the number of air temperature transitions through 0 ° C in the cold season, with an increase in the amount of liquid and mixed precipitation in the winter season, as well as strong winds. So far, for example, during the construction of new and repair facilities, constructive solutions that exclude an increase in the moisture content of building structures due to atmospheric influences, as well as materials that have adequate resistance to freezing and thawing cycles, are not used enough. Accelerated destruction of highways and other facilities is observed, operating costs are increasing, etc. The most dangerous consequences are associated with an increase in precipitation intensity.

In the current conditions, measures to adapt to climate change are necessary to reduce losses associated with observed and future climate changes. The large-scale socio-economic consequences of temperature contrasts, pressure drops and extreme precipitation observed in recent years indicate the vulnerability of the population, economic objects to negative climatic influences and the need to plan adaptation measures.

For that purpose, the Climate Doctrine of the Russian Federation, approved by Decree of the President of the Russian Federation No. 861-rp dated 17.12.2009, defined the main objectives of climate policy, which, among others, specifies "the development and implementation of operational and long-term measures to adapt to climate change" [4]. In accordance with the Doctrine of the decree of the Government of the Russian Federation dated 25.12.19 No. 3183-r approved the National Action Plan of the first stage of Adaptation to Climate Change for the period up to 2022, which presents "a state system of political, legislative, regulatory, economic and social measures implemented by federal executive authorities and subjects of the Russian Federation aimed at reducing the vulnerability of the national security system countries, economic entities and citizens due to climate change on the territory of our country" [5]. As of June 2022, the decree of the Russian Government approved regional plans for adaptation to climate change in the Republic of Crimea, Belgorod, Volgograd, Vologda, Kemerovo, Kursk and Penza regions. The sectoral plans of the Ministry of Health of Russia, the Ministry of Industry and Trade of Russia, the Ministry of Transport of Russia, the Ministry of Agriculture of Russia, the Ministry of Regional Development of Russia, the Ministry of Natural Resources of Russia, Rospotrebnadzor, the Ministry of Construction of Russia and the Ministry of Energy of Russia have also been approved [17].

To assess climate risks and work out adaptation measures in regional and sectoral plans, the methodological recommendations of the Ministry of Economic Development of Russia, introduced by the order of the Ministry of 13.05.21, were applied. No. 267 "On approval of methodological recommendations and indicators on adaptation to climate change", (together with "Methodological recommendations for assessing climate risks", "Methodological recommendations for ranking adaptation measures according to their

degree of priority", "Methodological recommendations for the formation of sectoral, regional and corporate plans for adaptation to climate change") [6].

2 Methods

"Methodological recommendations for assessing climate risks", "Methodological recommendations for ranking adaptation measures according to their degree of priority" are an appendix to the "National Action Plan of the first stage of adaptation to climate change for the period up to 2022", approved by Decree of the Government of the Russian Federation No. 3183-r dated December 25, 2019. The recommendations contain a unified approach to the organization and conduct of climate risk assessment.

The results of the analysis and study of regional plans for adaptation to climate change, prepared with the help of the above documents, show that almost all regions have provided measures to reduce the impact of hazardous climatic factors on the waste management sphere. In the methodology, climate factors are understood as a parameter of the climate system that changes under the influence of the internal dynamics of the climate system and (or) due to the effects of external factors on this system (fluctuations in solar radiation, changes in the chemical composition of the atmosphere, changes in the radiation properties of the surface, etc.). The object of influence is a component of an anthropogenic or natural system, the functioning of which depends on climate factors (Table 1,2,3) [6].

Table 1. Regional plan of adaptation to climate change in the Belgorod region for 2022-2030. II. Formation and improvement of the monitoring system and regulatory and methodological framework in terms of adaptation to climate change [17]

Name of the adaptation event	Term	Expected result	Executor
Improving the waste management system	2022-2030 гг.	Legal act	Ministry of Housing and Communal Services Belgorod Region, Ministry of Nature Management Belgorod region

Table 2. List of priority adaptation measures of the Volgograd region [17]

Name of the adaptation event	Terms of implemented activities	The type of document that includes the adaptation event and the expected result	Executor
Development of an integrated waste management system: creation and protection of a waste processing complex in the Volgograd Region	2022-2024гг.	The expected result is the preservation of ecosystems.	Committee of Natural Resources, Forestry and Ecology of the Volgograd region.

