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Recycling of Wastewater Treatment Plants Sludge in Urban Landscaping in West Siberia

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Abstract

Proposed method of disposal of precipitation sewage treatment plants and increase soil fertility in Nizhnevartovsk. The properties of soils obtained using precipitation generated in the wastewater treatment process of the city. The effect of dose sediment germination, growth and yield of lawn grass. The optimum content of sewage sludge in the soil. Lawn grass crops in soils produced using sewage sludge showed the resistance of plants to adverse conditions of continental climate in West Siberia. Soils obtained recommended for creating urban lawns, which will reduce the cost of purchasing the traditional types of fertilizers, eliminate the need for storage of sewage sludge.

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Keywords: Wastewater sludge; waste disposal; soil; landscaping; urban

1. Introduction

One of the determining factors of the mankind's existence and development is the environment, which accumulates more and more waste of human activity year by year [1, 2].

The problem of utilization of wastewater sludge, which is formed in process of sewage treatment and present oneself as special kind of waste, is actual for municipal facilities of all big cities of Russia.

On the sewer treatment facilities (STF) of the city of Nizhnevartovsk is about 15,000 m^3 of the dehydrated

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wastewater sludges are annually formed. For today sludge fields, which is about 5 hectares in total, are close to filling (Fig. 1).

Fig. 1. Sludge fields of Nizhnevartovsk's STF

Promising ways of wastewater's sludge recycling is their use in the production of construction materials [3÷5], for recultivation of soils [6], for land reclamation in the forestry and recreational purposes, for planting, forest nurseries and municipal facilities with growing seedlings, flowers, industrial crops [7÷10]. Disposal of sewage sludge reduces the cost of wastewater treatment and create further commercial product, which is can be sold, as well as the prevention of negative influence on the environment [11÷14].

Technogenic pollution and degradation of soils are problems of big cities [2], which is especially noticeable in northern climate in cities as Nizhnevartovsk, which is located along the Ob River. Lands of city and outskirts include well-drained uplands, forested areas and swamps most of which is backfilled. Its soils are characterized by the low content of nitric nitrogen; ammonium nitrogen; chlorides; phosphates; potassium. There is a gradual deterioration of chemical properties of soils: exhaustion of stocks of nutritious elements, alkalizing, acidifying and pollution by toxicants. The average content of organic matters in the soil samples – 4.9%. Soil quality don't satisfy required parameters for city soils [15]. Using of wastewater sludge as addition to soil of urban landscaping is solution to the problem of soil pollution and increasing their fertility [16, 17]. The sludge added to the depleted soil in the form of compost comprehensively improves its structure, returns to the soil initial abilities to a filtration and fixing, detains nutrients and moisture in a topsoil. Under the influence of the sludge, as a rule, soil acidity decreases, moisture content and their biological activity are increasing, which is especially important for soils of light granulometric composition of the Middle Ob. Soil regimes of heat, water and air are improving [11].

Wastewater sludge improves aggregate structure of soil and forms agronomical valuable structure by gathering humus and water strength of soil aggregates [18].

Efficiency of the sludge as component of soils in urban landscaping depends on climatic conditions and chemical composition of wastewater sludge of application location [7, 10, 19]. The problem of wastewater sludge utilization as soil component of urban landscape is not researched enough and demands additional study. For different territories with different bedrock, water regime, requires an individual treatment to creating artificial soil [20].

2. Subjects and Methods

For our research, wastewater sludge of primary and secondary sedimentation tanks of sewage treatment facilities of Nizhnevartovsk has taken. The sludge was dehydrated on centrifuges with use of reagents, which was on silt cards within two years. Experiments on local soil served as controls.

Through a system of capillary electrophoresis "Kapel 105M" was defined composition wastewater sludge and the local soil. The obtained results of statistical processing are presented in Table 1.

Table 1 – Chemical composition of wastewater sludge and soil of experimental section

№	Name of indicator	Units of measure	Value of indicator	
			Wastewater sludge	Soil
1	pH	[unit PH]	6.63	6.1
2	Ammonium nitrogen	[mg/kg]	11	10.89
3	Potassium	[mg/kg]	35.1	37.2
4	Sodium	[mg/kg]	19.2	7.5
5	Magnesium	[mg/kg]	137	13.7
6	Calcium	[mg/kg]	2806.8	141.1
7	Chlorides	[mg/kg]	10.7	6.7
8	Sulfates	[mg/kg]	6142	8.46
9	Nitrates	[mg/kg]	520	163.2
10	Phosphates	[mg/kg]	-	7.5

Heavy metals contained in wastewater sludge have toxic effects for environment, agricultural production and finally for human. This is the main deterrent factor using sludge of wastewater treatment plants as fertilizer [14, 21].

With long-term using of wastewater sludge there is a possibility of gathering heavy metals in soil. There is an opinion that risk of pollution of ground water by heavy metals is small, as it generally remains in places of sludge applying and moves slightly with leaking water [18].

