Objectives of increase of capacity and lifetime of municipal solid waste dump according to density index study

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Abstract. The problem of the optimal waste management of industrial and household waste is extremely important due to large amount of accumulated and annually produced waste. One of the crucial aims to improve ecological quality and environmental safety and compliance is to improve efficiency of waste management. The vast majority of solid domestic waste landfills are used up, but design, construction and place new territories into operation for receiving and waste disposal will take 3-5 years. In this work, issues of definition of the residual capacity of landfill are considered, aiming to expand the capacity and usage period, based on the solid landfill body density index research. Study object is solid household waste landfills in Rostov region, study subject is anthropogenic filling layers of the landfill. In order to support business objectives, there was conducted engineering and geological research, wells were drilled, laboratory studies were undertaken and soil tests were analyzed. Experimental results show the possibility to continue waste disposal works in the current landfill by means of increase of waste density index and free geometric scope.

1. Introduction
Nowadays, the issue of health protection and environment is world-wide topical. The amount of wastes is incrementally increasing as a result of industrial production and footprint.

More than 80 billion tons of various types of waste, including environmentally hazardous [1, 2], were disposed in Russia.

Waste treatment is implemented in different countries, according to economic capabilities, economic policy and legislation. The simplest and relatively cheap method of solid household waste (SHW) treatment is storage at sanitary landfills. The method of solid household waste disposal in landfills is one of the most widely used in Russia [3].

Rostov region is one of the leading regions because of its strategic position and economic and resource potential.

The source of the waste is population pressures, factories and organizations. There are 719 solid household waste disposal facilities, which annually take 4,5 million tons of waste, in Rostov region [4, 5]. The problem of the optimal waste management of industrial and household waste is extremely important due to large amount of accumulated and annually produced waste [6-7]. One of the crucial
aims to improve ecological quality and environmental safety and compliance is to improve efficiency of waste management [3, 5].

2. Problem urgency
The majority of landfills in Rostov region were built in the end of 90's of the 20th century. Their project involvement will be used up in the near future. However, they are free and underutilized according to height project index within the scope of given locations. The service age of a landfill is accounted according to the waste disposal capacity and process engineering solutions made in the project [3,6].

Process engineering solutions in the project development were based on the process of waste collection, transportation and disposal, relevant at that time, based on the usage of domestic car equipment and relevant characteristics in the majority of waste transportation and collection companies.

Current project landfills have been designed and used for 10-15 years, over this time there have been following significant changes, resulting in free capacity in the landfill within the scope of allotment:
- there has been high quality technical retooling of companies operating landfills, due to acquisition of equipment, not only for city sanitation, but also for works in a landfill;
- in accordance with rise in living standards, increase in supermarket chains which use almost completely plastic packages, resulting in changes in morphological composition of population and commercial city centers waste;
- Landfill performance characteristics have increased, resulting in the increasing density in waste working maps;
- total amount of waste in landfills has decreased because of waste sorting implementation, in other words development of waste management technologies;
- over the years, the height of waste storage has increased, which leads to vertical deformation and consolidation of underlying layers by overlying level.

Current landfills of Rostov-on-Don, as well as other cities of Russian Federation, are almost used up, but design, construction and place new territories into operation for receiving and waste disposal will take 3-5 years.[6].

Nowadays, objectives of calculating volume of actual waste and residual capacity is crucial.
The major contribution to research of solid household waste landfills, biochemical and physical processes and their influence on the environment was made by: Academy of community facility n.a. K.D. Pamfilov, Moscow State University, Institute of Biochemistry of Russian Academy of Sciences, Research Institute of Ecological Safety of Russian Academy of Sciences, St. Petersburg State University, St. Petersburg Polytechnic State University, Russian State University of Technology, Russian Federation Ministry of Natural Resources, State Sanitary & Epidemiological Surveillance Agency, Federal Service of Russia for Hydrometeorology and Monitoring of the Environment, Institute of geology and geochronology of Precambrian of Russian Academy of Sciences and others, and also domestic and foreign experts: Abramov N.F., Vaisman Ya. I., Gribanova L.P., Bartsev I.A., Maksimova S.V., Likhachev U.M., Nozhevnikova A.N., Pantskhava E.S., Christensen T., Shtengmann P. and others. [7-18]. Nowadays, there is insufficient information about density waste in landfills, and also, the subject of expansion of current landfills capacity and usage period has been little explored.

3. Discussion
The aim of the work is to research and provide data for identifying indicators of soil density and make decisions on study of residual capacity and usage period of SHW landfill. The investigation is concerned with solid household waste landfills in Rostov region, study subject is anthropogenous filling layers of the landfill, analysis and research of mechanical and physical properties of soil.
In order to support business objectives, there has been conducted the research in current landfill in Rostov region. The results of geophysical and geochemical observations show the active anaerobic destruction process in loaded landfill maps and vertical deformation.

