Utilization of industrial waste in the urban environment

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Abstract. The article discusses promising technologies for the process of utilization of industrial waste in an urban environment. Statistical data on waste accumulation in Russia, volumes and methods of their utilization are presented. The main world trends in the field of industrial waste disposal in the urban environment and the possibilities of their implementation in Russian cities are considered.

1. Introduction
The main characteristic of a natural ecosystem is its resilience and ability to restore balance. Biological species inhabiting the ecosystem perform certain functions, including the functions of removing and processing waste products of living organisms. Humanity in the modern world exists in the conditions of an individually created habitat - the technosphere. Like any artificially created habitat, the technosphere is not capable of independently maintaining balance and stability. The reason for this is the large number of individuals (people) living compactly in small areas. This is most typical for urban-type settlements. Food and water to feed the population comes from outside the city. Also, waste must be either disposed of within the system or removed from it. A large amount of waste generated within cities (consumer waste) and industry has led to a large amount of accumulated waste, which negatively affects the ecology of the environment and public health.

Only in recent decades has humanity come to understand the need to create new technologies and materials that would not destroy the ecological habitat. This is how new materials are created that can quickly decompose in the natural environment, technologies for the processing of materials and their secondary use, small and waste-free production, and closed-cycle technologies are being developed.

However, a large amount of waste accumulated in the previous century leads to the need to create a new concept of waste management. Waste generation and management have received significant attention from local, national, sub-regional, regional and international communities. Waste management policies are coming to the fore and many governments are developing national strategies for waste reduction and recycling. One of the most effective mechanisms in the field of waste reduction is informing and educating the population about the need for separate waste collection, reduction of consumption and recycling.

2. The current state of the problem of industrial waste disposal
In the modern world, one of the most important trends in the development of urban systems is the development and implementation of smart city projects. The issue of recycling industrial waste in such systems is one of the key factors for effective management of the urban environment. The orientation
of modern society towards the ecologization of all processes and branches of life is aimed, among other things, at the disposal of waste generated within the urban system [1–4].

Problems in the field of waste management in the urban environment in the modern world come to the fore. The existing urban systems are not able to independently cope with the volumes of industrial and consumer waste. The reason for the increase in the volume of waste is an increase in the quality of life in settlements and an increasing volume of production. This leads to a growing economic burden is, on the city budget, as to combat the problem of waste is necessary to direct the funds not only recycling, but also on the advertising campaigns informing the public about the dangers of waste on the environment and human health, and educational programs that increase environmental awareness, modernization of the waste management system.

One of the most important steps in waste management is the need to identify the sources of waste and formulate a strategy for their disposal and reduction. Table 1 shows the classification of waste and sources of their generation.

**Table 1.** Classification of production and consumption waste in urban conditions, sources of their formation and strategies for reduction / utilization.

| Waste class                     | Waste source                                                                 | Reduction / disposal strategy                  |
|---------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------|
| Solid household waste          | Urban population                                                             | Reuse, reduction, disposal, storage             |
| (includes solid, semi-solid,  |                                                                             |                                                 |
| liquid waste capable of rotting |                                                                             |                                                 |
| and not capable of rotting)    |                                                                             |                                                 |
| Runoff containing mineral     | Agricultural sector                                                         | Reduction, processing                           |
| fertilizers from fields,       | production, livestock                                                        |                                                 |
| runoff from livestock farms    |                                                                             |                                                 |
| Construction waste             | Building materials production, construction industry                         | Reuse, recycling, disposal                       |
| Oils and organic waste         | Various industries, processing industry, mining industry                      | Reduction, recycling, disposal                  |
| Hazardous toxic chemicals      | Pharmaceuticals, medicine, waste, including municipal sewage                 | Recycling, disposal                              |
| Radioactive waste              | Nuclear energy, medicine, science                                            | Reuse, recycling, disposal                       |
| Electronic waste, E-waste      | Urban population, industrial production                                       | Reduction, recycling and                        |
| Synthetic chemical waste       | Chemical production                                                         | Reduction, recycling , disposal                  |
| Gaseous emissions              | Industrial production, energy sector, greenhouse gases                       | Reduction, processing, use of alternative energy sources |

Thus, the main directions of the development of the waste management strategy can be identified. At the present stage of technological development of society, the main ways are to reduce and recycle consumption and production waste. In the future, many governments declare a policy called “zero
waste”. However, today mankind is faced with the problems of environmental pollution by waste with an ever-increasing population of cities and the level of consumption [4].

