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Prospects for the implementation of the state information system for waste management (using the Tyumen region as an example)

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Abstract

Relevance of work. One of the main state tasks is the organization of balanced management of production and consumption waste. An effective tool for integrated management in this area is the implementation of the state information system. The research results will contribute to the development of regional environmental monitoring based on modern digital technologies.

Purpose of the work: to study the current prospects for the implementation of the state information system for the management of production and consumption waste in the region (Tyumen region without autonomous okrugs).

Methods of research. The collection and systematization of information on the organization in the region of the management of production and consumption waste, including existing technologies for remote environmental monitoring, have been completed. A spatial digital model of the regional waste management is formed, on the basis of which the proposed solutions for the state information system have been tested. Statistical and geoinformation methods of study were used.

Results. The system for managing waste from production and consumption, which has been formed in the Tyumen Region, as well as information support for government bodies for making managerial decisions, does not correspond to modern challenges and existing potential. Existing issues in the way of a comprehensive state information representation of the industry are considered. Conditions and prospects for the implementation of the state information system at the regional level are systematized.

Conclusions. Using the Tyumen region as an example, the prospects for introducing a state system for the management of production and consumption waste were determined, and managerial measures in this direction were outlined.

Keywords: satellite data, remote sensing, waste disposal facilities, municipal solid waste, unauthorized landfills, monitoring, liquidation and reclamation.

Introduction

In 2018, according to the Regional Waste Cadastre of the Tyumen Region (this work presents the results of a study within the territory of the Tyumen Region without autonomous okrugs), the region's enterprises generated about 2.56 million tons of production and consumption waste [1]. The dynamics of information from reporting enterprises indicates a significant increase in all significant indicators in this area (Table 1); it should be noted that radioactive, biological and medical wastes are not subject to accounting in the cadastre [2], therefore, the aggregate de facto values are still higher.

If we look at the average values, we will also find here fundamental changes (Fig. 1): the mass of generated production and consumption waste increased on average by one person and one reporting organization (by 85 and 13% since 2010, respectively). In 2011, reporting enterprises overcame the average waste generation mark of 1 ton per inhabitant of the Tyumen region.

Such rapid dynamics cause environmental degradation, and accumulation and circulation are already a direct source of threats to the life of the population of the Tyumen region. As an example, the deterioration of public health due to fire at the landfill and the ingress of combustion products into the urban

environment of Zavodoukovsk in 2019 [4]. These phenomena can be recorded in the analysis of commonly available materials for remote sensing of the Earth (Fig. 2), where clouds of smoke from the polygon are clearly visible, covering a city line with a wide strip. The effectiveness of using remote monitoring of places of accumulation of production and consumption waste was noted in the works of local and foreign authors [5–7].

Obviously, due to the high social significance of the waste management system, the region needs an operational state information system in this area that ensures environmental safety and investment attractiveness of the territory. At the same time, in order to reduce budget spending limits, it should be comprehensive, technological, open, and self-developing. In this paper, we will present the results of an assessment of the main directions for its implementation in the Tyumen region, through the prism of informatization, we will give some prospects for the development of the waste management sector.

Methodology and information base of research

The normative legal act regulating the fundamentals of waste management in the Russian Federation is Federal Law dated 24.06.1998 no. 89-FZ [8]. But in its content, as well as

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Table 1. Dynamics of waste management of production and consumption at enterprises of the Tyumen region, 2010–2018 [1, 3].**Таблица 1. Динамика обращения с отходами производства и потребления на предприятиях Тюменской области, 2010–2018 гг. [1, 3].**

Year	Population as of 01.01., thousand people	Number of companies that have provided information	Waste production, thousand tons	Recovered and harmless wastes, thousand tons	Share of recovered and harmless wastes, %
2010	1338.3	2551	1229.20	351.69	28.6
2011	1352.4	3704	1749.60	773.32	44.2
2012	1373.3	4785	2022.40	985.91	48.8
2013	1397.2	4896	2665.20	1547.34	58.1
2014	1419.3	5280	2892.00	1742.41	60.3
2015	1441.9	5205	2830.00	1962.40	69.3
2016	1466.3	5673	2658.90	1946.80	73.2
2017	1488.3	5053	2468.23	1813.23	73.5
2018	1508.7	4681	2557.30	1899.50	74.3

Figure 1. Dynamics of growth of waste mass of production and consumption at enterprises of the Tyumen region in 2010–2018 [1, 3].**Рисунок 1. Динамика роста массы отходов производства и потребления на предприятиях Тюменской области в 2010–2018 гг. [1, 3].**

in the body of by-laws, the concept of “waste dump” as an object for storage, accumulation, or disposal of waste is not fixed. As a result, methodological confusion arises when in different departments and regions (including the Tyumen region) they use this term in their interpretation. In our work, we use the concept of “unauthorized disposal field” as the area on which illegal disposal of waste takes place.