Table 3. Regional Climate change Adaptation Plan of the Vologda Oblast. List of priority adaptation measures [17]

Name of the adaptation event	Terms of implemented activities	The type of document that includes the adaptation event and the expected result	Executor
Use of secondary resources of raw materials and waste	2030	Formation of an industry system of operational and long-term measures of adaptation to climate change	Department of Natural Resources and Environmental Protection of the region

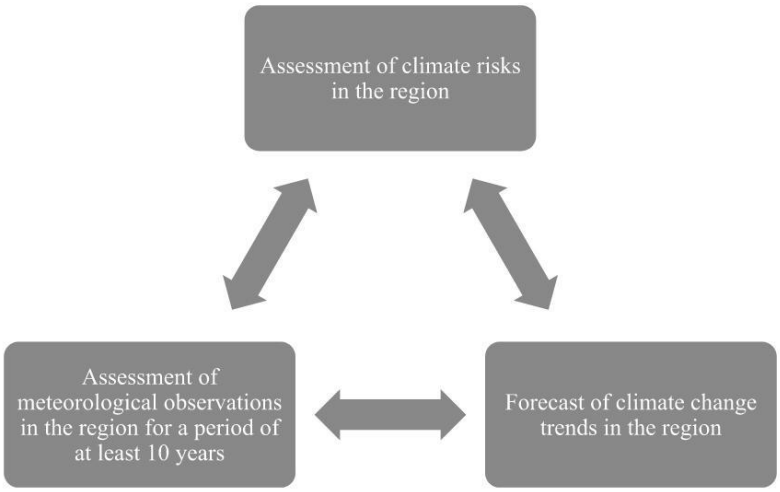

Fig. 1. Assessment of climate risks in the regions [14, 18]

In most regions, in territorial waste management schemes, construction and demolition waste (CDW) are not separated from solid municipal waste (SMW) and, for example, their burial takes place at SMW landfills. Only in 2 regions – in Moscow and Tatarstan there is a special procedure for the treatment of construction waste.

Therefore, the provisions of the methods for assessing climate risks, determining dangerous climatic factors, and ranking adaptation measures are also applicable to assessing, as an object of impact, exposure and vulnerability to the effects of climatic factors of such activities as the CDW management.

According to the generalization of the provisions of SP 325.1325800.2017 "Buildings and structures. Rules of work during dismantling and disposal", National standard GOSTR 57063-2016. "Resource conservation. Waste management. Indicators of the impact of generated waste on the environment", National standard GOSTR 57678-2017 "Resource conservation. Waste management. Elimination of construction waste" it is possible to identify the main factors of the impact of construction and demolition waste on the environment during the formation of waste and their disposal:

1) dustiness of the air (in adjacent populated areas should not exceed the maximum permissible concentrations MPC of 0.3 mg/m^3) [10];

2) the probability of weathering of the soil layer suitable for subsequent use, which must be removed during the planning of the territory and stored in a special designated place;

3) possible excess of the maximum permissible concentration (MPC) of harmful substances in construction waste and atmospheric air, as a result of evaporation under the

influence of high temperatures. The content of harmful substances in the atmosphere and adjacent populated areas must comply with SanPiN 1.2.3685-21 "Hygienic standards and requirements for ensuring safety and harmlessness to humans, environmental factors" [10];

4) removal of small-piece and fine-grained construction and demolition waste outside the construction site under the influence of strong winds, with transport, etc.;

5) leaching of harmful substances from stored waste as a result of precipitation;

6) with the formation of ice and ice on the roads, dangerous conditions are created for the movement of vehicles for the transportation of CDW, due to a decrease in the coupling qualities of the road surface, an increase in braking distance, car skidding, loss of maneuverability of transport, a decrease in speed;

7) removal of land resources from economic circulation during storage and disposal of construction and demolition waste and causing environmental damage to soils as a result of the negative impact of stored waste [7,8,9].

The influence of the above factors may be amplified by the impact of dangerous climatic factors and should be taken into account when planning adaptation measures to reduce the negative impact.

