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Food waste management policies and laws

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Abstract: The article is devoted to the issues of legal regulation and practical implementation of innovative and other best technologies in handling production and consumption waste in accordance with international acts, foreign and national Russian legislation. The authors consider this area in the context of achieving sustainable development goals. Particular attention is paid to the implementation of the state policy of the Russian Federation in the field of food waste management, as well as legislative measures of state support and stimulation of the introduction of the best available technologies in this area, including the use of public-law partnership mechanisms to eliminate accumulated environmental damage along with the requirements for the mandatory use of such technologies by enterprises that are the main polluters of the environment. As a result of the conducted research, the authors made conclusions and presented recommendations for clarifying the conceptual apparatus, improving, on the basis of a differentiated approach, scientific, methodological and legal support for the development and implementation of the best technologies in waste management applicable to all stages, types of production waste, as well as household (municipal) waste.

1 Introduction

The problem of waste is one of the key challenges of our time on a global and national scale, posing a real and potential danger to the environment, a threat to the health of the current and future generations of humanity. It concerns many modern experts around the world (see, for example, [1], [2], [3]). According to the forecast data of the report of the United Nations Environment Programme (UNEP) "Global Waste Management Outlook 2024", by 2050 the volume of municipal solid waste alone in the world will increase by more than 75 percent and reach almost 3.8 billion metric tons. In 2020, more than two billion metric tons of municipal solid waste were generated worldwide. For decades, such waste has accumulated and continues to be placed in landfills and dumps. For example, in 2022, New Zealand and Canada topped the list of countries in the Organization for Economic Cooperation and Development (OECD) in terms of the volume of municipal waste sent to landfills per capita - more than 600 kilograms (for comparison, in countries such as Denmark and Germany, less than 10 kilograms per person are sent to landfills annually. In Russia, in recent years, as a result of measures taken at the state level, a steady trend has emerged to reduce the volume of municipal solid waste (MSW). Thus, if in 2013 their amount was more than 60 million

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tons (about 400 kg of waste per person per year), then a decade later, about 46 million tons of MSW were generated in the Russian Federation with a total amount of production and consumption waste of 9278.8 million tons, which, however, does not yet correspond to the targets and objectives set in the strategic planning documents aimed at reforming the waste management industry as a whole.

The need to take systemic measures in this area is due to the negative impact of production and consumption waste, which, along with waste accumulated as a result of past economic and other activities, is a source of danger and threats to the sanitary and epidemiological well-being of the population and territories, potential and actual harm to human life and health, ecosystem damage, negative impact on environmental components, including flora and fauna, forests, atmospheric air, pollution of land, soil, water bodies, both surface and underground, including those used for drinking and domestic water supply. For many countries, the problem of waste is relevant for certain territories, for example, geoparks - geologically significant territories, both urban and rural [4].

The increase in the volume of production and consumption waste with a low level of its disposal, as well as the presence of a significant number of objects of accumulated environmental damage at the national level in Russia are not only highlighted among the internal threats to environmental safety, but are also considered as sources of environmental risks and associated threats to biological, chemical and other types of safety.

The aforementioned UNEP report provides expert estimates that improper waste disposal practices lead to environmental pollution, poor health and climate change. The hidden costs due to these factors may amount to US$640.3 billion by 2050. These factors have necessitated a revision of the waste management strategy, which is now focused on reducing and preventing waste generation, as well as on the transition to a circular economy and sustainable business models. This includes the introduction of advanced environmental, nature-like and other innovative technologies in all areas of economic activity and at each stage of waste management - from collection and transportation to neutralization, recycling and reuse of secondary resources. Environmental technologies play a key role in the waste management system. Their application is enshrined in the legislation of Russia and other countries, as well as in national strategies, which is consistent with the principles of sustainable development (SDG). These principles are aimed at harmonizing economic, environmental and social aspects [5, P. 165]. In addition, the transition to a circular economy as a socio-ecological-economic model [6] requires the introduction of effective economic and legal mechanisms [7], including public-private partnerships [8]. For effective waste management using the best available technologies, both legal regulation and methodological support are necessary, taking into account successful domestic and international experience.

2 Materials and methods

The article’s methodological framework relies on a combination of general scientific, specialized, and interdisciplinary research approaches. Key methods employed include logical analysis, systemic-structural examination, comparative legal studies, formal-legal interpretation, and other relevant techniques.