Vertical deformations of working substance begin during operational time within the process of SHW daily subsidence and continue after the closure under its own weight and developing biochemical processes and waste destruction [10-12].

Deformation rate and scope are of heterogeneous nature and can be determined by morphological composition of incoming waste; storage height and compaction degree during stowing; time, after stowing; landfill capacity; climate and geographic conditions and type of soil used for daily filling; type and characteristics of final covering.

Process of subsidence at different stages of a landfill life cycle is demonstrated in Table 1 [13].

| Lifecycle stage           | Mechanism of subsidence                        | Phase of subsidence       | Duration                        |
|--------------------------|------------------------------------------------|---------------------------|---------------------------------|
| Operational              | Deformation of waste inerts; compression       | Starting compression      | During operational time         |
| Recultivating            | Filtration compaction; Secondary consolidation; biochemical destruction | First compression         | From 2 months to 2-5 years after the closure |
| Intense methane phase    |                                               | Second compression        | Until the end of decay process  |

The processes of mechanical compression and filtering compaction prevail at the early stages of landfill life cycle. These vertical deformations are called landfill sludge. Biochemical processes of waste destruction with the biogas production prevail at the stages of remediation and post-remediation. These deformations are defined as subsiding. All the above factors influence the formation of the current landfill and increase the possibility to use its capacity by further filling. [14-15].

Also, high quality technical retooling of waste collection companies has had a high impact on the process of waste compaction: purchase of waste collection vehicles with Faun and Zoeller equipment, with higher density levels in the process of loading from container staging area into a vehicle. Also, the index of density at these vehicles is from 5,0 to 10,0, in comparison with previously used domestic waste collection vehicles with density index from 1,5 to 2,5.

Similar companies of Rostov-on-Don are also switching to vehicles with the back loading, with density index up to 6,0. However, nowadays, domestic vehicles are used to access to some districts, because of the type of urban planning. Waste collection with the help of the vehicles with small capacity and low density index has two stages: waste collected by these vehicles are loaded to special containers of large capacity at the stations of waste and compaction reloading, also the density index rises to 8,0-12,0. Waste collection vehicles move in special ladle of reloading station and unload its content there. The ladle can get load of several vehicles. After loading, the ladle is brought into the position of use and empty its contain out in the receiving unit.

In the receiving, waste is pressed into the large capacity container with compaction at the same time.

The large capacity container is connected with the receiving unit, with the help of oleo-dynamic latch mechanism. After loading, large container is loaded on the traction engine multi-lift and taken out to the landfill. Under these circumstances, the research of density index of current SHW landfill in Rostov region was conducted with the aim of increase its capacity and usage period.
4. Methods

In order to support business objectives, engineering and geological research was conducted, wells were drilled, laboratory studies were undertaken and soil tests were analyzed. The drilling was made by 146 mm diameter, by a churn-line method, by the driller УГБ-1ВС (UGB-1VS). There were drilled 6 technical strings up to 24 m down. To identify physical indicators of soil, there were taken undisturbed structure soil samples, according to the technology “in one stroke”. The interval of soil samples was 2.0 m.

The laboratory works resulted in the identifying of natural water content, density, plastic limit of soil.

Research is conducted in accordance to the requirements of current environmental regulations. The determination of physical characteristics was conducted according to State All-Union standard 5180-2015 [19]. The determination of soil density was conducted by the method of weighing in water, according to State All-Union standard 5180-2015. Statistical processing of soil data was according to State All-Union standard 20522-2012 [20].

In accordance to State All-Union standard 20522-2012, normative and physical soil characteristics were estimated from selected layer. Statistical estimates according to abovementioned State All-Union standard were performed for this. In this regard, measures of variability of soil index were taken into consideration. As a criterion of level of variability, used coefficient of variation was according to State All-Union standard 25022-2012.

5. Results

In a SHW landill there were opened quaternary anthropogen soil formations, according to State All-Union standard 25100-2011 [21], related to the category of man-made soils, with mechanic and hydrogenous colloidal structural bonds. The folding is monoclinal. According to research based on State All-union standard 20522-2012, there are the following geological layers in geological lithological section:

Layer-1 (tQIV) from 0,0 to 24,0m – to 1,0m: heterogeneous loam soil with the construction and household waste up to 40%. Lower: household waste, anthropogenic domestic and productive activity waste, with loamy layers, with capacity 20-3-cm, class of hazard – IV-V. Layer capacity – 24,0m. The layer was drilled by all wells. The drilling to the depth 24,0m №№ 1-6 did not open up groundwater.

