БИОЛОГИЯ ПОЧВ

UDC 631.4

E. Maksimova, E. Abakumov

ALLUVIATED SOILS OF THE SAINT-PETERSBURG CITY*

Saint-Petersburg macro urban landscape is situated in the most important part of the Baltic environment. This urban landscape is situated in the Neva Lowland and is known as the most anthropogenically transformed part of Russian North-West and Scandinavian region. Saint-Petersburg city has a huge area of hydraulically constructed (alluvial) soils or soil-like bodies, situated on the banks of the Gulf of Finland. These constructed grounds form the territory of parks in residential areas. Soils of the alluvial territories, created by human, play an important role in landscapes functioning and formation of ecological stability. Alluvial filled territories are considered as a semi-natural environmental model of landscape development in urban conditions. New formed soils of artificial landscapes have been described and their ecological functions are discussed as well. Constructed ground is characterized by problematic physical properties, which are not favourable for plants, soils of new formed plots show evidences of increased hyrdomorphism, gleyfication and formation of contrast layers phenomena. Artificial grounds of new hydraulically formed lands are characterized by number of soil-ecological problems. Refs 33. Figs 2. Tables 2.

Keywords: soils, alluviation, Baltic region, Gulf of Finland, monitoring, anthropogenically transformed soils.

Е. Максимова, Е. Абакумов

НАМЫВНЫЕ ПОЧВЫ САНКТ-ПЕТЕРБУРГА

Санкт-Петербургский государственный университет, Российская Федерация, 199034, Санкт-Петербург, Университетская наб., 7/9; doublemax@yandex.ru; e_abakumov@mail.ru, e.abakumov@bio.spbu.ru

Городской макроландшафт Санкт-Петербурга расположен в важнейшей части Балтийского региона. Этот городской ландшафт приурочен к Приневской низменности, известной, как регион, наиболее антропогенно измененный в Северо-Западном регионе России и Скандинавии. Санкт-Петербург характеризуется большой площадью почв, сконструированных гидравлически (в ходе искусственного аллювиального процесса). Эти почвы и почвоподобные тела расположены на берегах Финского залива. Конструированные грунты формируют территории парков в спальных районах. Вновь конструированные почвы играют важную роль в функционировании ландшафтов и формировании экологической стабильности территории. Искусственные аллювиальные территории рассмотрены как природно-антропогеная модель развития ландшафта в городских условиях. Обсуждаются также характеристики новообразованных почв и их экологические функции в искусственных ландшафтах. Конструированные грунты характеризуются проблематическими физическими свойствами (малопригодны для растений), что связано с повышенным гидроморфизмом, развитием глеевого процесса и формированием явления мембранной слоистости грунтов. Намывные почвы вновь созданных территорий характеризуются большим количеством экологических проблем. Библиогр. 33 назв. Ил. 2. Табл. 2.

Ключевые слова: искусственный намыв, Балтийский регион, Финский залив, мониторинг, антропогенно-трансформированные почвы.

* This work was supported by Saint-Petersburg State University grant number 1.37.151.2014 and Russian Foundation for Basic Research, project № 15-34-20844.

E. Maksimova (doublemax@yandex.ru), E. Abakumov (e_abakumov@mail.ru, e.abakumov@bio.spbu.ru): St. Petersburg State University, 7/9, Universitetskaya nab., St. Petersburg, 199034, Russian Federation.

1. Introduction. Alluvial filled grounds and their soil cover component in megapolices

Urbanization is the environmental and antropic process which develops actively in the cities of very different parts of the world. Urban environments are characterized by soil cover, enriched by technogenic and anthropogenic soils with relatively small portion of natural or semi-natural soils. Urban affect on terrestrial ecosystems results in formation of an urban type of ecosystems and soils [1, 2]. The urban ecosystem consists of the natural ecosystems' fragments incorporated into residential areas, industrial zones, traffic and agricultural habitats. Soils of these ecosystems are unified in one non-classification but soil ecological group: Soils of Urban, Industrial, Traffic, Mining and Military areas with acronym SUITMA, as it was proposed by International Union of Soil Scientists. Urban soil cover is the result of the crucial changes in natural soil cover, which is especially important for the urbanized territories [3]. The most important problems of the urban environment are devoted to the levels of soil biological activity, recreational quality and their physical properties. The soil sealing leads to degradation of environmental quality and provides the municipal decision makers to find new lands for residential areas and recreation zones. So, urban soils combine the natural and specific urban features and, therefore, are known as very different from typical orders of zonal (mature, benchmark) soils.

