ECOLOGICAL AND HYGIENIC ASPECTS OF SOLID WASTE DISPOSAL

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Disposal of solid domestic waste (SDW) is an important environmental and hygienic problem, but it causes not only environmental, but also great economic damage. From January 1, 2019, it was planned to carry out a reform of solid waste management. Many regions were not ready for waste reform. The problem of waste disposal is especially acute in federal cities. The goal is to study the readiness of regional operators in large cities (Moscow, St. Petersburg, Sevastopol) and students to solve the problem of waste disposal. A total of 100 solid waste collection sites were examined in the central and peripheral regions of Moscow, St. Petersburg and Sevastopol. An online survey of 356 medical students was conducted. When examining districts of three cities, the main difficulties in the peripheral regions were insufficient lighting, lack of fences and protective soil coverings, in the central regions — non-compliance with zoning in the location of sites in relation to the housing stock, lack of lids on containers, which worsens the sanitary and epidemiological situation. The main motivations for students to participate in separate waste collection were the convenience of container location and incentives; environmental problems were of interest to only 4% of respondents. The results of the study revealed the need to continue reforming the primary level of solid waste management and conducting environmental and hygienic education of the population, including youth and students, in terms of the importance of waste management using modern technologies.

Keywords: solid domestic waste, separate waste collection, students, survey, environmental and hygienic education

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Compliance with ethical standards: anonymous online survey did not infringe on human rights, did not endanger the participants, and met the biomedical ethics requirements.

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ЭКОЛОГО-ГИГИЕНИЧЕСКИЕ АСПЕКТЫ УТИЛИЗАЦИИ ТВЕРДЫХ БЫТОВЫХ ОТХОДОВ

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Утилизация твердых бытовых отходов (ТБО) является важной эколого-гигиенической проблемой, однако она наносит не только экологический, но и большой экономический ущерб. С 1 января 2019 г. предполагалось провести реформу обращения с ТБО. Многие регионы оказались не готовы к мусорной реформе. Особенно остро проблема утилизации отходов ощущается в городах федерального значения. Целью работы было изучить готовность региональных операторов крупных городов (Москвы, Санкт-Петербурга, Севастополя) и студентов к решению проблемы утилизации мусора. Обследованы 100 площадок для сбора ТБО в центральных и периферийных районах Москвы, Санкт-Петербурга и Севастополя. Проведен онлайн-опрос 356 студентов-медиков. Обследование районов трех городов показало, что основными трудностями периферических районов были недостаточное освещение, отсутствие ограждений и защитных покрытий почвы, а центральных районов — несоблюдение зональности в расположении площадок по отношению к жилому фонду, отсутствие крышек на контейнерах, что ухудшало санитарно-эпидемиологическую ситуацию. Основными мотивами участия студентов в раздельном сборе мусора были удобство расположения контейнеров и поощрения. Экологические проблемы интересовали только 4% респондентов. Результаты исследования выявили необходимость продолжения реформирования первичного звена обращения с ТБО и проведения эколого-гигиенического воспитания населения, в том числе молодежи и студентов, в отношении важности управления отходами, с использованием современных технологий.

Ключевые слова: твердые бытовые отходы, раздельный сбор мусора студенты, анкетирование, гигиеническое воспитание

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Соблюдение этических стандартов: анонимное онлайн-анкетирование не ущемляло прав человека, не подвергало его опасности и соответствовало требованиям биомедицинской этики.

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The environmental safety of any country largely depends on how it solves the problem of waste disposal. Accumulated waste, landfills, and deposits of toxic substances cause both environmental and economic damage of significant scale. Moreover, solid domestic waste (SDW) collection sites that are set up with violations of sanitary and hygienic requirements for their location and equipment present risks of infectious, parasitic, and other diseases [1].

Currently, there are three practiced methods of waste disposal: burial, incineration, and recycling, the latter being the safest for the environment. Until recently, the common approach to waste disposal in Russia was of extensive nature, i.e., the number of landfills was growing, and not all of them met the established hygienic requirements for the SDW burial grounds design and maintenance. A comparative assessment of the approaches to waste disposal in Russia has shown that

93–95% of garbage is buried, and only 7–5% — recycled. In the countries of the European Union, 40% of the wastes are buried, another 40% recycled into materials, and 20% processed into energy [2, 3].