The increase in the amount of consumption and industrial waste in urban areas leads to a number of negative consequences for the environment, for example:

- poisoning and pollution of ground and surface waters by filtrate, which are formed in places of waste storage;
- air pollution due to waste decomposition or combustion processes, the release of greenhouse and toxic gases into the atmosphere;
- reduction of biological diversity in places of waste accumulation, change of ecosystems to simpler ones with a predominance of scavengers in the species composition of the biocenosis, which poses a threat to the safety of the urban system;
- deterioration of the condition of water bodies due to pollution and clogging of channels, drains, which is conducive to water logging of water bodies, the development of pathogenic microorganisms and insect vectors of diseases in these territories, and a deterioration of recreational indicators.

In addition to the environmental load on the ecosystem of urban areas, waste storage on them has a negative impact on public health. We note in particular the following dangers:

- an increase in the number of living organisms (insects, rats, mice) capable of spreading diaphogenic microorganisms, which can cause outbreaks of infectious diseases, such as cholera, dysentery, malaria, plague, hepatitis and many others;
- pollution of waters and soils with heavy and radioactive metals such as mercury, cadmium, cesium, which can cause various diseases of the nervous, bone and other body systems in the population, the emergence of prerequisites for genetic deviations and mutations.

3. Industrial waste management in the urban environment

In a modern waste management system, there are a number of scenarios that can prevent the problems listed above.

The first scenario is based on the classical waste management model and includes a number of methods:

- removal and storage of waste at special facilities - landfills. The activities of such facilities are strictly regulated and monitored, and modern technologies make it possible to make this method of waste disposal safer for the environment and public health [5, 6];
- incineration of waste [7]. This method makes it possible to utilize industrial waste and consumer waste, as well as to obtain energy for the needs of the city;
- for the disposal of organic waste, composting methods are most often used, and the resulting product is used as fertilizer [8];
- part of the waste is reused to minimize the consumption of resources, such as metals or plastics, this method of disposal is called recycling;
- introduction at enterprises of quiet low-waste or closed production cycles and reduction of sources, which leads to savings in resources and an increase in the amount of waste [8].

Another way was proposed by a number of authors [9-11] and is based on the application of the concept of sustainable development in waste management issues. The structure of this scenario for reducing waste in urban systems is based on three main ideas:

1. Infrastructure for high-quality data collection on the product life cycle.
2. A set of business models and business strategies based on the obtained data about the product life cycle;
3. Intelligent system and infrastructure for monitoring the product life cycle, separate and timely collection based on sensors.

The proposed scenario assumes the use of certain technologies that are capable of providing the ability to control and manage. Blockchain [9, 12] and Internet of Things (IoT) [13] can become such technologies in modern urban systems.

Thus, the most effective model in the field of waste management in an urban environment can be the synthesis of information technologies and technologies for environmentally friendly waste disposal and recycling processes. Such a system is an Internet-recycling interconnection and is implemented through various Internet platforms [9, 14]. A schematic diagram of the Internet - recycling model is shown in Figure 1 [14].

![Figure 1. Diagram of the internet model – recycling (MSW - municipal solid waste) [14].](image)

The use of modern technologies in the field of waste processing will significantly reduce the loss of metals, including rare earth metals, in comparison with their simple storage at landfills. Recycling plastics and glass will reduce the stress on ecosystems. A significant advantage of using the technologies of the Internet model - recycling is the simplification of control and waste management, economic benefits, sustainable development of urban systems.

4. Volume of industrial and consumer waste, their use and disposal in Russia and the Rostov region

Despite the development and gradual introduction of modern waste management technologies, one of the problems of cities is the complexity or impossibility of processing and disposal of waste within the city, as this negatively affects the environmental indicators of the environment. This problem is typical for the majority of modern cities around the world.