The soils of urban environment can be classified in frames of following soil orders (units) [4, 5]: natural soils; natural-anthropogenic soils; anthropogenically deeply transformed soils; soil-like formations of anthropogenic and technogenic origin. The last ones are soils constructed by human for greening or building purposes, in many cases they have to be constructed on the mature geological material, but in the last time it has been more and more relevant to construct on the new alluvial filled territories both the soil and parent material body as well. Many of the coastal agglomerations have the lack of free or not sealed territories [6], but the necessity to built new industrial or recreation zones argues the alluviation of new lands. Construction of alluvial territories became an important issue for municipal and state decision makers of the major coastal cities. Alluviation activity crucially changes the urban environment and has many environmental issues and aspects [7]. Alluviated environment and pedological aspects are discussed in this paper on example of case study in the Saint-Petersburg city — the most representative of the Baltic cities which surface and landscape where crucially changed in the 20th century.

The aim of this work is to integrate investigations of alluviated soils in the world and in St. Petersburg particularly. The objectives are:

(i) To study history of the soil alluviation;

(ii) To study alluviation experience in Russia and Saint-Petersburg;

(iii) To assess a legal status of alluviated soils;

(iiii) To study a soil formation on alluvial filled grounds.

2. General information on soil alluviation

2.1. To the history of the soil alluviation

The artificial lands formation is known as have been started five centuries ago. At the beginning, alluviation was represented by coastal waters reclamation and construction of artificial soils [8]. Japan, Netherlands and United Arab Emirates are known as a most expe-

rienced countries in technologies of artificial alluviation. The artificial islands were created for the first time in the 17th century in Japan as traffic areas of the sea ports [9]. Alluvial territories and the networks of artificial channels were very important for the development of the European transport facilities in the late Middle Ages. The creation of alluvial areas in Europe has been started in the late Middle Ages. This was caused by the growth of urban population and by economical reasons. First of all, it concerns the Netherlands, where 40% of the country is situated on the alluvial territories [10]. In Denmark this areas reach 60% of territory and are presented mainly by agricultural lands. USA, China, Argentina, Brazil are known as the countries with the developing technologies of soils alluviation [8]. Artificial territories were established in the UAE, Bahrain, Singapore, China, Denmark, USA, Canada, Australia, Netherlands and some other countries. The most famous project by aggradation is the "Palm Islands" in the UAE with an area of over 13,000 hectares. Major projects have been implemented in Singapore (18% of alluvial lands), the Netherlands (the whole administrative unit — Flevoland province, located on the artificial land) and in the Sea of Japan [9]. Remarkably, that the Japanese alluvial islands Yumenoshima and Ogijima were aggraded with the use of technology of recycled wastes. The International Airport in Osaka Bay is also located on the artificial island. Moreover, Japan is underway the area of coral germs to "grow" on the remains of a coral reef for subsequent recognition of this area and its waters surrounding by the international community as the Japanese territory. There are also more exotic examples such as the Dubai transported archipelago "The World" in the form of the globe, underwater hotel "Poseidon" in the Bahamas and the floating islands in the waters of Tel Aviv [8]. So, the alluviation is modern construction technology of cities growth without consumption of natural and agricultural lands which provides the new facilities and possibilities for the residential and industrial areas growth.

