Cluster approach to production and consumption waste management in regional socio-economic systems

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Abstract. Nowadays, the 'greening' of the economy based on implementation of modern development priorities such as increasing the value of nature, natural resources, as well as a human being, human life and health has the prime importance for achieving sustainable development. Solving the problem of production and consumption waste is becoming one of the priority areas, since it simultaneously contains the following components: economic (disposal cost, saving natural resources), environmental (reducing releases of harmful substances into the environment) and social (new jobs, reducing the burden of diseases, fostering an attitude of care towards nature among the population). The creation and development of regional clusters of waste processing can be a key element in solving the problem.

1 Introduction

Modern world development is fraught with negative impact on the environment, depletion of natural resources, imbalance in the biosphere, and high rate of waste generation of various origins. It exacerbates social and environmental problems, and limits opportunities for further development. According to official data, 65 million tons of waste were produced in Russia in 2019 [1]. The volume of waste discarded annually increases by 1-2%, and by 2050 it will reach 100 million tons annually [2].

The current situation both in Russia and in the world with generation of production and consumption waste determines the priority of the problem for ensuring sustainable development.

Sustainable development is based on a harmonious combination of the triple priorities in sustainability, i.e. economy, nature, and society. However, throughout the 20th century, the focus was exclusively on economy, it led to a significant increase in anthropogenic impact on the environment. Although the term 'sustainable

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development' has been actively used since the 1990s, it most often means long-term stable socio-economic development, relegating the problem of preserving natural ecosystems to secondary importance.

As a result, it is necessary to deepen the 'greening' of the economy based on implementation of modern development priorities such as increasing the value of nature and its resources, as well as a human being, human life and health. The implementation of sustainable development goals based on a market economy includes ensuring the harmonization of market requirements for economic benefits while maintaining a favourable environment.

It is essential to support production modernization in the so-called 'double win' way, ensuring both economic efficiency and reducing the impact on the environment. The world experience of such production modernization shows that this approach is a way to ensure not only the growth of economic indicators, but also to improve the quality of life.

2 Methods and Materials

The study is based on general scientific research methods (analysis, synthesis, induction and deduction) and built upon the works of Russian and foreign scholars: B. R. Alzamora and R. T. de V. Barros [3] studied municipal waste management charging methods in different countries, D. E. T. Cervantes, A. L. Martinez, M. C. Hernandez, and A. L. G. de Cortazar [4] analysed indicators for evaluating municipal solid waste management, J. E. Santibanez-Aguilar, J. M. Ponce-Ortega, J. B. Gonzalez-Campos, M. Serna-Gonzalez, and M. M. El-Halwag [5] researched optimal planning for the sustainable utilization of municipal solid waste, C. Cheng, R. Zhu, R. G. Thompson, and L.-H. Zhang [6] examined multiple-stage solid waste management systems, B. D. Azevedo, L. F. Scavarda, R. G. G. Caiado, and M. Fuss [7] studied the German experience in improving urban household solid waste management. L.A. Mochalova and M.V. Polezhalova [8] substantiated the basic principles of solid municipal waste management; finally, H. Wiesmeth, and N.V. Starodubets [9] considered the solid municipal waste management in compliance with circular economy criteria.

3 Results and Discussion

Considering waste as 'rubbish' that should be disposed of, waste disposal costs have a major importance. However, this approach leads to national economic losses of potential secondary raw materials, natural resource depletion for future generations and rise in environmental impacts.

At the same time, the occurrence of advanced waste management system, where waste can be a resource for further production processes, raw materials for energy, etc., can serve as a platform for achieving the initial sustainable development goals. Moreover, the existing waste management systems have demonstrated their low economic and social efficiency, and led to the aggravation of a number of problems.

Waste generation can cause the following main irreversible damage:

- moreover, the use of land for siting landfills, that could be developed for construction and agricultural purposes, establishment operation, reclamation of landfills, and its maintenance after closure all these require significant capital expenditures;
- waste is a valuable energy raw material, reuse of waste saves natural resources, as well as the energy required for their extraction. In this regard, it is necessary to form the attitude towards waste as a potential resource in the society;

- costs for mental and physical health care;
- resource use fees, a pollution fee, environmental monitoring charges, etc.

Secondary flow of waste will increase the sustainability of regional socio-economic systems due to:

- economic effect (lower cost of secondary raw materials in comparison with primary ones, reduction of territories allocated for landfills and taken out of circulation);
- social effect (new jobs, fostering an attitude of care towards nature among the population, reducing the burden of diseases);
- ecological effect (saving non-renewable natural resources, reducing landfilled waste and releases of harmful substances into the environment).