The sphere of solid waste disposal management has been undergoing reformation for over 20 years; the process started with adoption of the Federal Law "On Industrial and Domestic Wastes" in 1998 [4].

The so-called "waste reform", a set of measures designed as part of the effort to improve environmental situation, was supposed to have been launched in the Russian regions on January 1, 2019. The specifics of waste management are given in a number of federal level regulations [5–11].

The waste reform aimed to fill the gaps in the existing legislation and relay the priorities of the state in this matter. Inter alia, it provided legal basis for waste sorting (separate collection of waste) and recycling. The reform focused on several interrelated problems simultaneously and sought to eliminate illegal landfills, popularize the concept of waste sorting, legalize this practice among waste disposal facility operators, and make sorting and recycling mandatory for the said operators.

According to the researchers, Russian regions were largely unprepared for the waste reform: the number of allocated landfills was insufficient, waste recycling plants remained unbuilt, there were no separate waste collection practices implemented. This was the state of affairs in Vladikavkaz, Omsk, Irkutsk region, and Krasnoyarsk [12–16].

Currently, the problem of solid waste disposal is particularly urgent in large cities. In this connection, Moscow, St. Petersburg, and Sevastopol were allowed to not comply with the provisions of the Federal Law 89-FZ that prescribed new ways of waste management from January 1, 2022, i.e., the waste reform was postponed in these cities for 3 years in order to let them develop the respective policies [3]. As highlighted by the researchers, a more difficult task is to change people's attitude towards the matter of waste generation and recycling itself, since one of the most important aspects of SDW management is awareness and understanding of the essence of the problem on the part of the population, especially young people [17, 18].

Thus, the topic of solid waste management is large and very complex. Review of the literature has shown that there are not many papers covering it, and most of them are part of conference proceedings, formalized as short articles or lists of statements. They mainly deal with legal, financial, and economic aspects of the matter, or have to do with administrative regulation of the problem.

This study aimed to investigate the readiness of regional operators in large cities (Moscow, St. Petersburg, Sevastopol) and young people (students) to become part of the solution to the problem of waste generation and recycling.

METHODS

Following the sanitary and hygienic requirements [1], in 2022, we surveyed SDW collection sites in the urbanized areas. The sites were located in the central (historically established) and peripheral (developing) areas of three federal cities: Moscow (Tverskaya, Filevsky Park, Konkovo districts), St. Petersburg (Admiralteysky, Vyborgsky districts, Kronstadt), and Sevastopol (Leninsky, Ostryaki districts). In each districts, we worked with 10 sites.

Surveying the sites, we considered the following parameters: zoning (distance between the site and the residential area, should have been in the range between 20 and 100 m); site surface type (asphalt, concrete, soil); fencing, if any (brick, concrete, metal), and greenery; convenient access roads and waster sorting arrangements; the number of containers on the site and their marking; container covers, if any, and roof above the site; lighting, if any. The study relied on the empirical method: observation, measurement of distance with a laser ruler, comparison.

Addressing the problem of waste sorting and SDW recycling, we surveyed medical students using an online questionnaire developed by the authors of this article. Three hundred and fifty six students of the N.I. Pirogov Russian National Research Medical University (aged 17 through 22 years) took the survey.

To analyze the number of solid waste collection containers in the central and peripheral districts of Moscow, St. Petersburg, and Sevastopol, we used StatTech software (Stattech; Russia). To avoid the effect of multiple comparisons, we applied the Newman–Keuls test after one-way ANOVA. Student's *t*-test was used for comparison of the peripheral and central districts of each city. The differences, after processing with application of the Newman–Keuls and Student's tests, were considered significant at the confidence level of 0.95.

RESULTS

The purpose of surveying sanitary and hygienic condition of waste collection sites in the peripheral and central districts of three cities of federal significance was to comparatively analyze their readiness for the waste reform. The results are given in Table 1.

We found that the surveyed sites have some specific features, but, overall, reformation of the front line of the waste management system is generally prepared and proceeds as planned. The zoning of inner yards of residential buildings was better realized in relatively young (Konkovo) districts and those located far from the city center (Vyborgsky, Ostryaki). The distance between the residential area and the waste collection site was often out of the regulated range (80-100% of cases) in districts that are closer to the city center or inside it, which probably stems from the specifics of development of such historical areas. Sanitary and hygienic regulations suggest covering waste collection sites with concrete or asphalt, a recommendation commonly followed in all districts of Moscow, Admiralteysky district of St. Petersburg, and Leninsky district of Sevastopol. In Vyborgsky district and Ostryaki, there are sites (10–20%) without any protective coating, i.e., their surface is soil.

