Reclamation of landfills and dumps of municipal solid waste in an energy efficient waste management system: methodology and practice

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Abstract. The article considers the methodological and practical aspects of reclamation of landfills and dumps of municipal solid waste in a waste management system. The general tendencies of system development in the context of elements of the international concept of waste hierarchy are analyzed. Statistics of the formation and burial of domestic waste indicate a strategic non-alternative to the rejection of landfill technologies in favor of environmentally, energy efficient and economically expedient ways of utilization of municipal waste as a world trend. Practical approaches to the study of territories on which there are dumps and landfills are considered to justify the design solutions for reclamation.

1. Introduction

The formation of waste and their utilization is one of the most ancient problems of humanity, the urgency of which increases with time.

Solid domestic wastes (SDW) (in the modern interpretation - municipal solid wastes (MSW) is classified as wastes that are generated in the process of human life and activity, accumulate in residential houses, public, educational, medical and other establishments and do not have further use for place of their generation. This waste group includes food waste, household items, garbage, fallen leaves, waste from cleaning and maintenance of apartments, waste paper, glass, metal, plastics, and polymeric materials [1]. Comparison of the definition of SDW in Russia with Western terminology shows that the term SDW uniquely answers the commonly used term "municipal solid waste".

The dynamics of municipal waste generation and disposal in landfills and dumps in the European Union in the period from 2000 to 2014, according to Eurostat [2], is presented in Table 1.

If we consider the average annual volumes of MSW generation in several countries and in Russia, according to official data, the situation looks as follows (million tons per year): Switzerland - 2.9, Japan - 44.5, Denmark -
in the different regions of the USA.

Table 2. Dynamics of MSW generation and disposal in dumps and landfills in the EU countries, kg per one inhabitant

| Country       | 2000 | 2005 | 2010 | 2012 | 2013 | 2014 | % to 2000 |
|---------------|------|------|------|------|------|------|-----------|
| Total for 28 EU countries |      |      |      |      |      |      |           |
| was formed    | 521  | 515  | 503  | 485  | 477  | 475  | 91        |
| buried        | 220  | 185  | 154  | 143  | 132  | -    |           |
| including:    |      |      |      |      |      |      |           |
| Austria,      | 580  | 575  | 562  | 579  | 578  | 565  | 97        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 196  | 65   | 18   | 25   | 23   | 23   | 12        |
| Belgium,      | 471  | 482  | 456  | 447  | 437  | 485  | 92        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 91   | 56   | 8    | 5    | 4    | 4    | 44        |
| Bulgaria,     | 612  | 588  | 554  | 460  | 432  | 442  | 72        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 400  | 411  | 318  | 298  | 307  | -    | 77        |
| Great Britain,| 577  | 581  | 509  | 477  | 482  | 482  | 84        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 468  | 374  | 234  | 177  | 164  | 134  | 29        |
| Hungary,      | 446  | 467  | 403  | 402  | 378  | 385  | 86        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 366  | 383  | 284  | 263  | 244  | 221  | 60        |
| Germany,      | 642  | 565  | 602  | 619  | 609  | 618  | 96        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 167  | 48   | 3    | 1    | 8    | 9    | 5.4       |
| Denmark,      | 610  | 662  | 673  | 750  | 752  | 759  | 124       |
| was formed    |      |      |      |      |      |      |           |
| buried        | 66   | 38   | 23   | 16   | 13   | 10   | 15        |
| Spain,        | 658  | 588  | 510  | 468  | 454  | 435  | 66        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 337  | 288  | 318  | 284  | 253  | 240  | 71        |
| Italy,        | 509  | 546  | 547  | 504  | 491  | 488  | 96        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 385  | 295  | 253  | 468  | 181  | 154  | 40        |
| Netherlands,  | 598  | 599  | 571  | 549  | 526  | 527  | 88        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 57   | 10   | 9    | 8    | 8    | 8    | 14        |
| Poland,       | 320  | 319  | 316  | 317  | 297  | 272  | 85        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 313  | 226  | 195  | 188  | 157  | 148  | 46        |
| Romania,      | 355  | 383  | 313  | 252  | 254  | 32   | 72        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 295  | 301  | 236  | 171  | 175  | 175  | -         |
| Finland,      | 502  | 478  | 470  | 506  | 493  | 482  | 96        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 305  | 282  | 212  | 166  | 124  | 84   | 28        |
| France,       | 514  | 530  | 533  | 523  | 517  | 511  | 99        |
| was formed    |      |      |      |      |      |      |           |
| buried        | 219  | 182  | 166  | 139  | 134  | 132  | 60        |
| Sweden,       | 428  | 477  | 439  | 450  | 451  | 438  | 102       |
| was formed    |      |      |      |      |      |      |           |
| buried        | 97   | 23   | 4    | 3    | 3    | 3    | 3.1       |
In the EU, there are about 30,000 closed and to be in the near future close, large and medium MSW landfills, where 4.5 bln Tons of wastes are accumulated. The Directive of the Council of the European Union 1999/31/EC from April, 26 1999 on landfills includes the unconditional prohibition of unauthorized waste disposal and run that Countries-Members ES should “prevent or reduce, as far as possible, adverse environmental impacts, in particular pollution of surface and underground water, soil and air, including gases causing the greenhouse effect, and associated with any possible risk to human health from the landfill, in all lifecycle of solid waste landfills”. Compulsory sorting and primary sampling of commodity fractions before the flow of waste to the landfill were defined.