Climate risk assessment involves the identification of dangerous climatic factors for the affected object, its exposure to these factors and vulnerability to them. Such an assessment is carried out for the territories of regions, sectors of the economy and subjects of economic activity (objects of influence). This assessment includes a retrospective assessment of the risk (based on data for the elapsed time period exceeding 10 years) and its forecast (based on observed and predicted trends in climate change for the duration of the operation of the affected object). In accordance with the methodology, climate risk is understood as a joint characteristic of the probability of dangerous manifestations of the climate factor and its impact (in the form of harm or damage) on the object of this impact, which is expressed in the amount of damage (in kind and (or) value terms) characteristic of the repeatability of the specified values of the dangerous climate factor [6].

Vulnerability of affected objects is a tendency or predisposition to adverse effects, including sensitivity or susceptibility to damage and limited ability to adapt. In turn, exposure to climatic factors is the degree of influence on the object of exposure to a dangerous climatic factor for this object [6] (Fig. 1, 2).

In accordance with the above-mentioned methodological documents, it is recommended to use the results of scientific research, scientific publications, hydrodynamic modeling, etc. to predict the further dynamics of characteristic climate risks, objects of impact, determine the composition of adaptation measures, and include new threats as a result of predicted climate changes. If there is a lack of data on the actual manifestations of dangerous climatic factors, it is recommended to use expert assessments [6]. However, the recommendations do not establish approaches and procedures for such assessments. Although it is obvious that various objects of impact have their own specifics of characteristic climate risks, activities carried out and adaptation measures [15,16].

As an illustration, Tables 4, 5 provide examples of possible hazardous climatic factors and vulnerabilities of impact objects developed during the study specifically in relation to construction and demolition waste management activities, as well as examples of critical values of climatic indicators for types of production activities vulnerable to climatic factors, in particular the management of construction waste [11].

Table 4. Examples of climatic factors and their relation to climatic risks and vulnerability of territories of regions and activities for the treatment of CDW [6,12,13]

The climate factor	Vulnerability description	Description of risks
Extreme precipitation and flooding	High exposure to floods, especially in cities. Overloaded, outdated, poorly maintained urban drainage and other engineering infrastructure. High water content, deformation of CDW volumes in storage and burial sites. High exposure to floods, especially in cities. Overloaded, outdated, poorly maintained urban drainage and other engineering infrastructure. High water content, deformation of CDW volumes in storage and burial sites.	Threat to life and health of people, destruction of livelihoods. With the increasing frequency of intense precipitation and the growth of urbanization, the level of risks increases. Flooding of ground infrastructure, damage to cargo and equipment. The danger of erosion of CDW volumes in places of storage and burial, leaching of harmful substances.
Increasing the frequency and intensity of extreme heat, including the effect of urban heat islands	High exposure in cities (especially older people, children, pregnant women and people with chronic diseases). Reducing the humidity of the OSS, increasing the ability to weathering dust and harmful substances. Failure of equipment and vehicles.	Increased mortality and morbidity during periods of extreme heat and increased atmospheric pollution. Interactions generated by dependence on conjugate systems lead to an increase in the effects of extreme phenomena. Deformation of tracks, overheating and malfunctions of infrastructure facilities and vehicles when handling the OSS.
Wind load growth	Causing harm to life, human health, animals, plants, the environment, property in places of education, storage, transportation, disposal of CDW. Loss of financial stability of economic entities in the field of waste management.	Dustiness of the air in the places of formation, storage, transportation, disposal of CDW, weathering of harmful substances and the removed soil layer on the construction site. The risks of filing lawsuits, claims for damages to the subjects of CDW handling activities
Icy-frost phenomena	Causing harm to human life, health, property during transportation of OS, causing economic damage to economic entities in the field of waste management.	Dangerous conditions are being created for the movement of urban transport, a decrease in the traction qualities of the road surface, an increase in the braking distance, a car skidding, loss of maneuverability of transport for the OSS, a decrease in the speed of movement.

