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Article

The production systems green development: Waste logistics and data-driven waste management

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Abstract: Increasing the environmental friendliness of production systems is largely dependent on the effective organization of waste logistics within a single enterprise or a system of interconnected market participants. The purpose of this article is to develop and test a methodology for evaluating a data-based waste logistics model, followed by solutions to reduce the level of waste in production. The methodology is based on the principle of balance between the generation and beneficial use of waste. The information base is data from mandatory state reporting, which determines the applicability of the methodology at the level of enterprises and management departments. The methodology is presented step by step, indicating data processing algorithms, their convolution into waste turnover efficiency coefficients, classification of coefficient values and subsequent interpretation, typology of waste logistics models with access to targeted solutions to improve the environmental sustainability of production. The practical implementation results of the proposed approach are presented using the production example of chemical products. Plastics production in primary forms has been determined, characterized by the interorganizational use of waste and the return of waste to the production cycle. Production of finished plastic products, characterized by a priority for the sale of waste to other enterprises. The proposed methodology can be used by enterprises to diagnose existing models for organizing waste circulation and design their own economically feasible model of waste processing and disposal.

Keywords: production waste; waste logistics; recycling; closed cycle; coefficients; production typology

1. Introduction

The problem of production and consumption waste logistics at industrial enterprises is urgent and requires the realization of scientific research and development of practical proposals. The need for a return of waste to the production cycle is obvious both from the point of view of environmental safety and from the economic benefit. Closed resource cycles are a basic element of the concept of a circular economy, the rationality of which is generally recognized in the global industry (Ryazanova and Zolotareva, 2020). Waste recycling differs markedly from the production of primary material in terms of profitability, energy efficiency, level of complexity of technological processes, etc. (Volkova, 2018).

In the scientific literature and practical publications, sufficient attention is paid to the problems of solid and liquid waste management, world experience in the field of waste logistics and building supply chains for secondary raw materials is studied and transmitted (Zaremohzzabieh et al., 2024). The type of production activity, the spatial location of enterprises, and the possibility of cooperation into a single resource system have a great influence on waste circulation (Dzie and Szlachetka, 2024). An interesting experience in waste logistics is offered in the framework of industrial parks, designed with consideration the resources transformation in the production chain until they are fully consumed (Yu, 2024).

The production waste use is possible in different variations: the absolute use of primary resources (waste-free production), the use of waste as secondary raw materials in one's own production, the sale of waste to other companies, waste disposal, etc. (Federal Law No. 89-FZ, 1998). Enterprises can combine waste use models, for example, partially recycling them for their own related products, and partially selling them. The choice of waste disposal model depends on many factors, including production goals, availability of equipment, and economic feasibility Among other things, the nature of the products produced and the type of raw materials used also affects the organization waste management. Under the condition of enterprises cooperation in order to build waste logistics, a production system capable of maximizing the use of primary and secondary raw materials in a closed cycle is formed (Malysheva et al., 2017). To manage waste management, company management and government environmental departments need objective information about the scale of generation and the types of the productive use of and consumption waste. In turn, the objectivity of information depends on the quality of the analysis of digital data and the techniques used (Meshalkin et al., 2021).

In connection with the above, the purpose of the article is to develop and test a methodology for assessing a waste logistics model based on data, followed by solutions to reduce the level of waste in production.

2. Materials and methods

The methodology for assessing the waste logistics model is based on the following analysis methods:

- balance method, the essence of which is to compare two groups of interrelated parameters to find solutions for industrial waste management (Sutyagin and Menshikov, 2023);
- an indicative method that involves converting private indicators into criteria for assessing the waste route and determining company priorities in the use of primary and secondary resources (Malysheva and Shinkevich, 2020);
- a typological method for systematizing waste logistics models of various manufacturing companies and a differentiated approach to developing solutions for managing the environmental friendliness of the production system (Orazova and Durdyeva, 2024).

To study the balance of the enterprises waste management system, the following blocks have been identified:

X1—presence of production waste at the beginning of the year (carryover balance of previous years);

X2—generation of waste in production during the year;

X3—receipt of waste from other organizations;

X4—processing (neutralization) of waste in our own production;

X5—waste disposal, including for recycling purposes;

X6—disposal of waste at our own landfills;

X7—transfer of waste to other organizations for recycling, neutralization, storage, and burial.

In the waste turnover balance:

incoming part—∑ (X2, X3);

consumable part—∑ (X4, X5, X6, X7).

Possible options to balance equality or inequality in the production waste use are presented in **Table 1**.

Table 1. Options for balance sheet equality/inequality in the turnover of production waste.

Balance condition	Waste use model
∑ (X4, X5, X6, X7) = ∑ (X2, X3)	complete recycling of waste generated during the year
∑ (X4, X5, X6, X7)/∑ (X2, X3) ≥ 1	complete processing of waste generated during the year, as well as partial processing of the carryover residue of waste from previous years
∑ (X4, X5, X6, X7)/∑ (X2, X3) <1	incomplete processing of waste generated during the year with the formation of a residue at the enterprise

Thus, the accumulated balance may be in the waste management system at the end of period *Y*. The higher value the excess of the expendable part of waste over the incoming part, the more efficiently the waste turnover system is organized at the production facility.