In Russia, according to Russian Nature Surveillance, there are 2,620 landfills for burial of municipal waste, 11,193 large illegal dumps are recorded, which pose a particular danger to the environment due to the lack of the required technology of waste storage, environmental measures and control over the state of the dumps [6].

In the Republic of Crimea, at the present time, the problem of waste management is sharply identified, which is associated not only with optimizing the management of waste streams and sanitary cleaning of settlement territories, but also with the presence of closed but highly loaded landfills of MSW, legal and illegal dumps within the boundaries of populated areas. Legislation until 2014 did not regulate the requirement for the disposal of landfills outside the city boundaries, which led to the location of such objects on the lands of settlements [2]. According to the official statistics in 2015, 3532.2 thousand m$^3$ of MSW were removed from the residential areas in the Crimea, of which 64.4 thousand m$^3$ were recycled in processing enterprises, the remaining volume of wastes was taken to landfills. In Sevastopol in 2015, 16.3 thousand tons of wastes of production and consumption were generated. The degree of use of these wastes in 2015 was less than 1% from the amount of their formation, the rest entered to the urban landfill.

As of 2016, there are 28 MSW landfills in the Republic of Crimea, from which only three are registered for state registration. In Sevastopol, one city-wide landfill is operating, located in the Pervomayskaya Balka near the town of Inkerman. It should be emphasized that in each settlement of Crimea there are from one to three closed and not operated landfills / legitimate dumps, which occupy an area up to 20 hectares, depending on the volume of wastes and the size of the settlement. Rational use of settlements lands requires the reclamation of closed landfills and dumps with the return of land plots to full-fledged economic circulation. Until 2018 it is planned to carry out reclamation at the landfills in Evpatoria, Feodosia, Dzhankoy, Armyansk, Chernomorskoye, Krasnogvardeyskoye, Sovetskiy, and Lenino. The task of reclamation of old dumps on Mekenzievy Mountains and in the area of the former thermal destruction plants that are located within the city boundaries, is facing Sevastopol.