2.2. Alluviation experience in Russia and Saint-Petersburg

New alluvial territories also have been used in city management in Russian Federation. Russia's first artificial island was created in the Samara region, its area is 8.95 ha. The "Tsarev hail" setlement is situated now on it. A major project of the creation of the island, named "Federation" with an area of about 250 hectares is sold in Sochi. It is also planned to build a new alluviated territories in the cities of Voronezh, Kazan, Novorossiysk, Nizhny Novgorod, and in Saint-Petersburg [9]. Nowadays artificial alluviated soils play an important role and occupy essential territories in the city of Saint-Petersburg. Three main types of soils are dominating in the Saint-Petersburg city: transported soils (created by the use of imported land during construction of landscaping); cultivated natural soil (in the forest parks and parks of the city suburbs) and the alluvial ones (created by reclamation of poorly silty sands and sandy loams on the coast of the Gulf of Finland). The ecological state of urban soils is not uniform and depends not only on their initial heterogeneity and anthropogenic factors, but also on the natural terrain features, the terms of the operating of greenery [11]. Alluviation of lands has been in use in St. Petersburg since the moment of its foundation. Initially it was used for the city flood protection. Further, artificial territories were created for the construction of port facilities [12]. Alluvial soils were widely created in the 1970s and 80s for green building and residential areas planning, some of them were cultivated, while others were managed as abandoned during 40 years [13]. Totally over these years 3.5 million m^2 were created by alluvial technologies in Saint-Petersburg [14]. The parts of the city, which are opened now to the delta of the Neva River and the Neva Bay, have been located on an

artificial grounds in 2002. The ground thickness is about 2–4 m and reaches in some cases up to 6–8 m. A great work of creating alluvial areas was made in the late 19th — early 20th centuries while the construction of Marine channel in Saint-Petersburg and port facilities in the area of Gutuevsky and Kanonersky islands. Since the late 1960s the huge areas were alluviated for new buildings creation on the Decembrists Island, at the residential districts Staraya Derevna, Komendantskiy aeroport and Dolgoye ozero and Yuzno-Primoskiy Park. New residential areas and parks were built at these areas after aggradation: Park of the 300th anniversary of St. Petersburg and Yuzno-Primoskiy Park. Maximum capacity of alluvial soil is fixed on Krestovsky island — near the Kirov's stadium. As a result of land reclamation at bay of the Bolshaya Neva the Bely Island was created, which was the place where the Central aeration station was housed. In the same way the configuration of the Western part of Vasilievsky island and Decembrists Island were changed [9, 12, 14]. A soil horizon and turf materials were removed from the surface and collected before aggradation in order to better grip sand material. After aggradation the soil surface was covered by soil-plant cover and a territory was planned. For the aggradation of the places, surrounding the Neva bay, sands from the bottom of the Neva Bay and Lahti spill lake were used.

Nowadays an ambitious project "Marine Facade" for construction of new territories on Vasilevsky Island is planned with an area of 476.7 ha. A Sea passenger port, section of the Western High-Speed Diameter, residential areas, new business center of St. Petersburg as well as Exhibition and Congress Centers are planned in "Marine Facade" [9, 12]. It is also planned to create two artificial islands in the Gulf of Finland in the Resort district of St. Petersburg at the site, located north of the settlement of Fox's Nose from the complex defenses and till the Sestroretsk. Within the project "New Beach" 450–500 ha of a new territory will be reclaimed near Sestroretsk and Lisij Nos, where it is planned to build more than 3 million m^2 of real estate [12].

The state of the alluvial grounds in St. Petersburg is important for regulation of water pollution, landscape changes, social and other problems. Furthermore, from a legal point of view the alluvial areas are not included in the subjects of the Russian Federation or municipalities. As a result there is not only the absence of a legal regime, but also slowing of the influx of investors in projects to create artificial lands.

2.3. Legal aspects of alluvial territories

National system of legislation and international instruments regulate the legal regime of artificial islands and structures, i.e. the objects, which were created as a result of human activity in order to ensure safety of navigation [6]. The status of the alluvial areas depends on the status of the water body (river, lake, sea), which is faced to alluviation and on the objectives of the planned land management. Alluvial areas can be created not only in the sea and river ports, but also in major metropolitan areas. Nowadays, the area of artificial alluvial lands increases especially in residential areas. The planned formation of alluvial areas in the Gulf of Finland with changing boundaries of St. Petersburg as a city of the federal significance in the direction of the water body currently makes the problem of the legal status of these alluvial areas. International legislation uses the term of the "artificial island" instead of "alluvium". The information about coordinates of artificial islands and a width of their safety zones (no more than 500 meters around the island) have to be communicated to all stakeholders in the map scale, suitable to accurately determine of their

position [6]. National legislation does not use the term "alluvial territory" and an approach of international legal instruments to the status of artificial islands is adopted, equating their legal regime to the legal regime of structures and installations. The concept of an artificial land can be formulated on the basis of natural-human object definition that according to Art. 1 of the Federal Law of 10th January, 2002 № 7-Federal Law "On Environmental Protection" it is an object that have been changed as a result of economic and other activities, and (or) human erected object having the properties of a natural object and having recreational and protective value. Based on the foregoing, the concept of artificial land plot corresponds to the definition of natural and anthropogenic object, but not fully as the possibility of using artificial land should be wider and determined by their purpose [8]. However, terms "artificial island" and "alluvial land" are different. The artificial island is considered as a human-made object. An alluvial land is a part of the alluvial areas [6].