The formation of carryover residue from production waste *Y* can be expressed in the form of a mathematical expression that has an incoming and outgoing part:

$$Y = \sum_{i=1}^{3} x_i - \sum_{i=4}^{7} x_i \quad (1)$$

At *Y* = 0, the balance equation of the waste management system will be as follows:

$$\sum_{i=1}^{3} x_i = \sum_{i=4}^{7} x_i \quad (2)$$

The information base for implementing the methodology for assessing the waste logistics model with subsequent reaching decisions to reduce the level of production waste is the state reporting of the Federal State Statistics Service No. 2-TP (waste), accumulating data on the formation, processing, disposal, neutralization, disposal of industrial waste (Order of Rosstat N 627, 2020).

3. Results and discussion

3.1. Balance analysis the main trends in the generation and use of waste using the example of chemical production

The main types of chemicals production and chemical products were selected as a local object of study according to the all-Russian classifier economic type activities

"OK 029-2014" (Order of Rosstandart N 14-ST, 2014). At the beginning of 2024, on average, one enterprise for the production of chemicals and chemical products accounted for ∑ (X1, X2, X3) = 718 thousand tons of waste with the consumable part ∑ (X4, X5, X6, X7) = 17 thousand tons (Rosprirodnadzor. Analytical data, 2024). Thus, the amount of the expenditure part is 42 times less than the revenue part, and the balance at the end of year *Y* is 701 thousand tons of waste per enterprise. The reduction in the volume of production waste at the enterprise is only 20 thousand tons. The current situation indicates the need to reengineer the waste management system, which today is not rational enough (Shinkevich and Malysheva, 2021) (**Table 2**).

Table 2. Waste management system organization of enterprises producing chemicals and chemical products (thousand tons per enterprise).

	X1	X2	X3	X4	X5	X6	X7	Y
Chemical products production	681.3	35.4	1.3	0.4	14.4	22.2	1.5	701.4
Basic inorganic chemicals production	1179.8	35.6	0.01	0.8	3.9	29.8	1.1	1209.4
Dyes and pigment production	882.9	12.9	62.0	0.01	0.3	74.7	0.6	956.9
Alcohols, phenol production	45.7	0.04	0	0	0.003	0	0.0	45.7
Basic organic chemicals production	18.1	1.6	0.002	1.4	0.001	0.02	0.3	18.1
Plastics and synthetic resins production	9.01	2.7	0.3	2.5	0.3	0.2	1.1	9.2
Synthetic rubber production	2.3	15.1	0	0.3	1.1	4.3	9.4	4.7
Paints and varnish production	0.7	0.1	0.002	0	0.01	0.0001	0.1	0.7

The incoming part (∑ (X2, X3)) and the outgoing part (∑ (X4, X5, X6, X7)) analysis of waste turnover allows us to identify production, where the ratio ∑ (X4, X5, X6, X7)/∑ (X2, X3) exceeds or equals one, which indicates complete processing of the waste generated during the year, as well as partial processing of the carryover residue of waste from previous years.

Provided ∑ (X4, X5, X6, X7)/∑ (X2, X3) < 1, production waste generated during the year or acquired from outside is not completely processed, and a certain part of the waste remains at the enterprise. The higher the excess on the waste part over the incoming part, the more efficiently the waste circulation system in production is organized (**Figure 1**).

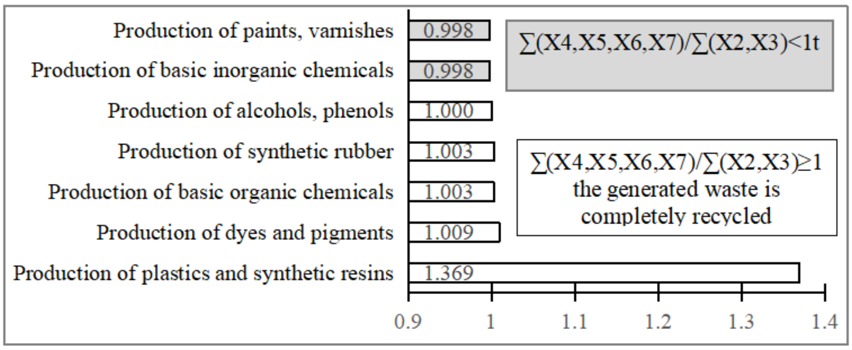

Figure 1. Excess of the expenditure side of the waste balance over the income portion for the production of chemicals and chemical products.

In the presented types case of chemical production, we can distinguish the production of basic inorganic chemicals (0.998) and the production of varnishes and paints (0.998), where a small proportion of waste cannot be processed and disposed of. For other industries, waste is processed completely $\sum$ (X4, X5, X6, X7)/$\sum$ (X2, X3) $\geq$ 1.

The priority in the field of waste management is set in the following order: 1) the maximum possible use of initial raw materials; 2) reducing the volume of production waste; 3) reducing the hazard class of waste; 4) waste treatment; 5) waste disposal; 6) waste disposal. At the same time, priority is given to the use of low-waste technologies and technologies that allow the disposal or waste processing at the enterprise where it was generated, rather than transferring waste to third parties (Grischenkova and Ressert, 2019).