2. Materials And Methods
A key point in the waste management methodology is the international concept of waste hierarchy, which in the conventional sense characterizes the waste management system as a hierarchical structure based on three principles: prevention, reuse and recycling of waste, improvement of technologies for final utilization and
monitoring. The European Environmental Agency has specified the options for handling with wastes, as the preference is reduced, as follows:

- minimization at the source of waste generation and prevention of waste generation («Zero Waste»);
- reuse;
- processing into raw materials and products;
- composting;
- incineration or burying with receiving the energy;
- burial without obtaining energy;
- incineration without obtaining energy.

Within the framework of this approach, it is obvious that a widespread method of landfilling at dumps and landfills occupies the lowest hierarchical level of organization of the system. This means that the existing model of waste management both in world practice and in Russia needs to be improved. An important part of the actualization of the principles of the hierarchy with the daily practice of waste management is the reclamation of landfills and dumps of MSW. Reclamation of landfills and dumps as waste disposal sites is currently being considered by the international and Russian communities as an important and necessary measure to reduce environmental risks associated with the accumulation and decomposition of MSW. The growing investment needs associated with the development of urbanized areas with the increasing cost of urban land is increase everywhere, which necessitates the involvement of land plots of landfills / dumps in a recurrent turnover. However, we have to state that the rate of remediation works in world and domestic practice is not sufficient to reduce the severity of the problem [7].

Environmental Protection Agency "Landfill Reclamation" (EPA, United States, Solid Waste and Emergency Response, 1997) notes that reclamation of landfills is a relatively new approach used to prevent the expansion of municipal landfills, which avoids additional tangible land acquisition costs for new objects. Reclamation projects at landfills have been successfully implemented in the USA throughout the country since the 1980s, in New Orleans, Washington, Chicago, Manhattan, and Las Vegas, etc. The work [8] is devoted to investigation of the results of the landfill reclamation project in the Florida, which area is 6.8 ha with a volume of wastes of 371 thousand m³. Examples of positive practices for reclamation of landfills and dumps are noted in [1, 5, 9].

Reclamation of dumps and landfills is also carried out in Russia. The scientific and methodological support of the issue and consideration of the results of the implementation of projects for the reclamation of waste disposal sites on a national scale are reflected, for example in [10, 11]. The landfills in Vladivostok, Moscow, St. Petersburg, Sudak, Sevastopol and many other cities have become objects of recultivation. In significant volumes, reclamation of illegal dumps is being carried out throughout the country: in Russia in 2017, about 20,000 dumps are planned for liquidation, in the Crimea - about 350, in Sevastopol - close to 300.

Examples of practices for reclamation of waste disposal sites are presented in Figure 1.

Undoubtedly, waste dumps and open storage sites do not have the right to exist, because colossal land resources are being seized in the country, long-term and directed pollution of natural environments and deterioration of people health are occur, the material value of recyclable material is lost meaningless, criminogenic societies are formed on the territories of dumps, etc. Refraction of the consciousness of the consumer and the manufacturer in terms of the ideology of «Zero Waste» and hierarchical waste management is, in our opinion, the starting point in the long way of solving the problem.

In the opinion of the authors, it is expedient to consider the reclamation of lands, occupied with waste, in several aspects: technological, land-planning, ecological-sanitary, economic, institutional, and socio-cultural. These aspects are closely interrelated and cause the necessity of integrality in the solution of the problem from the position of the system approach.