When writing the work, the UN environmental policy documents, international acts, Russian and foreign legislation in the field of sustainable development, waste management, transition to a closed-loop economy, as well as strategic planning documents adopted in the Russian Federation in the field of waste management were used, on the basis of which a systematic study of the state of legal regulation of the development and implementation of the best technologies for handling production and consumption waste was carried out, the result of which were conclusions and proposals for the further development of this area, taking into account international recommendations, current foreign experience, as well as advanced Russian developments and practices.

3 Results

The issues of environmental technologies in waste management must be considered in direct connection with the notion of sustainable development as an undoubtful basis for a state development, building harmonious relations in the field of interaction between society and nature. The usage of advanced environmental technologies, the adoption of environmentally sound technological solutions in the implementation of economic and other activities is an important means of achieving the sustainable development goals (SDGs) enshrined in the UN General Assembly Resolution "Transforming our world: the 2030 Agenda for Sustainable Development", in accordance with the indicators developed at the international and national levels the phased introduction of which is underway in Russia, including in relation to municipal solid waste. An illustrative example that is directly related to the field of waste management is SDG 11 "Sustainable cities and communities", to achieve this goal, the indicator "The share of municipal solid waste collected and disposed of at controlled sites from the total mass of municipal solid waste, broken down by city" was developed. The importance of achieving this goal is confirmed by the adoption of laws regulating the management of municipal solid waste in more than 86% of countries.

This indicator plays an important role in solving the problems of solid municipal (communal) waste all over the world under conditions of different levels of their recycling. Thus, if in Slovenia and Germany the level of recycling of solid municipal waste is 55.3 and 47 percent respectively, in South Korea - about 54 percent, then, for example, in Costa Rica the level of their recycling is less than 5 percent. The USA with a recycling level of less than 25 percent is the largest producer of solid municipal waste in the world, in terms of the amount of which they occupy second place after Denmark, followed by China. In these countries, the most common method of disposal of solid municipal waste is burial at landfills, each of which dumps more than 5,000 tons daily.

The Russian Federation has established the development of an advanced waste management system as a key governmental priority. This strategic initiative outlines several progressive targets: increasing waste processing rates from the current 8-9% to 60%, significantly decreasing landfill disposal volumes, implementing comprehensive source separation programs, and ultimately transitioning to circular economy principles. By 2030, the policy mandates that 100% of annually produced municipal solid waste undergoes sorting, limits landfill disposal to 50% of such waste, and requires at least 25% of industrial and consumer waste to be reintroduced into economic systems as recycled materials and secondary raw inputs.

The European Union has set targets for the recycling of packaging waste. According to the European Commission's Packaging and Packaging Waste Directive, at least 65% of all packaging waste must be recycled by 31 December 2025, and at least 70% by 31 December 2030. Recycling targets vary depending on the type of material. For example, at least 80% of ferrous metal packaging must be recycled by 2030, while for paper and cardboard this figure is 75%. In contrast, at least 55% of all plastic packaging must be recycled by 2030. In line with the EU Circular Economy Action Plan, the EU aims to ensure that all packaging is reused or recycled in a cost-effective manner by 2030.

Of particular importance is the systemic pollution of the environment with microplastics, which is acquiring a global character. For example, during a survey of the tropical eastern Pacific Ocean, its particles were found in 100% of samples [9]. It is important to take into account the emergence of environmental problems during the full cycle from the extraction of raw materials, production of plastic, its distribution, use and disposal as waste [10]. In

Russia, to solve the problem of microplastics, it is proposed to classify large microplastics in wastewater as waste, which can be collected by mechanical treatment of wastewater, and to standardize small ones as the concentration of pollutants [11].

Achieving targets, indicators and tasks in the field of food waste management presupposes the introduction of the best environmental technologies at all stages - their collection, accumulation, transportation, processing, disposal, neutralization, placement. Development and implementation of technologies for preventing waste formation and reducing their volume is the most priority area. In Russia, the introduction of the best available technologies in waste management as one of the important instruments of state policy is provided for in strategic planning documents and is enshrined in legislation.

Key mechanisms for enfourcing state policy in the sphere of environmental security are the promotion of BAT, the creation of facilities that meet modern environmental requirements and standards for the placement, disposal, processing and disposal of production and consumption waste. The environmental focus is also evident at the legislative level. In accordance with Article 28.1 of the Federal Law "On Environmental Protection" (2002), the use of BAT is aimed at the comprehensive prevention and (or) minimization of negative impacts on the environment. The law also stipulates that economic and other activities of government bodies, local government bodies, legal entities and individuals that have an impact on the environment must be carried out on the basis of environmental protection principles, including "ensuring the reduction of the negative impact of economic and other activities on the environment in accordance with environmental protection regulations, which can be achieved through the use of the best available technologies, taking into account economic and social factors."