3.2. Development of a methodology for assessing the production waste logistics model

In order to minimize resource consumption and manage the circulation of production waste, we have developed a methodology for assessing the waste logistics model. The methodology is relevant in conditions of limited resources when building a circular economy, when enterprises can intensify resource-saving approaches to organizing waste circulation, rationally use accumulated and newly generated production waste in order to obtain economic benefits (Dotsenko et al., 2023). The target audience of this development is ecological services of enterprises, public authorities supervising the organization of ecological production systems. In **Figure 2**, there are five steps in the sequence of actions for evaluating the industrial waste logistics model.

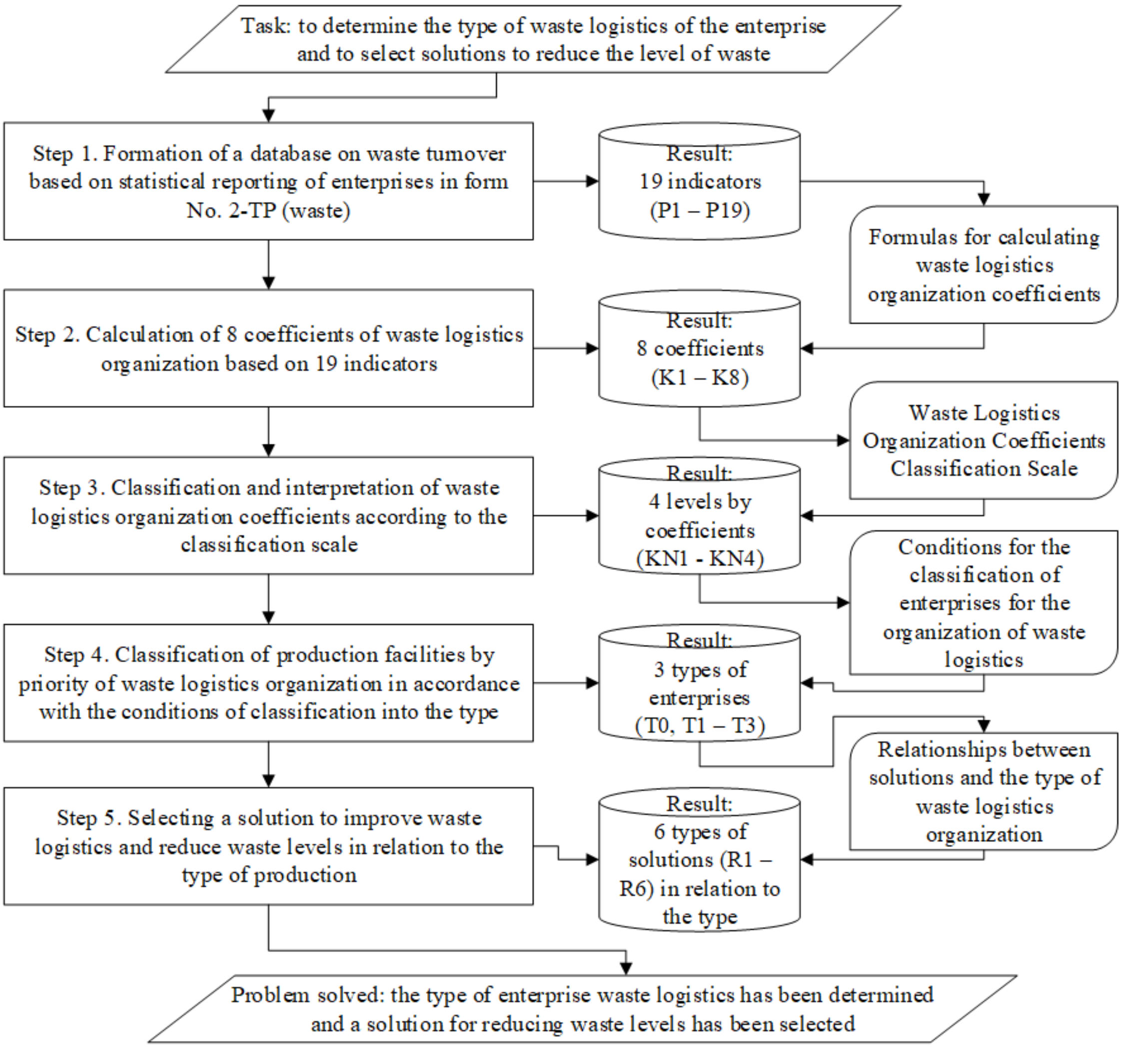

Figure 2. The assessment of a waste logistics model involves five steps.