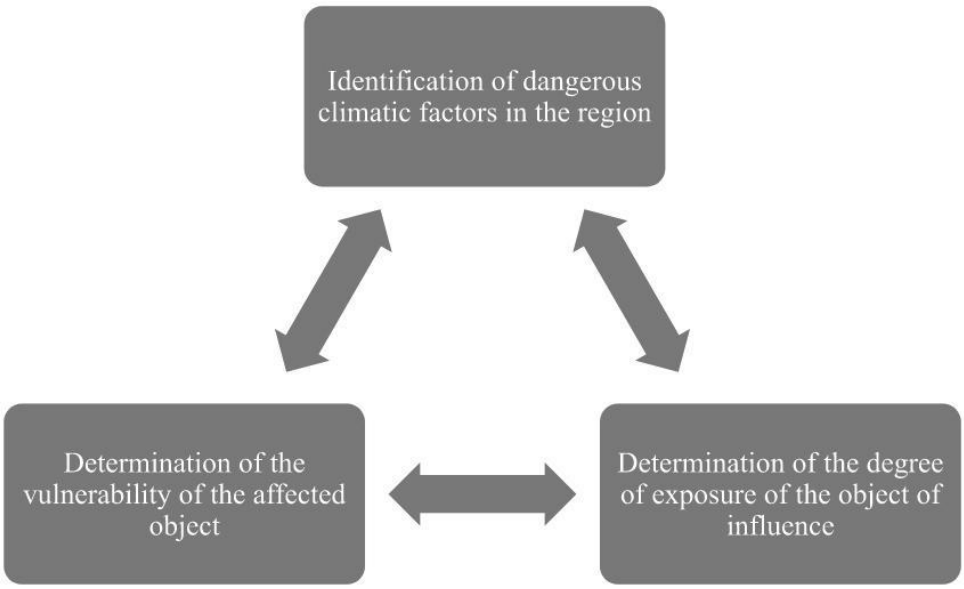

Fig. 2. Determination of dangerous climatic factors in the region [14, 18].

Table 5. Examples of critical values of hydrometeorological indicators for the most vulnerable to the effects of climatic factors in the management of construction waste and demolition of CDW [6,12,13]

Indicators	Critical indicators and consequences for economic activity
Wind	8 - 13 m/s: weathering of CDW and the resulting harmful substances
	14 - 24 m/s: removal of small-piece and fine-grained construction waste, possible shifting and overturning of vehicles during transportation of CDW, violation of the trajectory of movement, fuel overspending and tire wear
	Over 25 m/s: production operations when handling CDW outdoors become dangerous.
	Over 30 m/s: breakage of wires, breakdown of supports, felling of trees, destruction of enclosing structures of the construction site, threat to outdoor equipment.
Heavy snow, icy-frost deposits	Sleet more than 5 cm (especially with a sharp drop in air temperature): failures in the operation of transport for the transportation of CDW, difficulties in processing waste when mixing them with snow.
	Violations in the operation of equipment during the processing and disposal of CDW in the open air due to deposits on wires with a thickness of more than 20 mm: (in combination with wind): insulation damage, loss of electrical energy, massive wire breakage.
Ice and sleet on the roads	Any intensity: dangerous conditions for the movement of vehicles for the transportation of CDW, a decrease in the traction qualities of the road surface, an increase in the braking distance, the skidding of the car, loss of maneuverability of transport, a decrease in the speed of movement by 2 - 2.5 times.
Heavy rains and downpours	More than 30 mm in 1 hour: formation of rain floods and flooding of substations, damage to equipment for processing and disposal of CDW
	More than 50 mm in 12 hours: flooding of low sections of the road, erosion of the roadway, difficulties for the transportation of CDW.
Atmospheric temperature	Below -25 °C: breakdown of vehicles for transporting CDW, deformation of metal structures or rupture of pipes, shortening of rails, danger of frostbite of personnel.
	Frequent transitions through 0 °C: dangerous conditions for urban transport, reduced traction qualities of the pavement, rapid aging and destruction of materials, accelerated formation of construction waste.
	More than +25 °C (especially for several days): deformation of metal structures, elongation of rails, evaporation of harmful substances, decrease in CDW humidity.
	More than +30 °C: changes in the tension of wires, heating of generators, equipment for processing and disposal of CDW, the formation of bumps on the roads, shifting asphalt, the appearance of mirages.
	Temperature differences of 10 °C or more: rapid aging and destruction (corrosion) of materials, building structures, accelerated formation of CDW

3 Results and discussions

The existing experience in the development of regional adaptation plans to climate change allows us to note that all aspects of the development of adaptation measures and plans are related to the observed and predicted impact of climatic factors on the object of impact under consideration – the treatment of construction and demolition waste, the effectiveness of which can be assessed only in the future. However, the process of developing measures

and forecasting itself must be made the most developed in terms of the availability of the necessary tools, predicted indicators and the closest approximation directly to the object of impact.