Applying BAT in food waste management is directly put on a permanent footing in the Federal Law "On Production and Consumption Waste". The List of areas in which BAT is applied includes economic and (or) other activities that have a significant negative impact on the environment, on the utilization and disposal of waste, including thermal methods, as well as on the placement of production and consumption waste.

State-level regulation of optimal technological solutions for waste management represents a critical factor for Russia's ecological modernization and sustainable growth. Such governance mechanisms serve a dual purpose: facilitating technological progress while mediating between governmental priorities, societal expectations, and business interests, particularly for enterprises with potentially adverse environmental impacts. Effective implementation demands establishing comprehensive incentive structures, including:

- Economic motivation systems for secondary resource recovery
- Regulatory frameworks encouraging waste collection and processing
- Environmental standards based on Best Available Techniques (BAT)

Laws in Russia ensure both incentives and mandatory implementation of BAT regarding the facilities that have a notable negative impact on the environment and relate to the areas of application of such technologies (category I facilities). These include, for example, hazardous production facilities of special chemicals, coal mines, as well as other facilities for underground mining operations in subsoil areas where gas and (or) dust explosions may occur; sudden outbursts of rock; gas and (or) dust; rock bursts; water breakthroughs into underground mine workings. The requirement to apply BAT applies to activities at such facilities, including waste generation. It is especially important to solve environmental waste problems for Arctic territories, preventing ecosystem damage during exploration and extraction of minerals [12].

The effective application of BAT in waste management requires systematic development and periodic revision of BAT reference manuals, formal approval through Rosstandart directives as part of the national standardization system, comprehensive documentation of technological processes, operational methods, equipment specifications and other relevant technical parameters.

The BAT framework operates through:

- Establishment of technology-specific benchmarks in reference manuals;
- Subsequent development of environmental standards (within 6 months of manual publication/update);
- Mandatory compliance with published technological indicators.

In the sphere of food waste management, information and technical reference books have been approved on the best available technologies implemented by corporations in the area of waste disposal and deactivation, both by thermal and other methods. These reference books are also used for technological regulation in the context of obtaining comprehensive environmental permits, which legal entities and individual entrepreneurs carrying out economic and (or) other activities at Category I facilities are required to obtain .

An important purpose is the use of BAT in the field of elimination of accumulated environmental damage (AED), which allows to reduce the time for the entire range of works on its elimination and to reduce the cost of environmental projects. For these purposes, the order of Rosstandart approved an information and technical reference book on BAT, which applies to the activity of eliminating AED in relation to objects of accumulated damage included in the state register of AED objects.

The updating of information and technical reference books is due to the need to amend and supplement them in connection with the improvement of environmental legislation, including in terms of accounting for greenhouse gases, resource and energy conservation, identifying new best available technologies and parameters characterizing their impact on the environment with respect to tendencies in the food waste management. The future updating of BAT reference books is connected to priority areas of scientific and technological development in Russia, which enable significant scientific and technological achievements. Particular focus is placed on transitioning to nature-like technologies capable of replicating living nature's systems and processes through technical solutions and production methods that seamlessly integrate with the environment and natural material cycles.

Such technologies create new opportunities for developing sustainable production systems that maintain ecological balance and operate in harmony with natural mechanisms. Their advancement requires an interdisciplinary approach combining biology, chemistry, materials science, and engineering, which will ultimately lead to a new generation of environmentally safe and resource-efficient industrial practices.

Incorporating these solutions into BAT regulatory frameworks will help establish a more advanced environmental management system aligned with sustainable development principles and the transition to a circular economy.

At the same time, in practice, problems arise with the compliance of enterprises carrying out production activities at facilities that have a significant impact on the environment, including waste generation, with the requirements for the implementation of BAT before updating the current BAT reference books or before developing and approving new ones [13].