An important sanitary requirement is for the site to have a fence made of brick, concrete or metal. In two districts of Moscow, Tverskoy and Filevsky Park, we have found a significantly lower number of sites meeting this requirement.

Compared to the peripheral districts, central districts of Moscow, St. Petersburg, and Kronstadt had less sites surrounded with greenery. There, the share of such was only 30–40%. All the surveyed sites had convenient access ways, with the share thereof insignificantly lower in the Tverskoy district of Moscow and districts of Sevastopol.

Separate waste collection (recyclable materials and mixed waste) is practiced in Moscow and St. Petersburg, but there are fewer such sites (40-60%) in the central districts of these cities. In Sevastopol, there are separate containers for cardboard and plastic only; mixed waste, apparently, is collected through in-building garbage chutes. Therefore, we believe that waste sorting, as defined in SanPiN 2.1.3684-21, was not implemented at the time of the study.

All the surveyed sites had 2 to 5 containers for separate waste collection. As for the number of SDW containers, we

Table 1. Share (%) of the surveyed SDW sites in central and peripheral districts (cities of federal significance) that meet the sanitary and hygienic requirements (SanPiN 2.1.3684-21)

City	District	Zoning	Surface	Fencing	Greenery	Convenient access ways	Separate waste collection	Lids on containers and spanning roof	Lighting
Moscow	Tverskoy	20	100a	30m	30	90	40	50/10	30
	Filevsky Park	0	80a 20c	45b	60	100	100	100/50	40
	Konkovo	80	100a	80b	60	100	100	100/50	90
Saint Petersburg	Admiralteysky	0	80a 20c	80b 10m	40	100	60	20/30	80
	Vyborgsky	60	40a 50c 10s	100b	40	100	80	10/10	30
	Kronstadt	20	100a	50b 10cc 30m	30	100	70	30/30	40
Sevastopol	Leninsky	40	10a 90c	10cc 80m	100	80	0 70c* 20p*	100/100	90
	Ostryaki	100	20a 60c 20s	60m	100	80	0 40cp**	40/40	40

Note: a — asphalt, c — concrete, s — soil (types of site surface); cc — concrete, b — brick, m — metal (site fencing material); c* — cardboard, p* — plastic, cp** — cardboard and plastic.

have found that the district occupying central part of Sevastopol had significantly more of them than the district in Moscow's center (Tverskoy) (Table 2). Residents of the peripheral districts of St. Petersburg had more SDW containers at their disposal than residents of similar districts of Moscow and Sevastopol. In addition, we registered significantly fewer containers in the center of St. Petersburg compared to the remote districts of this city.

On many sites, containers were lidless, and there were no common spanning roof over them. This issue requires attention from regional operators. Leninsky district of Sevastopol was the exception: there, 100% of containers had lids, and the collection sites were under roof. As for lighting of the sites, many lacked it (all the included cities), with only Konkovo, Admiralteysky, and Leninsky districts having lamps over 80–90% of the SDW collection sites (Table 1).

In order to assess the commitment of students, who are the most mobile and active part of the young population, to waste sorting, we set up an online survey. According to the results thereof, about 90% of students believe that SDW disposal is an important task of the federal level, and separate collection of domestic waste (waste sorting) is one of the effective methods of solving it. Over 40% of students mentioned that the number of containers for SDW in the courtyards of residential buildings has increased in the year preceding the survey. However, only about 30% of the respondents actually sorted their garbage. The key motivation behind waste sorting, according to the majority (62%) of the participants of the survey, could closeness of the containers to the buildings and their convenient location, and 30% of the students noted that they would like to receive various incentives for separate garbage collection. Over 70% of the respondents claimed readiness to not use an in-house trash chute, if there is one, and sort waste.