According to ecological certificate wastewater sludge has a V class of danger. Content of heavy metals in sludge does not exceed MPC for I group (Table 2) it allows to use them in landscaping [22].

Toxicity of heavy metals depends on many factors: content of humus, pH of soil structure, granulometric composition of soil, presence of carbonates, climate, and features of plants. Presence of carbonates in soil affects to mobility of microelements. Presence of calcium in soil decreases toxicity and reduces absorption of metals by plants [21].

Table 2 – Content of heavy metals in sludge of silt platforms

Indicator	Content, [mg/kg]	MPC, [mg/kg]
Plumbum	30.5	250
Cadmium	0.34	15
Zinc	253	1750
Cupper	57.8	750
Nickel	7.9	200
Chrome	2.3	500
Mercury	0.26	7.5
Arsenic	1.3	10

Vegetative experiments were made in micro-field conditions. Experimental section was placed in Nizhnevartovsk and was consisted of 20 experimental platforms. Variants of experiments: wastewater sludge, original soil, mixture of wastewater sludge and soil. Dose of sludge for dry substance to original soil was 25%, 50% and 75% with the four-time repeat of each variant of mixture. Grass mixture “Sibiryak” (pasture ryegrass – 20 %, meadow fescue – 40 %, cane fescue – 40 %) was planted in each platform.

3. Results

Sowings of lawn grass to soil, formed with usage of sludge of sewage cleaning facilities, showed high stability for drying in conditions of warm, dried summer in 2013 with average temperature of the warmest month – July +21°C (+16.5°C according to results of long-term observations) (Fig. 2, 3).

a) b) c)

Fig. 2. Growth of lawn grass in experimental platforms (July 7, 2013): (a) 25% of sludge; (b) 50% of sludge; (c) 75% of sludge

Fig. 3. Phases of Growth of lawn grass in experimental platform with best results of productivity 25% of sludge: (a) rises (day 8); (b) active growth (day 15); (c) beginning of bush formation (day 22).

Long duration of light day in summer period at latitude 60°54’’ helped intensive growth of lawn grass (Fig. 4) and allowed in short period of time to make full testing of soil.

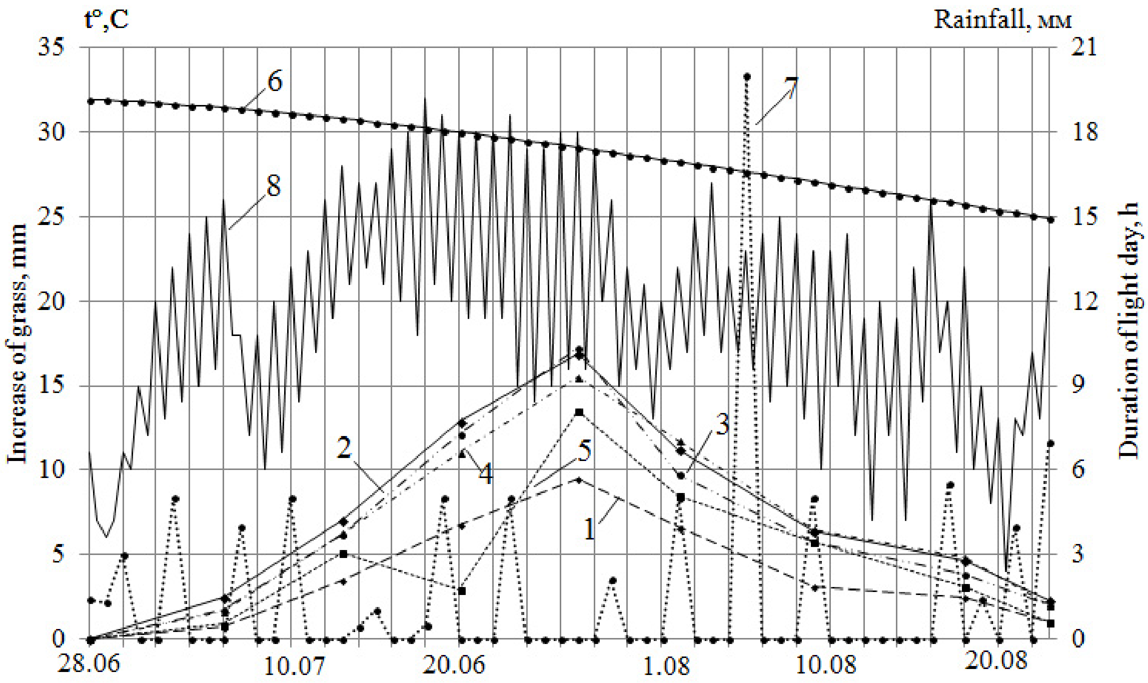

Fig. 4. Influence of climate conditions and doses of sludge of sewage cleaning facilities to increase of lawn grass 1 – control plot, 2 – 25 % of sludge, 3 – 50 % of sludge, 4 – 75 % of sludge, 5 – 100 % of sludge, 6 - duration of light day, 7 – sludge, 8 – temperature

Germination of seeds was determined after first rises. At the same time germination was determined laboratory conditions (Fig. 5).