The methodology includes five sequential blocks: a primary indicator on waste circulation block, calculating coefficients for organizing waste logistics system block, classifying and interpreting coefficients for organizing waste circulation system block, typing production according to the priority of organizing a waste circulation system block. The initial database for assessing waste logistics is 19 indicators on the formation, processing, disposal, neutralization, disposal of production and consumption waste (Form No. 2-TP (waste)), namely:

P1—availability of waste at the beginning of the period;

P2—waste generation period;

P3—receipt of waste from other organizations;

P4—receipt of waste from import;

P5—waste processed;

P6—waste disposed of;

P7—waste disposed of for reuse (recycling);

P8—disposed of pre-processed waste;

P9—waste neutralized;

P10—waste that has previously undergone treatment has been neutralized;

P11—waste transferred to other organizations for processing;

P12—waste transferred to other organizations for disposal;
P13—waste transferred to other organizations for disposal;
P14—waste transferred to other organizations for storage;
P15—waste transferred to other organizations for disposal;
P16—waste is placed at its own storage facilities;
P17—waste is disposed of at its own disposal facilities;
P18—availability of waste in the organization at the end of the period;
P19—number of organizations for a certain type of chemical production.

The methodology involves determining eight coefficients, the calculation procedure of which is indicated in **Table 3**.

Table 3. The procedure for calculating eight coefficients for organizing waste logistics system.

No.	Coefficient name (К)	Procedure for calculating the coefficient
К1	Waste growth rate in own production	К1 = P2/P1
К2	Waste acquisition rate	К2 = P3/P2
К3	Waste efficiency factor	К3 = P6/∑ (P2, P3)
К4	Waste recycling rate	К4 = P7/P6
К5	Waste sales ratio	К5 = ∑ (P11, P12, P13, P14, P15)/∑ (P1, P2, P3)
К6	Waste disposal rate at own landfills	К6 = ∑ (P16, P17)/∑ (P1, P2, P3)
К7	Waste turnover efficiency coefficient	К7 = P18/P1
К8	Factor of production scale of waste level	К8 = P18/P19

The next step provides the coefficients classification. Depending on the range of values, the coefficients are assigned a group code and a corresponding characteristic of waste logistics in production (**Table 4**).

Table 4. Classification scale for organizing the waste logistics system (using the example of chemical production).

No.	Ratio classification scale К	The code	Characteristics of waste logistics in production
К1	К1 < 1.0	К11	Less waste generated than carryover
	1.0 < К1 < 50.0	К12	Low waste generation
	50.0 < К1 < 100.0	К13	Average waste growth rate
	К1 > 100.0	К14	High level of waste growth
К2	К2 = 0	К21	Waste from other organizations is not purchased
	0 < К2 < 5.0	К22	Low level of waste acquisition
	5.0 < К2 < 50.0	К23	Average level of waste acquisition
	К2 > 50.0	К24	High level of waste acquisition
К3	К3 = 0	К31	Production waste was not recycled
	0 < К3 < 0.3	К32	Low level of waste recycling
	0.3 < К3 < 0.6	К33	Average level of industrial waste recycling
	0.6 < К3 < 1.0	К34	High level of industrial waste recycling
К4	К4 = 0	К41	Waste recycling was not carried out
	0 < К4 < 0.3	К42	Low level of waste recycling
	0.3 < К4 < 0.6	К43	Average level of industrial waste recycling
	0.6 < К4 < 1.0	К44	High level of recycling of production waste

Table 4. (*Continued*).

No.	Ratio classification scale К	The code	Characteristics of waste logistics in production
K5	K5 = 0	K51	Waste was not sold to other organizations
	0 < K5 < 0.3	K52	Low level of production waste sales
	0.3 < K5 < 0.6	K53	Average level of production waste sales
	0.6 < K5 < 1.0	K54	High level of production waste sales
K6	K6 = 0	K61	Waste was not disposed of at our own landfills
	0 < K6 < 0.1	K62	Low level of waste disposal at our own landfills
	0.1 < K6 < 0.5	K63	Average level of waste disposal at own landfills
	0.5 < K6 < 1.0	K64	High level of waste disposal at our own landfills
K7	K7 < 0.5	K71	High level of waste management efficiency
	0.5 < K7 < 1.0	K72	Waste management efficiency level is above average
	1.0 < K7 < 10.0	K73	Waste management efficiency level is below average
	K7 > 10.0	K74	Low level of waste management efficiency
K8	K8 < 10.0	K81	Low specific waste volume
	10.0 < K8 < 100.0	K82	Specific waste volume is below average
	100.0 < K8 < 1000.0	K83	The specific volume of waste is above average
	K8 > 1000.0	K84	Large specific volume of waste

At the final step, the type of production is determined according to the priority of organizing the waste circulation system. Depending on the conditions of production typification, three main models and corresponding codes are determined on the basis of coefficients classification (**Table 5**). The coefficients K2 "Waste Acquisition Coefficient", K3 "Waste Useful Use Coefficient", K4 "Waste Recycling Coefficient" and K5 "Waste Sales Coefficient", which, in our opinion, characterize the enterprise's environmental policy, are taken as the basis for determining the waste logistics organization model.

Table 5. Typification of production according to the priority of organizing the production waste logistics system.