3. Soil formation on alluvial filled grounds

3.1. Soil morphology and classification

The allocation, diagnosis and classification aspects of disturbed and anthropic soils horizons of urban soil are still poorly developed. Increased intensity of soil anthropogenic transformation requires new classification approaches [1]. The classification of urban soils is made both on the principles of morphological profile, and on the nature of the substrate, on the origin and development stages [7, 15–17]. In general, based on an analysis of national literature a disunity between researchers studying urban landscapes soils about their place in the Russian national classification can be concluded. Cultural layer formation takes place by surface accumulation of various types of material as a result of household human activity or by converting natural top layer during construction and improvement by bringing foreign materials in the natural soil. The composition of the transported layer includes a variety of elements such as broken brick, stone, rubble, various household items, abandoned foundations of old buildings, the remains of the destroyed building materials: cellars, wells, log and batten, cobblestone and asphalt pavements in modern cities [1]. An example of soil, constructed from different type of sediments is shown on the Fig. 1. This unhomogenous soil profile is characterized by quite changeable physical properties. Recently, along with the study of the influence of urban soils' contamination on the ecological state of urban environment the interest in the characteristics of their morphology is growing [17–21]. Researchers have noted that a significant place in the soil profiles of cities takes backfill, having at least one lithological discontinuity (see Fig. 1, sample photo of stratified soil with evident gleyic layer, soil is described in the park "Yuzno-Primorskiy").

3.2. Environmental issues of alluvial soils functioning

Morphology and chemistry of Saint-Petersburg alluvial soils have been studied in details by L. P. Kapel'kina [11, 22–24]. It was shown that the stages of pioneer succession are closely related to soil chemical status. Deep penetration of organic compounds (even hazardous substances) and nutrients (especially phosphates), trace elements into the soil profile are observed during the formation of soils on transported grounds, while the natural soils are enriched only in the upper horizons. The phenomena of soil (ground) over compaction was revealed in constructed alluvial soils as an effect of contrast layers

Fig. 1. Alluviated soil in the south part of Saint-Petersburg, gleyfication at the depth of 40 cm

contact. Young, new-formed soils are characterized by a high variability in physical and chemical features compared to soils of natural landscapes. L. P. Kapel'kina [22] noted that the current pedogenesis leads to an acidification of soil mass, increasing of total exchangeable bases. Even the podzolisation in entic form appears in some young soils of alluvial territories. Alluviated soil is characterized by decreasing of free porosity and increasing of water content within the depth (Tables 1, 2). New-formed soils of alluviated territories are characterized by following key features:

— alluvial soils are differentiated in profile texture, density and porosity;

— there is a sharp decline of soil infiltration rates within soil profile due to the contrast texture of grounds;

— groundwater level is exposed higher than 3 m and it is considered as affected by the ground texture and the distance of study plot from coast of river or bay;

— soil chemical properties are quite variable, namely the humus content changes within the special trend of organic particles accumulation in silt.

Artificial transported soils, on which were created many urban gardens, squares, street planting, have a neutral or slightly alkaline pH values and high or very high availability of nutrients [20, 25, 26]. However, these properties are typical for small depth (10–50 cm) of the transported layer, which is often found above the rubble. In particular they have a high bulk density (about 2.0 g/cm^3). Mechanical soil properties limit the developments of woods root system till the 0–10 cm uppermost soil layer [27, 28]. Gleyification due to waterlogging appears in many alluviated soils (Fig. 2) The main soil nutritients' content (N, P, K) is quite variable in urban soils. The most part of researchers have noted the high nitro-

Table 1. **Water content in selected alluviated soils, %**

Soil/depth, cm	10	20	30	40	50	60	70
Alluviated soil	25	25	40	50	70	80	100
Soil constructed on the alluviated ground	49	50	30	70	90	120	150