According to the survey, only 16% of the participants used recyclables collection points, with 30% and 18% of them bringing waste paper and plastics there. The rest mentioned remoteness of the collection points, lack of habit, or their own ignorance of the recycling possibilities as the reasons for not practicing it. And only a small part of the students (4%) understood and realistically assessed the environmental problems caused by pollution generated by SDW (Figure).

DISCUSSION

Studies by various authors show that, despite adoption of a number of laws and regulations, from 1998 to the present, the waste reform is being implemented very slowly. Today, it is easy learn the best practices of waste management from other countries, starting with sorting, through removal, to recycling, and burial.

In the leading European countries — Germany, Austria, Sweden, the Netherlands, Denmark, Belgium, etc. — there is a stepwise solution to the problem, which starts with explaining the population how and why to sort waste, then arrangement of the removal routines, further sorting, and construction of a high-end waste recycling plant. In Sweden, after careful sorting, about half of the solid waste is burned and converted into energy: for example, food waste becomes biogas. Another half is recycled. Only less than 1% of the wastes is buried [2, 3].

Table 2. Average number of SDW containers, central and peripheral districts of three cities

City	Average number of containers in the city's districts (n)		
	central and peripheral	central	peripheral
Moscow	2.67 ± 1.77 (n = 20)	2.00 ± 1.41 (n = 10)	3.27 ± 1.90 (n = 10)
Saint Petersburg	3.80 ± 1.61 (n = 20)	2.70 ± 0.95**** (n = 10)	4.90 ± 1.37* (n = 10)
Sevastopol	3.25 ± 1.55 (n = 20)	3.80 ± 1.55** (n = 10)	2.7 ± 1.42*** (n = 10)

Note: significant differences ($p \leq 0.05$), as shown by the Newman–Keuls test, between cities: * — Moscow and St. Petersburg, ** — Moscow and Sevastopol, *** — St. Petersburg and Sevastopol; significant differences ($p \leq 0.05$), as shown by the Student's t-test: **** — between central and peripheral districts.

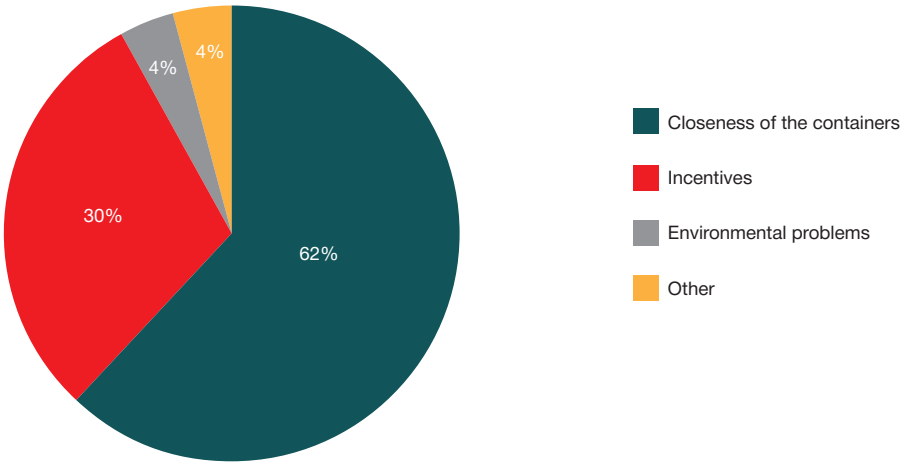

Fig. Distribution of students by their motivation for separate collection of SDW (%)

The Japanese garbage recycling system is as relevant. Compared to our country, Japan lacks territory for landfills, so Japanese use their waste-free system. The municipality determines the days and hours when certain type of garbage is collected and removed. Local authorities impose fines for violations of the order of garbage collection/removal [19, 20].

Some authors believe that Russian reform is better compatible with the Asian approach to the problem; according to them, application thereof will create new jobs and reduce the number of landfills, provide production capacities with cheap raw materials, and protect the country's ecology and public health [16].

Earlier, it was shown that in Moscow, regional operators started working in the context of the waste reform (prepared SDW collection sites, brought lidded containers for separate collection of solid waste) in 2019. The best results were registered in the developing peripheral areas (Savelovsky, Khoroshevsky). Unfortunately, in the Tverskoy district, it was hard to meet the sanitary and hygienic requirements for SDW collection sites due to the historical features of city center.