Typing condition according to classification codes	Type code	Type of production by priority of waste logistics system organization
If K23 and/or K24 is present	T1	Priority for purchasing waste from other enterprises for the purposes of own production, recycling, or other purposes
If K34 and/or K44 is present	T2	Priority for interorganizational beneficial use of waste, return of waste to the production cycle
If K53 and/or K54 is present	T3	Priority for the sale of waste to other organizations for the purposes of processing, disposal, neutralization, storage, disposal
If there are none of the codes: K23, K24, K34, K44, K53, K54	T0	Priority not defined

Provided that, as a result of the classification codes, the production does not have any of the listed codes K23, K24, K34, K44, K53, K54, then this type of activity is assigned "Priority not determined."

The proposed methodology can be implemented both by type of production (unit production processes) and by type of waste generated at the enterprise, according to the waste catalog (Order of Rosprirodnadzor N 242, 2017). Research can also be carried out on competing enterprises and manufacturers of products of the same name to determine the choice of priority in organizing waste circulation. The use of the methodology allows us to diagnose waste logistics models existing in practice at enterprises and design our own waste processing and disposal technology.

3.3. Results of testing the methodology for assessing the waste logistics model using the example of chemical production facilities

The practical implementation of the methodology was carried out on the basis of three productions of chemical products:

- production of plastics and synthetic resins in primary forms;
- production of plastic plates, strips, pipes, and profiles;
- production of plastic products for packaging goods.

The production of plastics and synthetic resins characterized by a large specific volume of production waste (K84) with a level of waste management efficiency below average (K73) (**Table 6**). Waste from this production is practically not purchased for recycling purposes (K22). A positive fact is the high level of recycling of waste subject to disposal (K44). However, the ratio of recycled waste to the amount of generated waste indicates a low coefficient of beneficial use of waste (K32), which is the main reason for the low efficiency of waste management.

In general, the type of production for organizing a waste logistics system can be characterized as a priority for the interorganizational beneficial use of waste, the return of waste to the production cycle (T2). Thus, in the production of plastics and synthetic resins, it is recommended to increase capacity for the beneficial use of waste, including their use as secondary material resources for the production of non-main products, or the economically feasible sale of waste to third parties.

Table 6. Testing methodology results in assessing the waste logistics model using the example of the plastics and synthetic resins' production in primary forms.

No.	Coefficient value	Group code	Characteristics of organizing waste logistics in production
K1	0.2988	K11	Less waste generated than carryover
K2	0.0990	K22	Low level of waste acquisition
K3	0.0999	K32	Low level of waste recycling
K4	0.8506	K44	High level of recycling of production waste
K5	0.0930	K52	Low level of production waste sales
K6	0.0144	K62	Low level of waste disposal at our own landfills
K7	1.0168	K73	Waste management efficiency level is below average
K8	9 162.61	K84	Large specific volume of waste
Type of production by priority of waste logistics system organization			**Type code**
Priority for interorganizational beneficial use of waste, return of waste to the production cycle			T2

In the plastic plates, strips, pipes and profiles production, a relatively small specific volume of waste is generated (K81) (**Table 7**). This type of production is characterized by a high level of waste sales to third parties (K54) and a low level of waste disposal at its own landfills (K62). Waste utilization and recycling are observed at an average level (K33, K43). Waste turnover efficiency is defined as “above average” (K72).

Production waste here is mainly represented by defective products made of polyethylene and polypropylene during their production. The type of production of organizing a waste circulation system can be characterized as a priority for the sale of waste to other organizations for the purposes of processing, recycling, neutralization, storage, disposal (T3). As special recommendations for the plastic plates, strips, pipes and profiles production, we can note the implementation of an effective product quality control system, including the use of MES information systems that take into account the specific features of production processes (Bao and Vitliemov, 2024).

Table 7. Testing methodology results in assessing the waste logistics model using the example of the production of plastic plates, strips, pipes, and profiles.

No.	Coefficient value	Group code	Characteristics of organizing waste logistics in production
K1	83.9470	K13	Average waste growth rate
K2	0.0892	K22	Low level of waste acquisition
K3	0.3025	K33	Average level of industrial waste recycling
K4	0.5732	K43	Average level of industrial waste recycling
K5	0.6880	K54	High level of production waste sales
K6	0.0001	K62	Low level of waste disposal at our own landfills
K7	0.7295	K72	Waste management efficiency level is above average
K8	0.97	K81	Low specific waste volume
Type of production by priority of waste logistics system organization			**Type code**
Priority for sale of waste to other organizations for treatment, recycling, neutralization, storage, disposal			T3

There is no obvious typology of waste circulation in the plastic products for packaging goods production (**Table 8**). This type of production is characterized by a mixed model of waste management, combining the interorganizational beneficial use of waste, return of waste to the production cycle (T2) and sale of waste to other organizations for the purposes of processing, treatment, neutralization, storage, disposal (T3). Waste from the plastic packaging production is disposed and processed as secondary raw materials within the enterprise (K34, K44), and is partially sold to third parties (K62). However, in the presence of a variety of tools for using waste, a high level of their growth is observed (K14), and the effectiveness of waste circulation is characterized as “below average” (K73).

Table 8. Testing methodology results in assessing the waste logistics model using the example of plastic product’s production of packaging goods.