Table 2. **Porosity in selected alluviated soils, %**

Soil/depth, cm	10	20	30	40	50	60	70
Alluviated soil	50	40	32	20	10	12	10
Soil constructed on the alluviated ground	23	22	18	10	11	12	7

gen, phosphorus and potassium content in transported layers and weakly disturbed soils compared to natural soils of suburbs [20, 25, 29, 30]. The post alluvial succession starts from the algae group, which provides the C and N accumulations and leads to decreasing of pH values [31, 32]. Soil fine earth shows more intensive changes due to vascular plants impact. These results in formation of micro horizons of soil (biological soil crusts), but the speed of soil profile differentiation is limited by the sediment density and over moisiting. Stabilization of initial ecosystems appears after the intensive ecogenetic succession at 20–30 years after alluviation [33]. So, while the environment, formed in alluvial ground is not natural, soils, formed there are different from the natural or even classical urban soils in terms of morphology and general functions (see Fig. 2, complicated soil profile with some artificial pedogenic features — white colored stone boulders and layers of iron oxidation, park of the 300th year anniversary of Saint-Petersburg).

Fig. 2. Artificial soil, constructed on alluviated ground, covered by building waste and humus reached material, northern part of Saint-Petersburg

The creation technology of alluvial soils is associated with a taking out ground from the bottom of the Gulf of Finland. As a result, stratified soils with a high content of silt fraction are formed. They are characterized by a high density. The tree planting of alluvial areas is currently performed with the aim of increasing of portion of parks and recreation zones. However, the development of trees' root system is often limited by a planting pits' size, as excessive density of alluvial soil prevents its normal growth. A discrepancy between the small volume of planting pit (root system) and the sprawling land-based mass (crown of the tree) is growing along with increasing of the trees age, which hampers the plants growth. The shrubs state on alluvial area is much better due to intrinsic more superficial root system. Lawn grasses develop satisfactorily, but in areas of high silt and clay particles deposition with heavy rainfall the water stagnation is observed [11]. With the aim to form a root layer, that would be the most relevant to the needs of plants in the best way, L. P. Kapel'kina [11] proposes to change the aggradation technology for landscaped areas. The lower part of the profile should be ground filled by easy draining sand particles and the upper layer (up to 0.5 m) — by loams with sufficient organic silt particles content. It is necessary to create a uniform and less layered strata when aggradation. The first clay and silty sediments have to be mixed with underlying sands to ensure a gradual change in the particle-size distribution along the profile. Artificial soil mixtures should be used for planting of alluvial areas. The most realistic artificial land components of soil mixtures can be municipal and some industrial waste such as a benthal deposits (silts), peats and composts on its basis, mowing and fallen leaves of large parks, seaweeds and other components. Ground mixtures must follow the requirements:

— to conserve a sufficient content of major plant nutrients needed for long-term growth of lawn grasses, trees and shrubs.

— to ensure an optimal water-air regime for plant growth.

— absence of substances toxic to plant growth and dangerous to the environment.

A number of special techniques are necessary for designing a landscape objects in such areas [14]:

— a selection of wood plants species resistant to prolonged flooding of root systems;

— a design of a semi-open and open landscapes with minimal use of wood plants and a wide use of shrubs with superficial root system that have more resistant to flooding root systems;

— an application of a local drainage for water-air soil regime regulation in planting pits.

A range of trees species for alluvial areas' landscaping should include species that are not demanding for soil fertility, naturally settled on aggradation sites and developing superficial root system: *Betula pendula, Populus alba, P. tremula* and *P. berolinensis, Salix schwerinii, S. purpurea, S. pentandra, S. fragilis* (a spherical shape), *Glauca Globosa.* A planting of *Acer platanoides, A. negundo, A. tataricum, Sorbus aucuparia, Malus baccata* is possible on soils with negligible density. The assortment of shrubs may include such species as *Aronia melanocarpa, Berberis vulgaris, Sambucus racemosa, Cornus alba, Chamaecytisus ruthenicus, Crataegus altaica, Crataegus sanguine, Rosa rugosa* and other species. The progressive soil-plant community succession is only possible in case of favourable combination of ground type, ground physical regime and type of primary plant community.