None of the surveyed sites was perfect. The flaws had to do with incorrect distance to the residential zone, and number of the sites without fences and separate garbage collection arrangements [21].

Our study has shown that cities of the federal level also tackle the task of improvement of the primary component of the waste reform. However, the sites located in the central or peripheral parts of each city meet the sanitary and hygienic requirements only partially. For example, in the Tverskoy and Admiralteysky districts, which lie in the central parts of the cities, many sites were allocated incorrectly, and, consequently, had insufficient amount of containers and poor greenery around them. In Sevastopol, on the contrary, 100% of garbage sites are surrounded by greenery, but they do not always have fencing and concrete or asphalt on the soil. The common advantage of all the surveyed sites were the convenient access roads.

At the same time, scientists believe that at the outset, the key to success of the waste reform is ecological and hygienic education of the young people and the general population. Surveying students of the Kuban State Technological University, the authors found that the ongoing environmental and hygienic reforms in the field of housing and utility services are perceived by the majority of young people positively, not negatively. However, there are psychological barriers preventing waste sorting from becoming a daily habit: students lack confidence in the feasibility of the relevant program and do not wish to incur additional costs in connection with the new waste management system [22].

Previously, there was conducted a survey of about 1500 residents of 41 districts of the Moscow region. Having analyzed its results, the authors of the paper based thereon concluded that it is advisable to intensify educational efforts aimed at the population that teach ecological culture and promote interactions with the regional operator in the context of solving pressing issues [18].

Despite the paucity of literature of this kind, the results of our study are consistent therewith.

An online survey of students at the N.I. Pirogov Russian National Research University has shown that the majority of them (90%) understood the importance of separate garbage collection, but less than 50% of the respondents actually sorted SDW.

Asked about the key incentive to adopt the waste sorting practice, students mentioned availability and convenient location of the respective containers but not the ecological and hygienic consequences of restraining from separate garbage collection. This indicates that they are not fully aware of the seriousness of the problem of waste management for the environment and human health. Therefore, it is necessary to actively explain the issues to the students and the general population using clear visual materials.

It is also important to popularize the recyclables collection points. As opposed to foreign countries, in Russia, this approach to waste management is rarely realized. According to the survey, only a small portion of the students (16%) brought waste (mostly paper) to such points, irregularly, with the main reason being remoteness of the recycling points and students' own ignorance. Therefore, we should practically work on making the youth understand the better effectiveness of processing of separately collected recyclables compared to production of the items from raw materials [23]. At the N.I. Pirogov Russian National Research Medical University, this problem was addressed: in the recreation areas, there were mounted separate garbage collection bins for waste paper, plastic lids, pens, batteries, blisters, small computer accessories, etc., which students and teachers use constantly. In addition to waste sorting, people can consume resources, such as water and electricity, rationally and economically, practicing the approach called "reasonable consumption." This allows solving not only ecological and hygienic, but also economic problems.

As the site surveys have shown, regional operators continue to actively work on the preparation of the primary component of the system of separate SDW collection and subsequent disposal. However, as our study has shown, a more difficult task is to educate the youth in the field of ecology and hygiene.

CONCLUSIONS

A sanitary and hygienic assessment of the SDW collection sites has shown that even at the initial stage of the waste reform, all cities of the federal level implemented measures enabling waste sorting, but the process has some specific features.

In the peripheral districts of the cities included in the study the main flaws about SDW collection sites were insufficient lighting and lack of fences and protective soil covering, and in the central districts the problems stemmed from incorrect allocation respective to the residential buildings, lack of greenery, lack of lids on containers or a common roof (Moscow, St. Petersburg) above the site, which worsened the sanitary and epidemiological situation.

According to the survey, about 80% of students are ready to sort garbage if there are the respective containers available. The main motives for SDW sorting were convenience of container location and incentives; only 4% of the respondents mentioned environmental issues in this connection.

Only 16% of respondents brought waste to the recyclables collection points, and the rest cited remoteness thereof, lack of habit or their own ignorance as the reasons for not doing so.

Based on the above, it is recommended to:

– use modern technologies to enable and intensify efforts aimed at educating population, young people and students in particular, about the importance of waste management and waste sorting;

– teach students how to sort SDW correctly, since properly sorted garbage can be processed more easily, faster and better;

– minimize the use of waste that cannot be recycled and does not decompose for a long time.

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