If we keep in mind the Tyumen regional regulatory legal framework, then waste management can be represented in the form of a model of interlinked technological processes (Fig. 3). In the structure of the presented direction of waste management, there is no cyclical nature that is inevitable when organizing the rational use of natural resources, as well as processes taking place in the environment of unauthorized landfills, reclamation of waste disposal sites, sale of goods and services, including recycling points, etc. as the final element of the working link of the landfill – this is a methodological dead end in the organization, as the result is the formation of new facilities and the preservation of completely filled places.

When evaluating directions it is necessary to determine the participants of information interaction. Information provider scheme (Fig. 4) may include the following players:

- executive state government bodies;
- local government bodies;
- corporate oversight organizations;
- organizations carrying out scientific and methodological supervision;
- public organizations for community or civic supervision.

Such a wide range of participants in the process is the key to systemic accounting of the requirements of each party, positioning of roles, complex programming of events with several concerned parties.

Methods of remote sensing of the Earth [10] help to remove the problem of objectivity of monitoring of unauthorized landfills [10]. The ultra-high resolution satellite images (0.5–1 m) from the satellites GeoEye, WorldView-1,2, QuickBird, Pleiades-1A, 1B, Ikonos and several others provide an operational picture. In order to determine the facts of reduction or increase

Figure 2. Yandex space photograph in the vicinity of the city Zavodoukovsk, 2019.
Рисунок 2. Космоснимок Yandex окрестностей г. Заводоуковска, 2019 г.

in the area of previously identified landfills, as well as to monitor the implementation of remediation measures, it is effective to use multi-temporal images of the same territory (Fig. 5), as a result, changes in the area characteristics of the object are clearly visible [11].

Another example is a landfill near the village of Posokhovo (Fig. 6) which is in the process of preparing for restoration; works should begin in 2020 [12]. Tasks associated with the detection of unauthorized landfills can be solved on the basis of multispectral aerospace images (Fig. 7). Landfills and their constituent materials absorb, emit and reflect electromagnetic waves, thus providing an opportunity to recognize and obtain data on the state of these objects [13]. For example, through the use of Uncontrolled Classification Algorithm (ISODATA) with multiple spectral channels. The result of applying this technique can be the creation of so-called decryption masks, which automate the search for waste accumulation sites.

The disadvantage of this method is the lack of a system of indicators of the landfill. There are consumer waste, construction waste, etc. "Unauthorized landfill" is an example of a volume mixed in composition, when besides plastic bottles and wood residues there may be potato tops, manure, etc. In this case, operating with a series of images of different times (Fig. 8) with cameral and field verification comes to the aid [14].

According to the results of a desk audit, legally verified results can not always be given: the distortion of remote sensing materials cannot be ruled out, as well as a lack of reliable spatial information. Field certification has the risks of significant time, material, organizational costs. One of the operational solutions is the use of unmanned aerial vehicles, and it is not necessary to equip specialized garrisons that service the use of this equipment, as corporate tracking systems for various purposes have been actively introduced in the regions: agricultural assessment, monitoring of forest fires, forest inventory, control over the extraction of common minerals, etc.

Numerous materials from these surveys, for most of which there are implementation regulations enshrined in regulatory legal acts, could be effectively used in the field of supervision of the treatment of production and consumption waste. Given the existing characteristics of orthophotomaps (Fig. 9), which exceed 1 cm per pixel, their use can effectively replace most field certifications.

In our opinion, an objective integrated solution to the totality of managerial tasks is the formation of a state information system (GIS) on a modern integrated technological basis. The methodology of its creation is based on the holistic principle taking into account the presence of direct and inverse relationships of natural, man-made and natural-anthropogenic objects. Applicable research methods: Earth remote sensing, statistical, mathematical and cartographic methods.

Directions for creating a state information system in the field of waste management for production and consumption in the Tyumen region

In the Tyumen region, according to the main indicators of socio-economic development, a positive trend is observed [16, 17]. According to the government, as of 01.01.2019, there were 613 unauthorized and 389 authorized landfills in the region that were planned to be liquidated in three years [18]; later there was a correction for the terms for 2026 [19], for 2027 [20]. Accordingly, even the timely execution of planned work involves a 7–10-year cycle of work, and this requires appropriate information support, including geoinformation. Each dump is, first of all, a land plot that has borders, an owner, encumbrances, easements. And if once it became attractive for waste disposal here (due to economic and logistical positions), then, while maintaining all the initial conditions for land use, this can happen again. This direction of the program implementation becomes effective when correlating the plan, fact, dynamics on the geographic information coverage.