With a shortage of land in the Crimea and their unique natural and recreational value, the total area of dumps and landfills is 215.2 hectares with a total waste volume of more than 55 million m³. The volume of waste at the Yalta landfill (closed) approaches to 6 million m³, in Simferopol, Sevastopol - 2.0-2.5 million m³ each, Alushta, Evpatoria, Sudak - 1.0-1.5 million m³ each. Quite often land, that requires reclamation, is located near the main highways, that is, they have good transport accessibility, and therefore are extremely attractive in terms of secondary development. However, they cannot be used without special events. Attention deserves the fact, that most of the waste disposal sites in the Crimea are located in inadmissible proximity to residential buildings, water objects, suburban forests, agricultural lands. So, the urban landfill in Simferopol (decommissioned in 2016) is located at a distance of 150 - 300 meters from the country, when the required sanitary break is 500 meters.
The situation of coexistence of waste disposal areas and other urban areas has now acquired a truly dramatic character. The solution to this problem is seen not just in carrying out remediation work, but in the rehabilitation of contaminated areas. It is known that recultivation of disturbed and contaminated lands are a complex of works consisting of technical and biological stages [12-17]. The current needs of investors, interested in the land, are oriented to a comfortable state of the environment not only within the narrow boundaries of the former dumps/landfill, but also beyond its borders. Rehabilitation of land is considered by science as a scientifically grounded set of measures (engineering, environmental, social) aimed at returning environmentally acceptable properties and qualities to environmental components [18-23]. In turn, the rehabilitation of waste contaminated land involves a comprehensive investigation of the waste disposal and the surrounding areas, the identification of methods for their sanitization, the work on the elimination of contamination seats and reclamation, as the final stage in restoring the regulatory quality of the land resources of the territory [24-26].

The choice of the direction of reclamation and the determination of the prospects for the use of restored lands should be preceded by comprehensive investigations, which will result in an aggregated assessment of the geocological state of the landfill site and its suitability for the placement of other objects.

### 3. Results and Discussions

For the efficient identification of illegal dumps monitoring of territories, which is an integral part of the waste management system, is effective. Among the methods for monitoring of dumps, two main blocks are singled out: remote (based on satellite images) and terrestrial (sampling and research in stationary laboratories). It is substantiated that the combination of remote and terrestrial methods is the most representative of the results in the monitoring system for solid waste dumps. In order to minimize the use of more expensive (both in terms of execution time and cost of research) terrestrial-based methods, it is expedient to perform a primary analysis, using space images. The identification of places of waste storage a certain territory is carried out by recognizing these objects on satellite images. The process of recognizing of dumps on satellite imagery data includes methods of visual and automated interpretation. It should be noted, that the analysis of distance sensing data (DSD) makes it possible not only to identify the location of dumps, but also to quickly collect the necessary database for carrying out activities to combat this negative phenomenon.
So, in order to optimize the process of dumps reclamation it is necessary, firstly, to classify them by location based on the criterion of the greatest potential environmental risk for the surrounding natural, technogenic and social environment. In determining the type of secondary use of the territory after the reclamation of dumps, information is needed that would allow to maximize the prospects for the secondary use of plots.

In this context, a wide range of opportunities arises, which gives the use of DSD in conjunction with the tools of geoinformation (GIS) modeling. For the classification of dumps by location, the following information is required:

1) landfill location in relation to residential development, which determines the degree of negative impact on the human body; to water objects - the probability of contamination of surface water; open mine workings - contamination of the geological environment and groundwater; forest areas - the probability of forest fires and the processes of vegetation suppression; agricultural lands - the possibility and degree of their pollution;

2) the relief of the site: the form of the relief (the negative form of the relief - increases the risk of groundwater contamination, the positive form of the relief - the possibility of running out of contaminated rain and snow melt waters), the slope and exposure of the slope (allows to determine the speed and direction of contaminated surface runoff);

3) the presence and degree of hazardous natural processes development: erosion (erosion and weathering of the surface layer of the soil contributes to the spread of pollutants throughout the soil profile and their penetration into underground aquifers); karst (probability of groundwater pollution); flooding and underflooding of the territory (pollution of surface and groundwater).