4. Conclusions

The landscape development on the coastal areas of Neva and the Gulf of Finland is one of the most important environmental issues of the Saint-Petersburg City. Saint-Petersburg is characterized by the lack of territories, appropriated to the residential areas and this problem has to be solved by creation of alluviated artificial areas. Saint-Petersburg city has a huge area of hydraulically constructed (alluvial) soils or soil-like bodies, situated on the banks of the Gulf of Finland on the territory of parks in residential areas. Soils of the alluvial territories, created by human play an important role in landscapes functioning and formation of environmental stability. Alluvial filled territories are considered as a natural environmental model of landscape development in urban conditions. A new formed soil of artificial landscapes has been described and their ecological functions are discussed as well. Constructed ground is characterized by problematic physical properties, which are not favorable for plants, soils of new formed plots show evidences of increased hyrdomorphism, gleyfication and formation of contrast layers phenomena. Artificial grounds of new hydraulically formed lands is characterized by number of soil-ecological problems, namely by the lack of nutrients, increased density, low water infiltration rate and waterlogging of the middle solum due to lithological contrasts. Success of new formed environment on alluvial territories is affected by the quality and stratification of exposed grounds. That is why this issue should be the key in environmental management of new formed landscapes of Saint-Petersburg. Creation of the ecologically balanced landscapes that are most relevant to the objectives of environmental management on site of alluvial lands requires, first of all, the development of science-based system of measures and sets the task to study a rate and basic laws of natural regeneration of ecosystems in disturbed ecosystems, a major component of which are soils. Abandoned post alluviated territories should be monitored in sense of landscape dynamics, soil properties and the plant community succession rate.

Acknowledgements: this work is dedicated to the memory of PhD, assistant professor of Saint-Petersburg University Olga Rastvorova.

References

1. Chasovskaja V. V. *Soil formation on alluvial soils in urban ecosystems*. PhD thesis. St. Petersburg, Russia, 2007.

2. Shamilishvili G. A., Abakumov E. V., Ryumin A. G. Assessment of the mobile forms of zinc and copper content in soil samples from areas of different land use on example of the Krasnogvardeisky District of the St. Petersburg. *Environmental Earth Science*, 2015. DOI 10.1007/s12665-015-4379-6.

3. Dobrovol'skij G. V. *Soil, city, ecology*. Moscow, Russia, 1977.

4. Shishov L. L., Tonkonogov V. D., Lebedeva I. I., Gerasimova M. I. *Classification and diagnosis of Russian soils. Dokuchaev soil institute*. Moscow, Russia, 2004.

5. Sincov A. V., Barmi A. N. Modern classification of soils in urban areas. *Geology, geography and global energy*, 2011, 3(42), Astrakhan, Russia, pp. 149–155.

6. Ivanova T. G. Some features of legal status of the alluvial territory in modern conditions. *Vestnik of Saint-Petersburg University. Series 14. Law*, 2011, issue 4, pp. 10–17.

7. Burghardt W. Soils in urban and industrial environments. *Z. Pflanzenernahr. Bodenkd.*, 1994, 157, pp. 205–214.

8. Mel'nikov N. N. Artificial land plot: search for a universal definition. *Magazine of Russian law*, 2011, 5(173), pp. 24–30.

9. Tributs O. A. Problems of alluvial territories' cadastre. *Intellectual potential of the XXI century: levels of knowledge*, 2010, 1. Novosibirsk, Russia, pp. 217–221.

10. Van der Meulen M. J., Van der Spek A. J. F., De Lange G., Gruijters S. H. L. L., Van Gessel S. F., Nguyen B.-L., Maljers D., Schokker J., Mulder J. P. M., Van der Krogt R. A. A. Regional Sediment Deficits in the Dutch Lowlands: Implications for Long-Term Land-Use Options. *J. Soils Sediments*, 2007, 7(1), pp. 9–16.

11. Kapel'kina L. P. *Ecological bases of recultivation of technogenic and urban landscapes in the forest zone*. Doctor thesis. Moscow, Russia, 1994.

12. Kozhevnikov N. N., Levinovskii E. A. Hydraulic filling of coastal territories for housing construction and urban development of St. Petersburg. *Hydrotechnical Construction*, 1997, 31(9), pp. 551–555.

13. Abakumov E. V., Maksimova E. Yu. Problems of alluvially dumped soils of the Gulf of Finland. *Proceedings of 1st conference in St. Petersburg State University devoted to the "Year of the Gulf of Finland — 2012" "Our common Gulf of Finland"*. 2012. St. Petersburg, Russia. 16 February 2012, pp. 9–12.