The necessity to amend the regulation of the BAT use in waste management is also largely determined by the variability of technical regulation documents containing recommendations on the application of BAT in this area, among which the following can be distinguished (see Table 1):

Table 1. Technical regulation documents containing recommendations on the application of BAT

Number	Types of documents
1	general provisions relating to the field of production and consumption waste management, including waste quality control; waste processing methodology, waste recycling and disposal; waste placement; waste management; elimination of accumulated damage to the environment
2	recommendations for the implementation of BAT in relation to individual stages (phases) of handling production waste (for example, during their processing, disposal, rendering harmless) or in relation to various waste hazard classes (for example, ITS 52-2022. Information and technical reference book on best available technologies. Handling waste of hazard classes I and II)
3	exact scope and stringency requirements adapted to account for technological feasibility and sector-specific conditions while maintaining alignment with national environmental quality objectives and international commitments on sustainable industrial development
4	the absence of provisions in technical regulation documents for certain sectors of the economy concerning the implementation of BAT in waste management

In order to improve the regulatory and methodological framework governing the application of BAT in the management of production and consumption waste, it is necessary to eliminate existing gaps in the regulatory framework by incorporating solutions to problems of practical implementation. This process should systematically integrate both domestic and international best practices, while aligning with guidance from relevant global standards and policy instruments. Modernization requires a balanced approach that takes into account operational realities and theoretical models, while ensuring that the designed structure combines technical feasibility with environmental efficiency. Particular attention should be paid to adapting successful foreign methodologies to Russia's specific industrial and ecological context, creating harmonized standards that meet both national environmental objectives and internationally recognized benchmarks for sustainable waste management practices.

4 Discussion

Legal regulation of the development and implementation of BAT in waste management is associated primarily with the conceptual apparatus, the scientifically based definition of which largely determines the formation of practical experience in their application in various sectors of the economy and the housing and utilities sector.

The Federal Law "On Environmental Protection" provides a general definition of the best available technology (BAT), which is understood as the technology for the production of products (goods), the performance of work, the provision of services, determined on the basis of modern achievements of science and technology and the best combination of criteria for achieving environmental protection goals, subject to the technical feasibility of its application.

The regulatory frameworks of the European Union, United States, and various other jurisdictions employ distinct terminology that continues to evolve alongside legislative advancements. A notable example includes the "best existing technology" standard established under the European Union Council Directive 96/61/EC (September 24, 1996) concerning integrated pollution prevention and control, though this directive has since been superseded. This conceptual approach was recognized as a comprehensive environmental protection mechanism, serving as a foundational element that unified diverse ecological, economic, and technical measures into an interdependent system of mutually reinforcing policies. The terminology and its associated regulatory applications demonstrate the dynamic nature of environmental governance instruments as they adapt to emerging sustainability challenges and technological progress across different legal systems.

In Directive 2008/98/EC of the European Parliament and of the Council of the European Union "On waste and the repeal of certain Directives") contains the term and concept of "best available technologies", the use of which is planned along with waste management methods in waste management plans containing a general policy in this area, including measures taken to improve environmentally sound preparation for the reuse, recycling, disposal and destruction of waste.

The Directive establishes comprehensive environmental and health protection measures through a multi-faceted approach to sustainable resource management. By mandating waste prevention, impact reduction, and enhanced resource efficiency, it creates a regulatory foundation crucial for circular economy transition. Central to this framework is the extended producer responsibility principle, which incentivizes eco-design and life-cycle resource optimization in product development.

The Directive's conceptual framework incorporates both the "best available technologies" standard and detailed waste classification terminology. Beyond fundamental categories like "waste", "hazardous waste", and "municipal solid waste", it specifies distinct waste streams including construction/demolition materials, biowaste, food waste, and waste oils - a differentiation critical for targeted BAT application.

Equally significant are the Directive's operational definitions governing waste management processes. These encompass the complete value chain from collection and transportation to disposal (including sorting) and destruction, with provisions for operational oversight and post-treatment site management. The framework also codifies key circular economy mechanisms such as:

- Separate collection systems;
- Waste prevention protocols;
- Reuse and preparation for reuse standards;
- Backfill operations.

This terminological precision enables consistent implementation of waste hierarchy principles across member states while providing the legal clarity necessary for BAT integration across diverse waste streams and industrial sectors. The Directive's comprehensive approach thus serves as both a regulatory blueprint and practical toolkit for sustainable materials management.

The provisions of the Directive are reflected in the legislation of EU member states, for example, in Germany all waste disposal and recycling processes are regulated by the Law on the Circular Economy in Waste Management / Kreislaufwirtschaftsgesetzes (KrWG) of 24 February 2012 (amended 04.4.2016), aimed at achieving three main goals: preventing waste generation, optimising the process of its involvement in recycling and more efficient use of natural resources. Technological solutions and opportunities are highlighted among the means of achieving these goals.