Based on the analysis of the DSD (Landsat database in the public domain), we identified 11 illegal dumps in the administrative territory of the Western Crimea and assessed their location according to the above parameters. The analysis of the received information was carried out by deciphering objects, located around them, in the radius of the protective zone of 500 m. The recognition of objects was carried out visually on the basis of direct and indirect deciphering criterions. As a result, dumps were found, densely adjacent to residential buildings (Fig. 2), water bodies (Fig. 3), open mine workings (Fig. 4), agricultural land (Fig. 5).
The presence and degree of development of erosion processes were determined from satellite imagery using visual decoding methods, which is acceptable in small areas. On the images of territories, adjacent to some of the identified dumps, characteristic signs of water and wind erosion were recognized:

- banded structures of erosive furrows as a result of the development of water erosion;
- light spots of deflated soils, having soft, fuzzy outlines, stretched into ribbons and oriented in the direction of prevailing winds: jet or cellular image of the imagery, resulting from the wind redistribution of material and the formation of Aeolian microrelief with intensive development of deflation processes.

As a result of the analysis, we proposed the classification of dumps by location and land planning restrictions. The results are aggregated in Table 3.

Table 3. Classification of illegal dumps of MSW by location

| Type   | Distance to ..., m | Slope steepness | Slope exposition (in side...) | Degree of erosion development | The level of potential environmental risk |
|--------|--------------------|-----------------|-------------------------------|------------------------------|------------------------------------------|
|        | Residential        | Water bodies    | Open mine workings            | Woodlands                    | Agricultural lands                       |
|        | development        |                 |                               |                              |                                          |
| 1      | 1 <500             | >500, but less  | >500                          | >500                         | >500                                     | Middle  |
|        |                    | 700             |                               |                              |                                          | High     |
|        |                    |                 | to 0.08                       |                              |                                          | Middle   |
| 2      | >500               | >500, >500, >500| >500                          | >500                         | >500                                     | Middle   |
|        |                    |                 | to 0.09-0.18                  |                              |                                          | High     |
| 3      | <500               | >500, >500, >500| >500                          | >500                         | >500                                     | Low      |
|        |                    |                 | to 0.08                       |                              |                                          | High     |
| 4      | >500               | >500, >500, >500| >500                          | >500                         | >500                                     | Middle   |
|        |                    |                 | to 0.08                       |                              |                                          | High     |
| 5      | >500               | >500, >500, >500| >500                          | >500                         | >500                                     | High     |
|        |                    |                 | 0.19-0.3                      |                              |                                          | High     |
| 6      | >500               | >500, >500, >500| >500                          | >500                         | >500                                     | Middle   |
|        |                    |                 | 0.59-0.76                     |                              |                                          | High     |
| 7      | >500               | >500, <500, >500| >500                          | >500                         | >500                                     | Low      |
|        |                    |                 | 0.31-0.43                     |                              |                                          | Middle   |
| 8      | <500               | >500, >500, >500| >500                          | >500                         | >500                                     | Middle   |
|        |                    |                 | 0.31-0.43                     |                              |                                          | High     |
| 9      | >500               | >500, >500, >500| >500                          | >500                         | >500                                     | Low      |
|        |                    |                 | 0.09-0.18                     |                              |                                          | Middle   |
| 10     | >500               | >500, >500, >500| >500                          | >500                         | >500                                     | Middle   |
|        |                    |                 | 0.59-0.76                     |                              |                                          | Low      |
| 11     | >500               | >500, >500, >500| >500                          | >500                         | >500                                     | Low      |
|        |                    |                 | to 0.08                       |                              |                                          | Low      |
Surface methods for surveying dumps and their land plots include reconnaissance, field geodetic and engineering-geological work, instrumental measurements, sampling and laboratory studies.

The negative impact (\( B_{\text{neg}} \)) of dumps and landfills on the environment determines the functional [27]:

\[ B_{\text{neg}} = F(S_{pl}, O_{enj}, C_{ex}, W_{sdw}, M_{sdw}, C_{kl}) \] (1)

where: \( S_{pl} \) - the area of the land plot; \( O_{enj} \) - system of engineering and technical characteristics of the facility; \( C_{ex} \) - a system of operating conditions; \( W_{sdw} \) - the volume of accumulated waste; \( M_{sdw} \) - the morphological composition of waste; \( C_{kl} \) - a system of natural and climatic conditions of the territory.