No.	Coefficient value	Group code	Characteristics of organizing waste logistics in production
K1	174.5613	K14	High level of waste growth
K2	0.9794	K22	Low level of waste acquisition
K3	0.6239	K34	High level of industrial waste recycling
K4	0.9728	K44	High level of recycling of production waste
K5	0.3709	K53	Average level of production waste sales

Table 8. (*Continued*).

No.	Coefficient value	Group code	Characteristics of organizing waste logistics in production
K6	0.0002	K62	Low level of waste disposal at our own landfills
K7	2.4001	K73	Waste management efficiency level is below average
K8	2.24	K81	Low specific waste volume
Type of production by priority of waste logistics system organization			**Type code**
Priority for interorganizational beneficial use of waste, return of waste to the production cycle Priority for the sale of waste to other organizations for the purposes of processing, disposal, neutralization, storage, disposal			T2, T3

Just as in the production of plastic pipes and profiles, the bulk of waste from the production of plastic packaging is recycled polyethylene in the form of granules or crumbs, intended for the production of non-responsible technical products using various processing methods, including to reduce the cost of goods. These industries can be recommended to organize production facilities for granulating secondary polymers for sale or use in their own production (O'Rourke et al., 2022). Also, relevant is the optimization of the product quality control system through modern digital solutions.

Figure 3 structures the solutions for improving the organization of the waste logistics system and reducing the level of waste produced in relation to the type of production. The following directions (*R*) are proposed as management decisions for organizing the waste circulation system:

R1—organization of an economically feasible system for purchasing waste and secondary raw materials from third parties to reduce the cost of main products and produce non-responsible products (Zile et al., 2020);

R2—increasing production capacity for the beneficial use of waste as secondary resources;

R3—organization of a waste recycling system in a closed production cycle (Pfisterer et al., 2024);

R4—organization of an economically feasible system for selling waste to third parties (Papafloratos et al., 2023);

R5—organization of production processes for technological processing of waste into secondary raw materials (granulation of secondary polymers);

R6—product quality control optimization system through modern digital technologies (LI and Nik Azman, 2024).