The sustainable development of regional systems is ensured by a systematic approach to the development of their potential. Scientific literature identifies the following types of potentials for regional development:

- material and technical segment (ecological, natural resource, economic-geographical, demographic), i.e. block of basic resource potentials of the territory;
- financial and economic segment (labor, production, budgetary, socio-infrastructural, export-import) combines local potentials, designed to contribute to the basic resource potentials;
- innovation and institutional segment (scientific and innovative, investment, regulatory support) determines the region's readiness for socio-economic transformations.

At the same time, due to the fact that waste as secondary raw material expands regional resource potential, the authors suggest adding 'resource potential of production and consumption waste' into the material and technical segment. It should be highlighted that considering municipal solid waste (MSW) as 'natural resource potential' is not correct, since it is not a natural resource, but anthropogenic, generated as a result of human activity. In addition, some aspects of waste flow as a part of economic turnover do not allow including WSB to any other type of regional potential, but it is quite possible to determine the relationship between the segments.

The use of secondary raw materials i.e., the resource approach to solving the waste management problem will expand the regional resource potential and increase its ecological capacity and social capital.

The cluster approach, *widely implemented* by the economies of many countries, provides the business entity with a number of advantages: sustainable development and advanced economic competitiveness; solving the problems of modernization and technological development; dealing with the insufficiency of investment, personnel, energy, raw materials and other resources; acceleration of innovative development processes; stimulation of active interaction between industrial enterprises, state and end-users [10].

Thus, according to E. S. Zakharchenko, 'a cluster of waste processing enterprises is a territorial system that provides coordinated interaction of the subjects of production and consumption waste management for the implementation of secondary material resources flows in order to ensure an eco-friendly and safe living environment' [11].

According to the authors, this definition should be expanded by taking into account not only the flows of secondary material resources, but also hazardous waste, otherwise, the authorities' interest in this cluster decreases. In general, a cluster of waste processing enterprises is a complex of enterprises of different types of business industries involved into life cycle of waste. 'Clustering partnership occurs initially on an intersectoral basis. Waste generated in one industry can be used as a secondary resource in the same industry and in other industries. The circulation of secondary resources between business industries contributes to the intersectoral integration of knowledge and the occurrence of fundamentally new innovative solutions' [11].

Federal Law No. 488-FZ dated December 31, 2014 'On industrial policy in the Russian Federation' marks the industrial cluster as 'a set of industrial entities, tied together with relations in the certain industry due to territorial proximity and functional dependence, and located on the territory of one or more subjects of the Russian Federation'[12].This confirms the need and prospects of such a tool at present, and the current regulatory framework for the development of industrial clusters points to the readiness of the state to implement it.

A potential regional waste treatment cluster can become an effective tool for implementing sustainable development policy of a state. Among the advantages of establishing regional waste recycling clusters are:

1. At the macro level: 'transparency' of waste management; 'convenience' of developing tools to encourage resource conservation; creating a single space for waste generation and its treatment; active development of resource conservation; expanding awareness of resource conservation as a natural stage in the progress of modern society within the framework of sustainable development; development of territories with special legal status and the PPP (Public Private Partnership) mechanism (establishing special economic zones).
2. At the meso-level: increasing production efficiency through resource conservation and the use of secondary raw materials; optimization of 'search and sale' of secondary raw materials; development of industrial symbiosis (waste from one industry is used as raw materials in another industry); development of a new processing industry or a complex.
3. At the micro level: reorientation of production processes to resource-saving technologies; adaptation of a waste collection system to new technologies; transformation of organizational culture under the influence of resource conservation; sanitation and cleaning of territories; development of innovations in the waste and secondary resources sector.

The following principles are fundamental for establishing a waste cluster [13]:

1. Resource principle of cluster formation. Waste is considered as raw material elements of the cluster.
2. The principle of regional zoning, taking into account the natural resource potential (natural and climatic conditions, regional primary resource base, and economic infrastructure).
3. The principle of the primary role of regional authorities (the authorities of the subjects of the Russian Federation and the local authorities) in developing environmental policy on waste management.
4. Improving extended producer responsibility in waste management (for controlling the raw material flows in a waste cluster).

In addition, I. R. Makarova and V. M. Tarbaeva in their work have distinguished the fifth principle: the allocation of two subclusters, production waste and consumption waste.

The authors do not share this opinion, since the main task of the cluster is to ensure cost-effective waste management and environmental protection through the collection, sorting and processing of highly profitable secondary raw materials (regardless of waste generators). Thus, it is more expedient to single out a separate subcluster of hazardous waste (medical waste, batteries, accumulators, mercury lamps, etc.) and a subcluster of organic waste (the technology of their processing is significantly different from other types of waste).