Proceeding from this, we proposed a program of geoecological surveys for waste disposal sites, which was tested on a number of landfills and dumps in the Crimea. The results of the research are the basis for the development of design solutions for site remediation.

Complex geoecological surveys are based on the following tasks:

- engineering-geological study of the landfill site and body on drilling materials;
- definition of morphological and morphometric composition of wastes, their resource value and the possibility of secondary use of technogenic soils;
- assessment of the potential risk of development of hazardous natural and technogenic processes;
- determination of the chemical composition and degree of chemical contamination of the waste and soil in the landfill area, in the sanitary zone or in adjacent areas in the absence of such;
- study of the chemical composition and degree of pollution of underground aquifers, the organization of hydro-observation wells for subsequent monitoring;
- determination of the degree of atmospheric air pollution;
- radiological, sanitary-bacteriological and microbial survey of the landfill and soil layer;
- development of alternative options for territory using in accordance with modern urban planning and environmental standards;
- determination of basic design solutions for the disturbed territory reclamtion.

As an example, separate results of surveys at three dumps in the cities of Simferopol, Sevastopol, and Kerch are given. Nearly all of the surface of the landfill and sanitary zone was sampled on each of the sampled objects. Sampling of soil from the surface was carried out using the "envelope" method 1 \( \times \) 1 m on a 20 \( \times \) 20 m grid. The average number of soil samples was 45 samples. Drilling of wells was carried out to bedrock with the number of wells from 5 to 15, depending on the landfill area, to the depth of 10-25 meters. The sampling of the wells' contents was carried out after 1.0 m to the drilled depth.

In the morphological classification of solid waste, groups were identified: paper, cardboard, wood, metal, textiles, bones, glass, rubber, stones, plastics, technogenic soil.

The chemical composition and the degree of soil contamination were determined by the content of heavy metals, petroleum products and other pollutants and compounds. To assess the general chemical contamination of the territory a generally accepted indicator of chemical contamination \( Z_{c} \) was used, characterizing the degree of soil contamination with harmful substances of various hazard classes:

\[ Z_{c} = \sum_{i} K_{c,i} = \sum_{i} \frac{C_{cd,i}}{C_{bgc,i}} \] (2)

where: \( K_{c,i} \) - an indicator of the level of anomalous content of the element; \( C_{cd,i} \) - the content of the element on the object under study, mg/kg; \( C_{bgc,i} \) - background content of the element, mg/kg; \( i \) - amount of toxic elements.
By the value of $Z_c$, the following categories of pollution of the territory are distinguished: the permissible $Z_c \leq 16$; moderately dangerous $16 < Z_c \leq 32$, dangerous $32 < Z_c \leq 128$, extremely dangerous $Z_c > 128$.

For radiometric control, samples were taken proportionally along the well profile from their surface to the bottom (an average of 15 measurements per well).

In the sanitary-bacteriological survey of waste and soil, the presence of bacteria of the Escherichia coli group and general biological contamination was established in them, which makes it possible to detect the contamination of the territory by microorganisms and to establish the capacity of the investigated landfill layer for self-cleaning.

Groundwater quality control and landfill leachate composition was carried out by sampling from wells at the opening of aquifers or landfill leachate lenses, as well as from the network of hydro-observation wells (if they were organized earlier than the survey period) in an average of 10 measurements per well. All samples were examined in specialized laboratories.

In general, the results of the survey made it possible to do general conclusions:

- The drilling of the layer occurred in complicated conditions, as the density of the waste is uneven, and their storage was carried out without compaction. As a result, the stratum is permeated with numerous voids, which were fixed by the failures of the drilling tool. Drilling often caused breakage of the drill through the encountered concrete, reinforced concrete and metal monoliths, which are weakly susceptible to destruction.

- The total pollution of the studied dumps by toxic elements was found to be quite high: it is $32 < Z_c \leq 128$, which correspond to the "dangerous" category (Fig. 8).