The categorical and conceptual apparatus provided for in the Directive, along with other provisions containing instruments and mechanisms for waste management and the transition to a closed-loop economy, as well as positive foreign experience in these areas, are of interest for strategic planning and legal support for waste management aimed at achieving the national development goals of the Russian Federation, including the following priorities in the field of waste management: elimination of accumulated harm; transition to a new system for handling municipal solid waste (MSW); introduction of separate waste collection; creation of a modern waste management, recycling and disposal industry; transition to a closed-loop economy, implementation of the "polluter pays" principle and application of the extended producer responsibility mechanism.

5 Conclusions

The presented analysis allows us to conclude that the Russian state policy and legislation fully comply with international and foreign waste management practices, legal regulation of relations in the field of waste management, including the development and implementation of the best environmental and other technologies. The developed legal and methodological support allows us to select the most suitable and accessible technologies for processing various types of waste, based on the BAT principle and taking into account the requirements of regulatory documents. In practice, the choice of a specific technology depends on many factors, including the composition of waste, its volume, availability of resources and economic feasibility. The introduction of BAT requires an integrated approach, including the improvement of technological processes, the organization of separate waste collection, the development of recycling infrastructure, informing and involving the population, and systemic solutions to other issues.

Strategic improvements in waste management policies and legislation should focus on several key priorities to advance the transition to a circular economy.

A critical area is consumer waste management, which requires targeted measures such as establishing separate collection systems and implementing waste-specific disposal methods based on material properties (e.g., organic, biodegradable). This approach ensures more efficient sorting, recycling, and recovery of valuable materials.

Another essential step is harmonizing terminology and legal definitions, particularly for concepts such as "consumer waste" (distinct from municipal solid waste), "separate accumulation," and "separate collection." Aligning these definitions with international best practices will enhance regulatory clarity and enforcement.

Given the complexity of consumer waste challenges, a multi-faceted strategy is needed, combining:

- Economic incentives (e.g., subsidies for separate collection, support for eco-innovation);
- Technological advancements (development of energy-efficient and low-waste production methods);
- Public engagement (awareness campaigns to promote responsible consumption and participation in waste segregation).

Finally, policy coherence is crucial — ensuring that waste management strategies align with broader economic and environmental goals, such as eco-innovation, sustainable production, and scientific advancements in recycling technologies. A unified approach across sectoral strategies will maximize efficiency and accelerate the shift toward a closed-loop economy.

In order to achieve the strategic planning indicators in the sphere of development of a sustainable and integrated system of waste management, implementation and subsequent application of BAT in this area, it is necessary to continue systematically the work on development and approval of technical regulation documents in the sphere of application of BAT in waste management, as well as updating information and technical reference books, which will contribute to increasing the efficiency of the organizational and legal mechanism for regulating the complex of relations in this area to achieve strategic goals and objectives aimed at preventing and reducing the negative impact on the environment of economic, housing and communal and other activities, the implementation of which is accompanied by the formation of waste, ensuring a favorable environmental situation and living conditions for the population, realizing the rights of citizens to a favorable environment.

A scientifically grounded improvement of strategic planning frameworks for waste management and circular economy development—combining robust theoretical foundations with empirical validation during implementation—will significantly enhance policy effectiveness by enabling dynamic strategy adjustments based on real-world performance data, quantitative assessments of waste stream efficiency, and predictive modeling of system improvements. This strengthened approach systematically evaluates material flow interventions while integrating lifecycle assessments into policy design and measuring circularity indicators across economic sectors, supported by three critical components: (1) theoretical frameworks from industrial ecology and circular economy principles, (2) methodological rigor through standardized monitoring protocols, and (3) empirical validation via pilot programs and iterative policy refinement. The resulting system facilitates data-driven decision-making in resource management, continuous improvement of waste reduction strategies, scientifically validated transition pathways to circularity, and adaptive governance responsive to technological and market developments. Successful implementation requires establishing dedicated research units for policy evaluation, developing integrated data systems to track material flows, creating feedback mechanisms between policymakers and implementers, and instituting regular revision cycles for strategic documents based on performance metrics—ensuring waste management strategies maintain both scientific credibility and practical effectiveness throughout their implementation lifecycle while driving measurable progress toward sustainable materials management and closed-loop production systems.

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