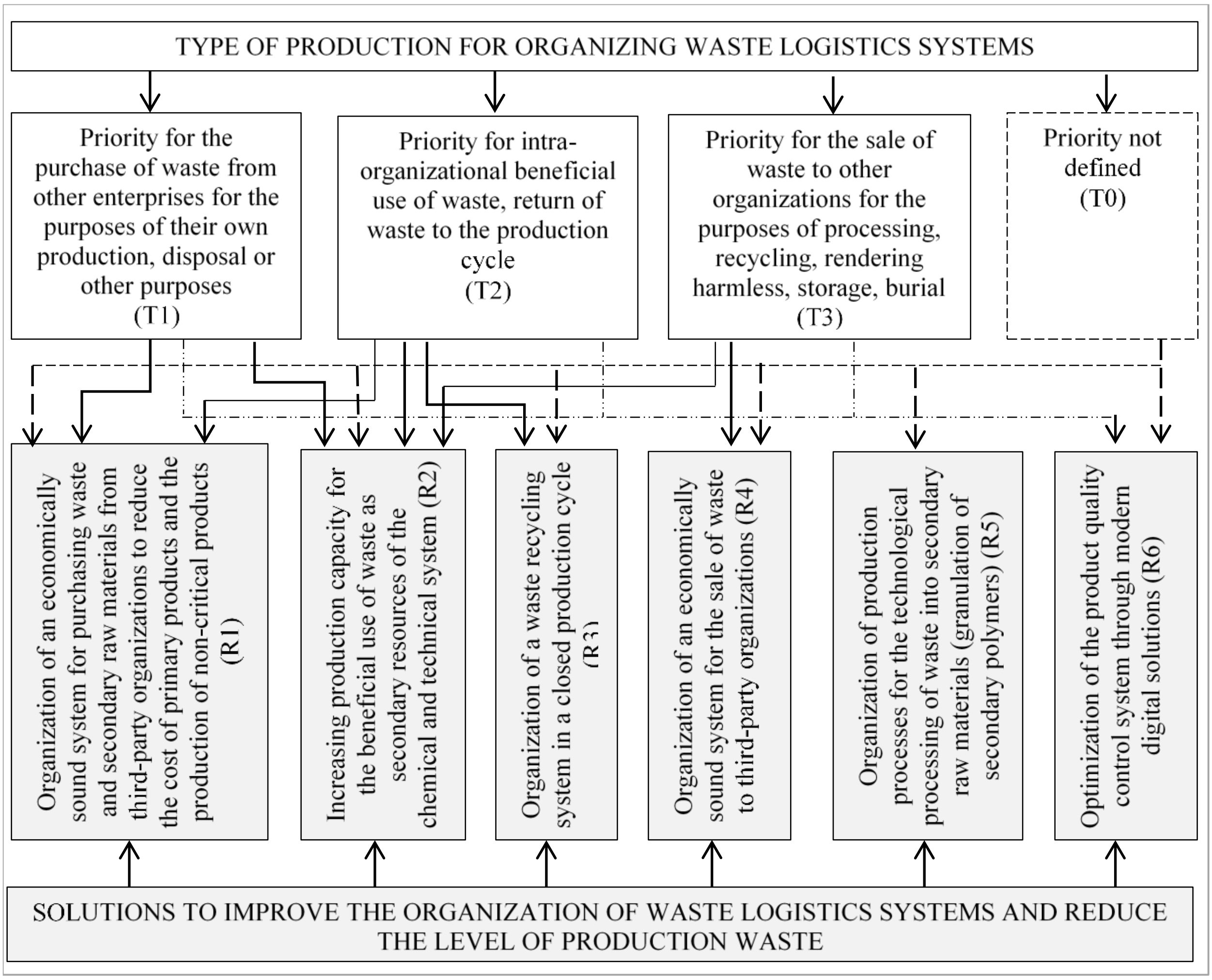

Figure 3. Solutions to improve the waste logistics system and reduce waste levels in relation to the production type.

The following relationship has been established with the type of waste management model:

- with priority for purchasing waste from other enterprises for their own production, recycling or other purposes (T1)—solutions to improve the organization of the waste logistics system R1, R2, R6;
- with priority given the interorganizational beneficial use of waste, return of waste to the production cycle (T2)—solutions to improve the organization of the waste logistics system R1, R2, R3, R6;
- with priority for the sale of waste to other organizations for the purposes of processing, disposal, neutralization, storage, disposal (T3)—solutions to improve the organization of the waste logistics system R4, R2, R6;
- with an uncertain waste management model all possible solutions to improve the organization of the waste logistics system R1, R2, R3, R4, R5, R6.

Thus, the proposed methodology can be used by enterprises to diagnose existing models for organizing waste circulation and design their own economically feasible model of waste processing and disposal.

4. Discussion

As the results of the study show, the organization of waste logistics by type of production varies significantly, which is due to both the specifics of technological processes and the existing production waste management policy of the enterprise. At some enterprises, the system of waste disposal and processing can be organized at their own facilities or their own landfills, while at others it is preferable to sell the waste to third parties. The development of a circular economy in general, and a closed production system in particular, largely depends on the development of a waste logistics policy. Solving the problems of waste circulation should be a priority both at the level of enterprise management and at the level of government administration and regulation of resource flows.

Among the chemical production plants under study, there is no priority for purchasing waste from other enterprises for the purposes of their own production, recycling or other purposes (type T1). Enterprises is mainly focused on the interorganizational beneficial use of waste and the return of waste to the production cycle (type T2). In the case of the production of plastic products for packaging goods, there is a priority for the sale of waste to other organizations for the purposes of processing, recycling, neutralization, storage, and disposal (type T3).

The effectiveness of waste logistics as a whole can be determined at an average level, which was largely influenced by the waste recycling system organized at the enterprise. In all likelihood, the presence of waste during the production of plastic products indicates the presence of defects. Some defects are technically inevitable - products in violation of specified parameters as a result of re-equipment of equipment (Sheverdyaev and Yavkina, 2017).

The other part is a violation of the parameters and quality of the product due to the human factor. Consequently, effective organization and management of production lines and product quality control will minimize the share of defective products and, accordingly, reduce the volume of waste generated. In chemical production, waste or defective products are products that do not meet established quality standards or technical specifications and require additional recycling (Aminova et al., 2023).

Based on the availability of a large-scale information based on the generation and use of waste, a methodology has been developed for assessing the organization of the waste logistics system in an enterprise: 1) coefficient calculation for organizing the waste logistics system, 2) classification and interpretation of coefficients for organizing the waste logistics system, 3) typification of production according to the priority of organizing the logistics system waste. In other words, the essence of the methodology is the sequential reduction of 19 partial indicators to 8 coefficients—indicators of the efficiency of use of production waste. Classification of numerical values within the established range of the measurement scale makes it possible to assess the degree of use of a particular waste route and establish the nature of the enterprise’s environmental strategy, identifying problem areas in waste management. Based on the classification of coefficients, three main types are determined according to the priority of organizing the waste logistics system: priority for the acquisition of waste from other enterprises for the purposes of their own production, recycling or other purposes; Priority for interorganizational beneficial use of waste, return of waste to the production cycle; priority for the sale of waste to other organizations for the purposes of processing, disposal, neutralization, storage, and disposal.

5. Conclusion

The practical implementation of the methodology based on three types of production of chemical products showed that for the production of plastics and synthetic resins in primary forms, priority is given to the interorganizational beneficial use of waste and the return of waste to the production cycle (T2). In the production of plastic products (plates, strips, pipes, profiles), there is predominantly a priority for the sale of waste to other organizations for the purposes of processing, recycling, neutralization, storage, and disposal (T3). In the production of plastic products for packaging goods, a mixed nature of waste logistics can be seen, combining the return of waste to the production cycle (T2) and the sale of waste to other organizations (T3). The effectiveness of waste logistics in general for the industries under study can be determined at an average level, mainly due to the waste recycling system organized at the enterprises.

At the conclusion of the study, decisions are structured to reduce the level of waste of enterprises in connection with the type of production of organizing a waste logistics system. The proposed methodology can be used by companies to diagnose existing models to organize to organize waste circulation and design their own economically feasible waste processing and disposal model.