14. Mel'nichuk I. A. Problems of a coastal landscape spaces development in Neva and the Gulf of Finland. *Proceedings of the XIV International Conference "Problems of large cities' landscaping"*. 2011, vol. 1. 23–24 March 2011. Moscow, Russia, pp. 127–128.

15. Blume H.-P. Classification of soils in urban agglomerations. *Catene*, 1989, 16, pp. 269–275.

16. Konecka-Betley K., Yanowska E., Luniewska-Broda Y., Szpotansk M. *Wstepna klastfikacja gleb aglomeracja Warszawskiej*. Warszawa, Poland, 1985, pp. 125–135. (In Polish)

17. Rohmistrov V. L., Ivanova T. G. Change of sod-podzolic soils in conditions of a large industrial center. *Soil Science*, 1985, 5, pp. 71–76.

18. Bridges E. M. Soils in the urban jungle. *Geografical magaz*., 1989, 61, pp. 1–4.

19. Dolotov V. A., Ponomareva V. V. To the soils characteristic of Leningrad Summer garden. *Soil Science*, 1982, 9, pp. 134–138.

20. Huot H., Simonnot M.-O., Marion Ph., Yvon J., De Donato Ph., Morel J.-L. Characteristics and potential pedogenetic processes of a Technosol developing on iron industry deposists. *J. Soil Sediments*, 2013, 13, pp. 555–568.

21. Short J. R., Fanning D. S., McIntosh M. S., Foss J. E., Paterson J. C. Soils of the mall in Washington, D. C. *Soil Science Society of America Journal*, 1986, 50, pp. 699–705.

22. Kapel'kina L. P. *Characteristics of alluvial soils in Gulf of Finland due to their use for a landscaping*. PhD thesis. Leningrad, Russia, 1974.

23. Kapel'kina L. P. Pioneer vegetation and primary soil formation on alluvial soils of the Gulf of Finland coast. *Interuniversity proceedings "Forestry, forest crops and soil science"*. Leningrad, Russia, 1980, 9, pp. 74–78.

24. Kapel'kina L. P. Some properties of alluvial soils of the Gulf of Finland. *Forestry. Scientific works of Forest engineering academy*, 1973, 155, pp. 48–52.

25. Kutepov Yu. I., Kutepova N. A. Technogenesis of alluvial rocks. *Geoecology*, 2003, 5, pp. 405–417.

26. Stroganova M. N., Mjagkova A. D., Prokof'eva T. V. The role of soils in urban ecosystems. *Soil Science*, 1997, 1, pp. 96–101.

27. Abakumov E. V. Soil-ecological characteristics of South Seaside park of St. Petersburg in connection with the problem of alluvial soils landscaping. *Problems of large cities landscaping,* 2005, 11, pp. 181–183.

28. Blight G. E. Properties of pumped tailings fill. *Journal of the South African Institute of mining and metallurgy*, 1979, October, pp. 446–453.

29. Bashirova F. N. Some indicators of industrial and domestic pollution of soils in Kuzbass cities. *Nature conservation in the Urals*, 1966, V, pp. 79–83.

30. Zemljanickij L. T., Poltavskaja I. A., Zheldakova G. G. *Urban soils preparing for landscaping*. Moscow, Russia, 1962.

31. Shherbatenko V. I., Shushueva M. G. Characteristic features of a vegetation syngenesis on hydrodumps of Gramoteinskij coal open-pit mine in Kuzbass. *Problems of land reclamation in the USSR Novosibirsk*, 1974, pp. 172–179.

32. Shushueva M. G. Nitrogen-fixing blue-green algae distribution on the dumps of coal mining in Kuzbass. *Restoration of technogenic landscapes of Siberia Novosibirsk*, 1977, pp. 56–64.

33. Makhonina G. I. The soil and vegetation cover formation process on dumps of Akkermanovskij iron ore deposit. *Plants and industrial environment Sverdlovsk*, 1976, pp. 12–17.

Статья поступила в редакцию 19 августа, принята 19 октября 2015 г.

Authors information:

Maksimova Ekaterina — Master of Soil Science, PhD student
Evgeny Abakumov — Dr. in Soil science and soil ecology, Professor