According to the regional operator (LLC "TEO"), as of November 1, 2019, there are 18 117 container sites when necessary

Figure 3. Model for the development of the sphere of solid municipal waste management (MSW) in the Tyumen region [9].
Рисунок 3. Модель развития сферы обращения с твердыми коммунальными отходами (ТКО) в Тюменской области [9].

Figure 4. Conceptual scheme of the organization of information interaction between data providers in the field of waste management of production and consumption.
Рисунок 4. Концептуальная схема организации информационного взаимодействия между поставщиками данных в сфере обращения с отходами производства и потребления.

Figure 5. Multiple-time images of a solid waste landfill near Yalutorovsk.
Рисунок 5. Разновременные изображения полигона ТБО вблизи г. Ялutorовска.

Figure 6. Dynamics of development of the polygon.
Рисунок 6. Динамика развития полигона.

Figure 7. Using multispectral imaging to detect landfills [13].
Рисунок 7. Использование мультиспектральной съемки для обнаружения свалок [13].

Figure 8. Long-term monitoring of the waste disposal facility [13].
Рисунок 8. Многолетний мониторинг объекта размещения отходов [13].

just 23 576. Container park – 23 898 pcs., need – 32 290 pcs. [21]. At the same time, their geographical location in the municipalities (demand) is not reflected in the public sphere: the regional operator's map (Fig. 10) contains information on two city districts (Tyumen, Tobolsk) from 29 municipalities of the region.

For example, in the Abatsky district there is not a single installed garbage container, and the accumulation of MSW occurs in bags or special containers according to paragraph 3.1.3 of the Decree of the Government of the Tyumen Region dated 10.05.2018, no. 185-p [23]. However, the sanitary and epidemiological rules and regulations of SanPiN 2.1.7.1322-03. 2.1.7. do not allow the accumulation of waste on unequipped sites (in drafts of new regulatory legal acts as well) [24]. This legal conflict significantly undermines waste management

planning, including its positioning for public institutions. Here is one notable example: foliage in a park and foliage of the park in a plastic bag are two completely different threats to the environment, while not in favor of human intervention. Another example requiring its own information field is the location of container sites. Residents of rural settlements clamour against the installation of waste bins near residential buildings and want container sites to be outside their village, at a distance of 300 m with normal sanitary rules not exceeding 100 m [25].

A separate focus is monitoring fires at landfills. Self-ignition of garbage can be detected by using images simultaneously in the visible and thermal ranges (Fig. 11), comparing them with materials in the public sphere [4, 26]. Despite the negative consequences, this phenomenon of "heat generation"

Figure 9. High resolution orthophotomap prepared for the purpose of inventorying agricultural land [15].

Рисунок 9. Ортофотоплан высокого разрешения, подготовленный для целей инвентаризации сельскохозяйственных земель [15].

Figure 10. Location of container sites in the city Tyumen [22].

Рисунок 10. Расположение контейнерных площадок в г. Тюмени [22].

can turn into valuable information that helps in the detection of unauthorized landfills [27]. If gas is collected, it can be used as an alternative fuel for energy needs. [28], which is already an economic effect correlated with security.

A separate direction is the selection of information resources. They should be legitimate, complete, relevant, correlate with other sources. Examples of these ratios and their significance are varied. Here are some examples.

Public cadastral map as a source of information on the status of the land. According to the scheme [9], the landfill was identified on the lands of the forest fund near the village called *no.votarmansky* (Fig. 12). Today it is identified on satellite images, directly verified during the field exercise, but there is no correlation of the site with the forest fund on the public cadastral map. The problem of attributive discrepancy.

Geoportal of the Tyumen region as a source of state spatial information of the Tyumen region. The object on the

map of authorized landfills is located within the boundaries of the reserve (Fig. 13, 14), which contradicts the current regulatory legal acts [30]. The problem of spatial discrepancy.

Another area that requires its own separate informational presentation is the financial and economic aspects of presenting the waste management sphere, first of all, information on levies from the population and enterprises for 10 months of 2019. According to the Tyumen Ecological Association [21], the percentage of levy from individuals per month can reach more than 90%, the percentage of levy from legal entities from the forecast charge reaches only 50.9%. Accordingly, within the boundaries of each municipality, their “bottlenecks” in non-payments can be identified, for which a set of targeted measures can be planned.

Transportation volumes indicate that the actual value of waste removed from temporary storage sites is 13% less than what was approved by the tariff (Table 2). If this situation

Figure 11. Multiple-time images of a solid waste landfill near the town of Zavodoukovsk.
Рисунок 11. Разновременные изображения полигона ТБО вблизи г. Заводоуковска.