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References

Aminova D., Magtymov B., Melyaev O. (2023). Innovative technologies in the chemical industry. Cognition Rerum. 10: 35-37.

Bao G., Vitliemov P. (2024). An Approach to Building a Smart Decision-Making Process in a Manufacturing Organization in Terms of Profitability. Eng. Proc. 70: 35.

Dotsenko E.Yu., Ezdina N.P., Mudrova (2023). Business models of the circular economy. Post-Soviet continent. 2(38): 94-106.

Dzie J., Szlachetka O. (2024). Waste or Raw Material? Perlite Concrete as Part of a Sustainable Materials Management Process in the Construction Sector. Sustainability. 16: 6818.

Federal Law of June 24, 1998 No. 89-FZ “On Production and Consumption Waste”. (1998). Available online: URL: https://www.consultant.ru/document/cons_doc_LAW_19109/?ysclid=lzmfxj6t45882456149 (accessed August 10, 2024).

Grishchenkova Y.V., Ressert M. (2019). An efficient and environmentally friendly waste management system. Municipal solid waste. 3(153): 44-46.

He Y., Zaremohzzabieh Z., Rahman H.A., et al. (2024). Applying participatory research in solid waste management: A systematic literature review and evaluation reporting. Journal of Infrastructure, Policy and Development. 8(5): 5072.

L.I. D., Nik Azman N.H. (2024). A review of the impact of artificial intelligence (Al) trust concerns on digital Chinese Yuan (E-CNY) to promote Chinese economic low-carbon sustainable development. Journal of Infrastructure, Policy and Development. 8(1): 2238.

Malysheva T.V., Shinkevich A.I. (2020). Computer program “Automated system for assessing the waste circulation model in the production of chemical products.” No. 2020619252 dated 08/13/2020.

Malysheva T.V., Shinkevich A.I., Zelenkina E.V., et al. (2017). Development and concentration efficiency study of enterprises innovation activity in real sector of economy. Eurasian Journal of Analytical Chemistry. 12(7): 1347-1356.

Meshalkin V.P., Shinkevich A.I., Malysheva T.V. (2021). Systematic analysis of the efficiency of secondary energy resource use in circular economy. ChemChemTech. 64(8): 79-89.

O'Rourke K., Wurzer C., Murray J., et al. (2022). Diverted from Landfill: Reuse of Single-Use Plastic Packaging Waste. Polymers. 14: 5485.

Orazova S., Durdyeva Sh. (2024). Methods and algorithms of scientific research. Symbol of Science: International Scientific Journal. 1(5-1): 74-75.

Order of Rosprirodnadzor of May 22, 2017 N 242 "On approval of the Federal classification catalog of waste". Available online: URL: https://rpn.gov.ru/fkko/ (accessed August 3, 2024).

Order of Rosstandart of January 31, 2014 N 14-ST "On the adoption and implementation of the All-Russian classifier of types of economic activity OK 029-2014". (2014). Available online: URL: https://normativ.kontur.ru/document?moduleId=1&documentId=241621 (accessed August 12, 2024).

Order of Rosstat of October 9, 2020 N 627 "On approval of the federal statistical monitoring form with instructions for filling it out for the organization of federal statistical monitoring of production and consumption waste by the Federal Service for Supervision of Natural Resources". (2020). Available online: URL: https://base.garant.ru/74748082/ (accessed August 10, 2024).

Papafloratos T., Markidis I., Kotzaivazoglou I., et al. (2023). Sustainability Material Topics and Materiality Analysis in the Chemical Industry. Sustainability. 15: 14014.

Pfisterer I., Rinberg R., Kroll L., et al. (2024). Quality-Driven Allocation Method to Promote the Circular Economy for Plastic Components in the Automotive Industry. Recycling. 9: 67.

Rosprirodnadzor. Analytical data (2024). Available online: URL: https://rpn.gov.ru/open-service/analytic-data/statistic-reports/production-consumption-waste/ (accessed August 10, 2024).

Ryazanova O.E., Zolotareva V.P. (2020). Circular economy. Publishing house "KnoRus", 120 p.

Sheverdyaev O.N., Yavkina N.V. (2017). Recycling of plastics. Advances in chemistry and chemical technology. 1(105): 41-45.

Shinkevich A.I., Malysheva T.V., (2021). Computer program "Program for making decisions on environmental engineering of chemical production." No. 2021680681 dated 12/15/2021.

Sutyagin A.A., Menshikov V.V. (2023). Basics of calculations. In: Material balance of chemical processes. South Ural State Humanitarian and Pedagogical University, 106 p.

Volkova A.V. (2018). Waste recycling market. National Research University, Higher School of Economics, 87 p.

Yu L., Chen S., Tan, Z. (2024). Analysis of Solid Waste Treatment and Management in Typical Chinese Industrial Parks with the Goal of Sustainable Development and Future Suggestions. Sustainability. 16: 6731.

Zile E.A., Belozersky A.Yu., Savinkov S.V. (2020). High-density polyethylene can be produced from plastic waste. Advances in chemistry and chemical technology. 34, 3(226): 35-37.