Physical and mechanical soil properties of the current landfill were analyzed according to performance-test data, the results are listed in the Table 2.

| Table 2 – Physical mechanical soil properties |
|----------------------------------------------|
| Index | Moisture load, % | Density, g/cm³ | Poriness, % | Porosity fractions, unit fraction |
|       | Soil particle | Soil | Dry soil | Soil | Dry soil | Soil | Dry soil |
| Quantity | 62 | 9 | 72 | 72 | 9 | 9 |
| Characteristic value | 16,3 | 2,70 | 1,35 | 1,15 | 56,8 | 1,32 |
| Minimum | 11,6 | 2,69 | 1,25 | 1,07 | 55,9 | 1,27 |
| Maximum | 21,30 | 2,70 | 1,46 | 1,33 | 58,1 | 1,39 |
| Average deviation | 2,40 | 0,01 | 0,06 | 0,06 | 0,72 | 0,04 |
| Variability index | 0,10 | 0,00 | 0,04 | 0,04 | 0,01 | 0,03 |
| Estimated value: - under probability 0,85 | 1,34 | 1,14 |
| - under probability 0,95 | 1,34 | 1,14 |
Geotechnical and topographical surveys of monolith selection by a churn-line method in 6 wells, were carried out in order to confirm by experiment.

As a result of selected monolith weighing, according to the volumetric data, the average value of density is 1,34 g/cm³. According to t.2.6 “Design, operation and re-cultivation of SHW landfills guideline” [22], after double SHW compaction by bulldozer, density characteristic value is 570-670 kg/m³ (0,57-0,67 g/cm³), after quadruple – 670-800 kg/m³ (0,67-0,8 g/cm³). Soil density data, at natural moisture, determined by practical consideration, is from 1,25 to 1,46 and it is 1,34g/cm³. Comparison of SHW density data with *-guideline, t.2.6 [22], leads to the conclusion that the level of compaction is high according to studied landfill expansion and depth up to 24m.

The method of compaction is mechanized, by quadruple bulldozer compaction REM-25 (РЭМ), with the operating weight 26 t., with the maximum of crushing force more than 127кН. Through this process, 1m³ of SHW transform into 0,25 m³ of consolidated waste. Geometrically, 4m³ can be stored on 1 m³. According to the engineering survey, calculation of residual geometrical capacity of the landfill is 212400 m³. As a result, taking into consideration the quadruple compaction, 849600 m³ of SHW can be stored in the landfill. Total capacity of the landfill will be 1138464 tons, at the waste density of 1,34 t/m³. At the rate of 150000 tons of annual intake the usage time of the landfill will be 7,5 years.

6. Conclusions
The implementation of the aforementioned modern technologies for waste collection and waste disposal decreased physical amount of SHW disposal by increasing density index from calculated 0,8-0,85 t/m³ to really measured 1,34 t/m³, which is confirmed by research. In connection with the above, the current landfill has the capacity to continue works by increasing of density.

In view of this, to measure waste density and estimate residual capacity to increase usage period, it is necessary to do extra research in current landfills.

The solution of this problem will improve efficiency of current landfills, which is important not only for Rostov region, but also for Rostov-on-Don.

Acknowledgements
The study had no sponsorship.

References
[1] Gosudarstvenny`j doklad «O sostoyanii i ob ohrane okruzhayushhej sredy` Rossijskoj Federacii v 2017 godu» [E`lektronny`j resurs].– URL:http://www.mnr.gov.ru/docs/
[2] Prikaz Minprirody` Rossii ot 14.08.2013 N 298 «Ob utverzhdenii kompleksnoj strategii obrashhe-

nyi s tverdy`mi kommunal`ny`mi (by`tovy`mi) otxodami v Rossijskoj Federacii» [E`lektronny`j resurs]. – URL: http://docs.cntd.ru/document/499041934. (data obrashheniya
20.06.2019)
[3] E`kologicheskie problemy` antropogenny`x lanshaftov Rostovskoj oblasti / V.V. Privalenko, O.S. Bezuglova. T.1: E`kologiya goroda Rostova-na-Donu. Rostov-na-Donu, 2003.
[4] Upravlenie otxodami. Poligonny`e texnologii zaxoroneniya tverdy`x otxodov. Rek-

kul`tivaciya i poste`kspluatacionnoe obsluzhivanie poligona: monografiya / Ya.I. Vajsman [i dr.]; pod red. Ya.I. Vajsmana. – Perm` izd-vo Prem. nacz. issled. Politexn. un-ta, 2012. – 244 s.
[5] Omelchenko E.V., Trushkova E.A., Sidelnikov M.V., Pushenko S.L., Staseva E.V. Algorithm re-