It is necessary to maximize waste collection during the waste treatment process. Each regional cluster should install sorting stations for disinfection, sorting, packaging and delivery of waste to processing plants. Sorting stations accumulate all waste generated in the region: SMW, production and consumption waste, industrial waste, construction waste, and medical waste.

The authors do not include waste from the extractive industries in the proposed clusters. According to GOST 30775-2001 '*Resource saving. Waste management. Waste classification, identification and coding. Basic Provisions*' [14], which identifies types of wastes (Appendix A1), first of all, the cluster is supposed to include enterprises belonging to the following groups: 2, 3, 4, 11, 12, 15, 17, 18, 20.

Part of industrial process waste generated by enterprise can be used as an additional material to the main raw materials (a certain percentage of the main raw materials), and waste that cannot be used as an additive in the main technological process should be sent to waste sorting stations or enterprises for recycling (these enterprises operate only on waste from other industries or receive waste from waste sorting stations).

The authors deem to follow the principle of 'cluster specialization' expedient; it allows circulation of resources / waste between regional clusters.

The main participants of the waste processing cluster (structural elements of the cluster system) include government agencies, universities and research institutes, private investors, enterprises engaged in waste accumulation, sorting, collection and transportation, processing into intermediate raw materials, production from secondary raw materials, and disposal.

Universities and research institutes take part in the process of cluster concept formation, the development of new technologies and equipment, and training of specialists to work within the cluster. The organizations responsible for waste collection and transportation can be different: municipal services collecting household waste, enterprises generated waste, business entities interested in collecting secondary raw materials; burial of waste can be done at landfill sites or special enterprises, depending on the waste collection system. Enterprises that provide waste sorting and waste primary processing into secondary raw materials also differ. Thus, the selective waste collection provides the supply of high-quality secondary raw materials (at the first stages of introduction of the selective collection system, this seems impossible); it allows managing without sorting lines. If the overall waste collection system is in place or separate collection is poorly organized, then sorting lines for the incoming waste should be used; it is also necessary to add to the cluster enterprises that use secondary raw materials in the production process, and operate at the expense of non-state funding sources or on the basis of PPP (public-private partnership) [15].

In addition, in order to create conditions for the competitive regional development and strengthen the competitiveness of the national economy as a whole, government authorities should be involved in organizing effective interaction within the cluster.

In our opinion, clustering should have a targeted character, when the initiative for its formation and development belongs to the state. Government authorities will perform the following functions: create legal and regulatory framework for the activities of subjects-participants in the cluster, focused on the regulation of technical and technological processes and organizational and economic relations avoiding planned and administrative characteristics; form a stable structure of the cluster linked on a long-term basis with the federal center; monitoring, analysis and forecasting of macro- and meso-environment; targeted state investment in financing cluster activities, and direct financing of innovations; create environment conducive to attracting private investment (for example, issuing so-called 'green' government securities). Federal bonds, as one of the lowest-risk investment options, can attract significant financial capital through public-private partnerships. The role of the state in attracting investment for waste management is extremely important, since this industry is capital-intensive and low-margin, which creates barriers to the independent participation of private investors. Thus, state 'green' bonds, like 'eco-deposits' in state banks, should be targeted to ensure the transparent use of attracted funds. Since the

guarantor of the fulfillment of obligations under federal loan bonds is the state, the bankruptcy risk of these securities is low.

The creation and functioning of regional clusters will contribute to the development of digitalization, infrastructure support, legislative regulation, human resources, technological research, and economic, environmental and social effects.

The authors suggest carrying out a set of activities for successful implementation of the proposed tool.

1. Legislative regulation: development and implementation of economic-stimulus instruments of clustering at the legislative level, coordination of the cluster development strategy with strategic directions.

2. Infrastructure creation: informational (create databases of enterprises using secondary raw materials and being currently ready to process it; configure electronic document flow to track the movement of waste from a producer (collector) to a processor (including blockchain technology)) and production (create and develop waste processing enterprises, collection points for secondary raw materials and hazardous waste, establish communication lines).

3. Staffing: advanced resource conservation and resource efficiency training for management personnel of enterprises, courses for other specialists from enterprises involved in the waste recycling cluster, revision of educational programs.

4. Technological research: participate in R&D in the field of improving resource-saving technologies, commercialization of production methods based on secondary raw materials.

4 Conclusion

The creation and development of waste management and recycling clusters, where waste is considered as a resource, is an important direction of strengthening sustainable development of territorial socio-economic systems. At the same time, it is necessary to realize the high capital intensity of this project with obvious results, but of a mixed nature, i.e. at insignificant economic effect, a high level of social and environmental benefits will be achieved. In this case, it is advisable to develop mechanisms for public-private partnership.

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