Figure 12. Unauthorized landfills on a public cadastral map [29].
Рисунок 12. Несанкционированные свалки на публичной кадастровой карте [29].

persists by the end of the year, then this information can become an information basis for revising the size of the tariff, which will reduce social risks and provide information for citizens in an accessible form.

Conclusion

In general, the prospects for the introduction of a modern state information system for the management of production and consumption waste at the regional level are determined by the regulatory framework, the level of technological digitalization, the current environmental situation, and the position of civil society. Using the example of a single region, we can note the possibility of prompt and relatively inexpensive integrated implementation, but taking into account the implementation

of relevant measures. Each region, municipality can similarly assess the prospects for introducing a state information system in the field of waste management in relation to its territory, its current environmental status, and the priorities of the territorial community of people.

We recommend to executive authorities and local authorities of the Tyumen region:

1. Create a zone free of landfills and landfills within a radius of 100 km from the city of Tyumen; to create GIS for increasing the environmental and aesthetic attractiveness of the city and the suburban area.
2. To conduct an inventory of waste disposal facilities for production and consumption based on remote sensing mate-

Figure 13. Location of authorized landfills on the Special Protected Natural Areas [31, 32].
Рисунок 13. Расположение санкционированных свалок на землях ООПТ [31, 32].

Figure 14. Location of landfill on the public cadastral map [29].
Рисунок 14. Местоположение свалки на публичной кадастровой карте [29].

Table 2. Transportation volumes according to the results of 10 months of 2019 [21].

Таблица 2. Объемы транспортирования по итогам 10 месяцев 2019 г. [21].

Name of subdivision	Approved in tariff, t	Regulatory require-ment, t	As of October 31, 2019			
			Mass, t	Number of cars, units/day	Number of people, day	Run, unit
Tyumen directorate	283 388	216 626	270 232	90	180	68 625
Tobolsk Authority	46 753	35 792	40 259	15	30	9150
Ishim Authority	69 823	45 555	45 128	27	54	12 353
Yuzhnoe Authority	45 042	32 682	31 435	15	30	8235
<i>Subtotal</i>	445 005	330 655	387 054	147	294	98 363

rials, data from the Department of Subsoil Use and Ecology of the Tyumen Region, as well as data from interactive maps of public organizations.

3. To create a unified register on the current state of all waste disposal facilities, including complete and objective information about these facilities, monitoring the development of landfills and their reclamation processes, as well as systematizing the results with legal documentation to establish the correspondence of the actual boundaries of landfill permits, inspection materials and public supervision.

4. To form some relevant materials (as part of the existing GIS of the Tyumen Region) of the advanced sheet for the management of production and consumption waste with the assignment of a responsible operator for its management, as well as to place a list of business entities collecting waste from production and consumption from the population and organizations.

5. Provide actual and planned information on the location of infrastructure facilities in the field of waste management (waste sorting facilities, container sites), as well as financial and economic indicators in the context of municipalities.

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Перспективы внедрения государственной информационной системы по обращению с отходами (на примере Тюменской области)

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Аннотация

Актуальность работы. Одной из основных государственных задач является организация сбалансированного обращения с отходами производства и потребления. Эффективным инструментом комплексного управления в данной сфере является внедрение государственной информационной системы. Результаты исследований внесут вклад в развитие регионального экологического мониторинга на базе современных цифровых технологий.

Цель работы: исследовать современные перспективы внедрения государственной информационной системы по обращению с отходами производства и потребления на территории региона (Тюменская область без автономных округов).

Методы изучения. Выполнен сбор, систематизация сведений по организации в регионе обращения с отходами производства и потребления, включая имеющиеся технологии дистанционного экологического мониторинга. Сформирована пространственная цифровая модель регионального обращения с отходами, на основе которой апробированы предлагаемые решения для государственной информационной системы. Используются статистический и геоинформационный методы изучения.

Результаты. Сформировавшаяся в Тюменской области система по обращению с отходами производства и потребления, а также информационное обеспечение органов власти для принятия управленческих решений не соответствует современным вызовам и имеющемуся потенциалу. Рассмотрены существующие проблемы на пути комплексного государственного информационного представления отрасли. Систематизированы предпосылки и перспективы внедрения государственной информационной системы на региональном уровне.

Выводы. На примере Тюменской области определены перспективы внедрения государственной системы по обращению с отходами производства и потребления, намечены управленческие практические мероприятия в данном направлении.

Ключевые слова: космические снимки, дистанционное зондирование, объекты размещения отходов, твердые коммунальные отходы, несанкционированные свалки, мониторинг, ликвидация и рекультивация.

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