search exposure dust emissions enterprises of building production on the environment. // IOP
Conference Series: Earth and Environmental Science Current Problems and Solutions. Ser.
"Ecology and Safety in the Technosphere: Current Problems and Solutions" 2017. S. 012018.
[6] Rummyanceva A.V., Berezyuk M.V., Rummyanceva E.I. E`kologoe`konomicheskoe obosnovanie
proekta po pererabotke tverdy`x kommunal`ny`x otxodov na osnove sovremenny`x texnologij //
Vestnik VGTU. Seriya E`konomika i upravlenie. № 3, 2017. S.31-38.
[7] Lassini, P. Reclamation of old and new landfills and their integration with the environment / P. Lassini, G. Sala, F. Sartori / 6th, International waste management and landfill symposium. Sardinia. –1999. – V. 4. – P. 415 – 422 [Електронний] ресурс. Рецензія доступу: http://www.gbv.de/dms/tib-ub-hannover/319191907.pdf. (data обрashheniya 12.06.2019)

[8] R.P.Stearns, T.D.Wright, B.A.Stirrat. Landfill gas recovery and utilization at Industry Hills, California // Waste Management & Research. – 1984. - №2. – P. 153-161 [Електронний] ресурс. – URL: https://www.sciencedirect.com/science/article/pii/0734242X8490137X. (data obrashheniya 19.05.2019)

[9] Utilizaciya i pererabotka tvyordy’x by’tovy’x otxodov : uchebnoe posobie / A. S. Klinkov, P. S. Belyaev, V. G. Odno1’ko, M. V. Sokolov, P. V. Makeev, I. V. Shashkov. – Tambov : Izd-vo FGBOU VPO «TGTU», 2015. – 100 e’kz. – 188 s.

[10] Armisheva, G.T. Rekuperaciya resursov pri zaxoroneni tverdy’x by’tovy’x otxodov / Avtoreferat dissertacii na soiskanie uchenoy stepeni kandidata texnicheskiх nauk, g. Perm’ – 2008. [Електронний] ресурс. – URL: http://earthpapers.net/rekuperatsiya-resursov-pri-zahoroneniitverdyh-bytovых-othodov#.ixzz5J8Dp3eZH. (data obrashheniya 22.06.2019)

[11] Vajsman, Ya.I. Razrabotka metodologicheskix principov sozdaniya i optimizacii ucheta dvizheniya otxodov s cel’yu povy’sheniya e’kologo-e’konomiko-social’noj e’ffektivnosti upravleniya ix obrashheniem / Ya.I. Vajsman , O.A. Tagilova, E.L. Sadoxina. [Електронний] ресурс. – URL: http://www.komeco.ru/pressa/ecip_2013_12.pdf.

[12] Barcev, I.A. Xarakteristika sistem’ upravleniya pererabotkoj TBO: struktura i sostavny’e e’lementy’ / I.A. Barcev, I.S. Docenko // UE’eKS, 10/2013. [Електронний] ресурс. – URL: http://uecs.ru/marketing/item/2434-2013-10-17-07-25-35.

[13] Maksimova Svetlana Valentinovna. E’kologicheskie osnovy’ osvoeniya territorij zakry’ty’x svalok i poligonov zaxoroneniya tverdy’x by’tovy’x otxodov / N.N. Slyusar’, Yu.M. Zagorskaya, G.V. Il’iny’x // Vestnik PNIPU. Prikladnaya e’kologiya. Urbanistika. – 2014. – № 77-85.

[14] Slyusar’, N.N. Principy’ upravleniya poligonom zaxoroneniya tverdy’x kommunal’ny’x otxodov na razny’x e’tapax zhiznennogo cikla / N.N. Slyusar’, A.Yu. Puxnyuk // Vestnik PNIPU. Prikladnaya e’kologiya. Urbanistika. – 2016. – № 2. – s. 148-164.

[15] Methodological tool «Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site» (Version 06.0.1) // UNFCCC CDM Executive Board, EB 66 Report, Annex 46. – 2012. – 16 p.

[16] GOST 5180-2015 Grunty’. Metody’ laboratornogo opredeleniya fizicheskix karakteristik [Tekst]. // M. - 2015

[17] GOST 20522-2012 Grunty’. Metody’ statisticheskix obrabotki rezultatov ispy’taniy [Tekst] // M. - 2012.

[18] GOST 25100-2011 Grunty’. Klassifikaciya (s popravkoj). – Vzamen GOST 25100-95; Vved. 01.01.2013.

[19] Instrukciya po proektirovaniyu, e’kspluatatsii i rekul’tivacii poligonov dlya tverdy’x by’tovy’x otxodov / Utverzhdena Ministerstvom stroitel’stva Rossii skoj Federacii 2 noyabrya 1996 goda.