- Exceeding the maximum permissible concentrations (MPC) is typical for highly toxic elements of hazard classes 1-2: Ni, Zn, Co, Cd, Pb (Fig. 9).

- Pollutants accumulation in the landfill depends on the nature of the waste (composition, condition, age), their location in the body and on the surface of the landfill, and is generally uneven. There are local ultrahigh concentrations of elements, i.e. So-called "hurricane" concentrations (Fig. 10).

Figure 8: The total pollution $Z_c$ of the landfill site in Simferopol (light background - the smallest values, dark background - the largest values).
The nature of the chemical composition of the waste strata indicates the previous disposal of industrial waste.

Radiation monitoring of wastes showed no deviations from the norms of radiological safety by the total specific activity of natural radionuclides (radium Ra-226, thorium Th-232, potassium K-40 and radon).

For sanitary-bacteriological indicators, the samples taken are clean.

The gas generation capacity of the dumps is quite low. Organized waste landfills have the acceptable potential of biogas, where sustained necessary gas generation conditions.

Organized processing of closed landfills and dumps, on which construction waste was additionally stored, is often profitable for secondary raw materials.

When reclaiming dumps, which have been used for a long time as a surrogate for technically equipped landfills, one should pay attention to such category as "technogenic soils". The use of man-made soil, which is 60-70% of the volume of the landfill, is of particular interest. The data given in [28-32] allow considering the technogenic soil as a stabilized end product of waste decomposition in combination with natural soils, introduced into the body of the landfill during operation. Technogenic soils are approaching by physomechanical properties to natural water-saturated loams and clays. The lower layers of the dump body are highly mineralized; the organic components are poorly expressed.

The material of the landfill has a fine fraction and high homogeneity. The mineralized soil is characterized by the absence of a pathogenic microflora and a satisfactory sanitary and epidemiological
condition. In the absence of chemical, radiological and bacteriological contamination, technogenic soil can be considered as a very promising material for reuse:

- as a secondary surface insulation at the same dump with its progressive reclamation and operation of the area and volume (the stage of technical reclamation);
- as a secondary intermediate insulation at the landfills of the MSW;
- as a building soil in the organization of backfill;
- for the creation of road slopes with anti-erosion fixation with polymer film mixtures or natural vegetation;
- for the creation of forest protection and forestry bands outside the residential areas.

The expediency of technogenic soil material recycling depends on the level of risk, associated with the concentration of pollutants. Prior to the planning of dumps resource flows, it is necessary to establish the degree of soil contamination with heavy metals and an acceptable level of risk. Such an assessment is mandatory, because in the case of detection of an increased concentration of toxic substances, the possibility of using of landfills and dumps technogenic soils can significantly narrow. The Environmental Protection Agency (EPA) has developed indicators to assess the level of contaminated technogenic soil by including them in its Soil Screening Guidance (SSG) - guidelines for the treatment of contaminated sites. A number of European countries have developed similar standards, based on an adequate risk assessment. In Russia there is a discussion of the issue.

The reclaimed areas are suitable for open warehouses, non-capital buildings and structures, parking lots, sports fields and golf courses, training grounds for motocross, sports shooting and other sports. However, world experience shows that the priority direction is landscape restoration and organization of various green zones.

4. Conclusions

Theoretical and practical results of the research allow asserting the necessity and demand for reclamation of dumps and closed landfills of municipal waste in order to stabilize the ecological state of the environment and re-develop the territory. The technology of reclamation and the choice of perspective use of land plots depend on the qualitative and quantitative parameters of the object, which are established as a result of geocological surveys. For the rapid identification of waste storage and disposal sites, it is advisable to use the capabilities of distance sensing and GIS modeling. The obtained results can be used to determine the extent and sequence of remediation works, the justification for investments in the development of strategies and schemes for territorial planning at the local and regional levels.

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