For Russia, the problem is no less urgent than for other countries. So, according to the Federal State Statistics Service in the period from 2016 to 2018 there was an increase in the amount of industrial and consumer waste [15]. At the same time, the percentage of waste utilization of various classes of environmental hazard remains quite low (tables 2 and 3). This may indicate a lack of production capacity for waste processing. It also signals the need for a paradigm shift in waste management.
**Table 2.** Formation, use and disposal of production and consumption waste by classes of hazard for the environment (thousand tons) *

| Class of danger | Production and consumption waste generation | Utilization and neutralization of production and consumption waste |
|----------------|---------------------------------------------|-------------------------------------------------------------|
|                | 2016 | 2017 | 2018 | 2016 | 2017 | 2018 |
| I class of danger | 28   | 21   | 22   | 18   | 15   | 9   |
| II class of danger | 304  | 218  | 256  | 347  | 296  | 237 |
| III hazard class | 19347 | 17083 | 20418 | 18494 | 15983 | 18843 |
| IV hazard class | 78584 | 90406 | 77319 | 67599 | 52593 | 62264 |
| V hazard class | 5343050 | 107729 | 7168039 | 3157248 | 18843 |

* According to Federal state statistic service [15]

**Table 3.** Exported by special transport of solid municipal waste and liquid waste from the territories of urban settlements (thousand cubic meters) *

| Exported in a year | solid municipal waste | liquid waste | Disposed of solid municipal waste to facilities used for waste treatment (waste processing plants and enterprises for preliminary waste preparation) |
|--------------------|-----------------------|--------------|----------------------------------------------------------------------------------------------------------|
|                    | 2016                  | 2017         | 2018                                                                                                    |
|                    | 268758                | 36854        | 23880                                                                                                   |
|                    | 274423                | 36515        | 27877                                                                                                   |
|                    | 275434                | 41697        | 28096                                                                                                   |

* According to Federal state statistic service [15]

However, it should be noted that in 2019 the situation in the field of waste management has changed for the better. For example, according to the data [16] in the Rostov region of the Russian Federation, there is a significant increase in the amount of used or disposed production and consumption wastes (table 4).

**Table 4.** Waste generation, use and neutralization in the Rostov region in 2017-2019 (tons) *

|                          | The amount of production waste generated and consumption | The amount of used production and consumption waste | The amount of neutralized production waste and consumption |
|--------------------------|----------------------------------------------------------|----------------------------------------------------|----------------------------------------------------------|
| 2017                     | 4224711.1                                                | 1367804.9                                          | 350044.7                                                |
| 2018                     | 3558953.8                                                | 1275283.9                                          | 377946.4                                                |
| 2019                     | 3110606.0                                                | 1674280.0                                          | 4199088.0                                                |

* Starting from 2019, observations are carried out in accordance with the order of the Federal State Statistics Service of 12.12.2019 No. 766 “On approval of the federal statistical observation form with instructions on how to fill it out for the organization by the Federal Service for Supervision of Natural Resources Management of the Federal Statistical Monitoring of Production and Consumption Wastes”.

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Based on the data in Table 4, it can be noted that the total amount of waste recycled and disposed of in 2019 is greater than that produced. This is due to the increased priority in the field of environmental protection and the introduction of new technologies for waste management. So in the Rostov region the construction of an intermunicipal ecological waste processing complex is being completed. A landfill, a bio-composting site and a waste sorting complex are located on the territory of the complex. According to [16], this enterprise is a modern ecological complex of facilities with a closed cycle of waste management: reception, processing, neutralization, disposal and disposal. The commissioning of this complex can significantly improve the environmental situation in the region.

5. Conclusion
Effective waste management in urban systems is one of the priorities of environmental science today. The use of modern technologies in the future and in the present can improve the quality of life of the population and reduce the burden on ecosystems, as well as the economic sphere, which is one of the priority goals of sustainable development.

Waste reduction is one of the priority policy goals of many countries around the world. Modern technologies can significantly reduce the amount of waste in most industrial sectors, as well as consumption waste. One of the solutions is waste reduction, re-production, recycling, rational use. These methods and strategies for dealing with waste are implemented both in production and privately by the population of cities.

Analysis of the statistical materials presented shows an improvement in the situation with waste processing, as well as a decrease in accumulated waste stocks. This will ultimately lead to an improvement in the ecological situation in urban systems and in the surrounding areas.

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