Based on the analysis of the preliminary experience of climate risk assessment and the development of adaptation measures for the object of impact – the sphere of construction waste management, some issues can be identified, the solution of which would increase the effectiveness of adaptation to the effects of hazardous climatic factors both in the field of CDW management and housing and communal services facilities as a whole.

1. "Methodological recommendations for assessing climate risks", "Methodological recommendations for ranking adaptation measures according to their degree of priority", "Methodological recommendations for the formation of sectoral, regional and corporate plans for adaptation to climate change", introduced by the order of the Ministry of 13.05.21 No. 267 do not contain a sufficient list of climatic factors and more detailed impact indicators and they do not take into account the specifics of the types of economic activity.
2. Territorial waste management schemes of the subjects of the Russian Federation do not contain plans for the adaptation of economic activities to climate change. With regard to waste management, in order to systematize and give an appropriate legal level to adaptation plans, measures for adaptation to climate change should be included in territorial waste management schemes.
3. As noted above in the methodological documents, it is allowed that if there is a lack of data on the actual manifestations of dangerous climatic factors, it is recommended to use expert assessments. However, approaches and procedures for conducting such assessments, requirements for experts, taking into account that various objects of impact have their own specifics of characteristic climate risks, activities carried out and adaptation measures, are not established.
4. There are no effective economic mechanisms for preventing and eliminating the negative consequences of the climate change impact on the objects of CDW waste management, restoration of damage caused to the components of the natural environment, material damage and damage caused to human life and health. On March 11, 2023, the Decree of the Government of the Russian Federation No. 559-r approved the "National Action Plan for the second stage of adaptation to climate change for the period up to 2025", which also includes the "Action Plan for organizational, regulatory, scientific, methodological and informational support for the implementation of the national action plan for the second stage of adaptation to climate change on the period until 2025" [18]. The decree of the Government of Russia and the plan provide for the development of insurance mechanisms, taking into account the need for economic entities to adapt to the negative consequences of climate change and the development of methods of insurance, reinsurance of natural disaster risks [18]. However, it should be noted that insurance products aimed at covering damages from natural disasters in one form or another exist. The difficulty is the assessment and coverage of damages in the event of the implementation of dangerous climatic factors:
    - sharp deviations from the average or predicted extreme daily monthly, annual values of air temperature or precipitation amount in the region;
    - long periods with changes in the values of climatic and weather variables;
    - long periods with special conditions;

- an increase in temperatures above/below the critical level for this region [18].

4 Conclusions

It should be noted, that at present the regulatory and legal support that allows regulating various aspects of the adaptation of objects of economic activity to the negative effects of climate change is only beginning to take shape and is still fragmentary and does not reflect all the conditions and problems that arise. This also applies to the sphere of waste management of construction and demolition waste (CDW). At this stage, in order to create an algorithm for assessing, identifying dangerous climatic factors, and reducing their impact on the affected objects, it is necessary

- development of lists of probable adaptation measures depending on the source of climate risk and the type of economic activity, including for the sphere of CDW management;
- determination of the boundary values of climatic indicators for the most vulnerable types of production activities to the effects of climatic factors;
- creation and updating of lists of sources of climate risks according to the intensity of propagation, duration and level of danger for various objects of impact;
- finalize the lists of climatic factors and their relationship to climatic risks and vulnerabilities, taking into account the characteristics of various impact objects and types of economic activity, including the management of construction and demolition waste (CDW);
- when licensing waste management activities by the Federal Service for Supervision in the Field of Nature Management and Environmental Protection, the availability of a liability insurance policy for causing harm to the environment, property, life and health of people should be checked.

In Moscow and the Moscow Region, when the Department of Construction of the City of Moscow issues a permit for the movement of construction and demolition waste, including soils, in the list of necessary documentation submitted by the applicant – legal entities and individual entrepreneurs performing the functions of a state customer or developer, general contractor or technical customer at construction and demolition waste generation facilities, include the following about the possibility of financial coverage of liability in case of harm. The information should be placed in the automated information system "Regulation of the movement of construction, demolition waste and soil in the city of Moscow" (AIS "CDW").

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