In the end of season after 60 days after seeding, we determined productivity of sowing of lawn grass. For this purpose grass was cut and raw mass of each plot individually was weighted, then dried completely, not mixing, and weighted once again (Fig. 5).

During introduction to sandy soil of Nizhnevartovsk of water waste sludge, productivity, in comparison with control platform without introduction of water waste sludge, increased significantly. During introduction to local soil of 25 % of wastewater sludge – 2.8 times; 50 % of sludge – 1.7 times; 75 % of sludge – 1.9 times. Growing lawn grass in only one water waste sludge, productivity in comparison with control platform with local soil decreased up to 28.6 %.

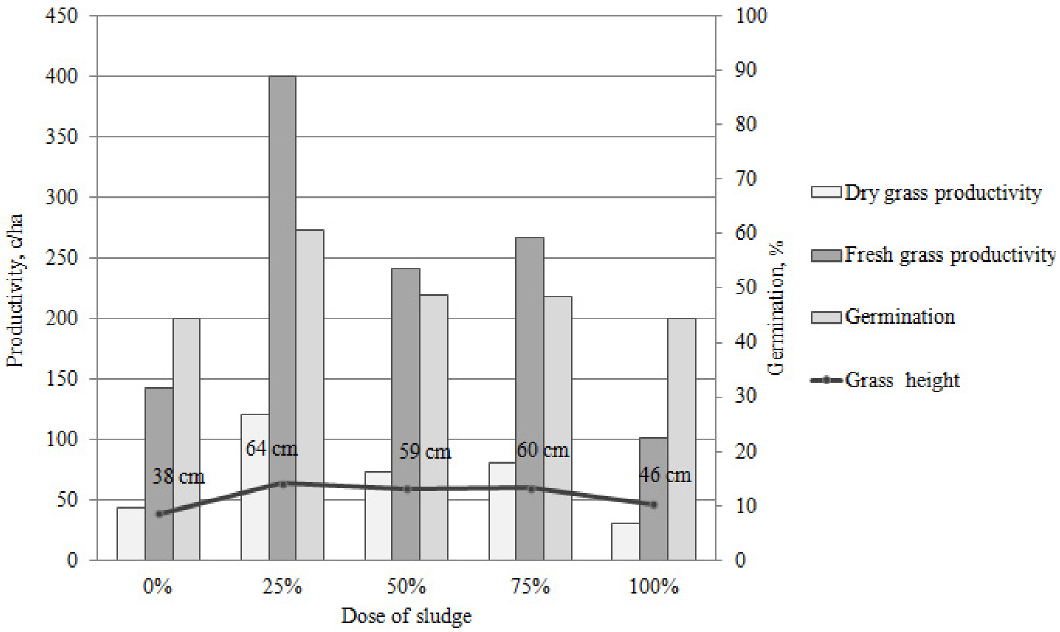

Fig. 5. Influence of dose of sludge to productivity, height and germination of lawn grass

Mathematical dependence of germination, productivity, growth of lawn grass from content of sludge in soil in form of empirical equation of regression on sampling of limited volume was made with the help of methods of regression analysis.

Analysis of received experimental information showed that the best approximation of researched values give a nonlinear equations of regression (1) in form of polynomials 2, 3, 4 – degree of kind:

$$y_i = b_0 + b_1 x_i + b_2 x_i^2 + b_3 x_i^3 + b_4 x_i^4 + e_i \tag{1}$$

In result of regression analysis of information, we received following nonlinear empirical equations of regression: germination in %

$$y = 44.5 + 2.3067x - 0.095x^2 + 0.0013x^3 + 0.0006x^4 \tag{2}$$

productivity for fresh grass in c/ ha

$$y = 142.51 + 36.371x - 1.527x^2 + 0.022x^3 + 0.0001x^4 \tag{3}$$

productivity for dry grass in c/ ha

$$y = 42.754 + 10.912x - 0.458x^2 + 0.0066x^3 + 0.00005x^4 \quad (4)$$

growth of grass in cm

$$y = 38.33 + 2.6689x - 0.0945x^2 + 0.0013x^3 + 0.000006x^4 \quad (5)$$

Coefficients b_0, b_1, b_2, b_3, b_4 of each received empirical equations of regression (2) – (5) were determined on PC using LINEAR() function in Microsoft Excel, which besides estimates of coefficients of regression, which gives the values of their standard errors, coefficient of determination, standard error of equation of regression. Standard errors of estimates of coefficients of researched equations of regression are equal 0, it shows their statistical significance. Coefficient of determination, which shows combined influence of all the variables, included to equation of plural regression, is equal 1. Errors e_i for every constructed empirical equation of regression are practically equal 0.

4. Conclusion

The research testify that wastewater sludge of sewer treatment facilities can form a basis for creation of artificial soils as their application significantly increases crop of lawn grass and fertility of soils in adverse conditions of continental climate of West Siberia. The optimal combination of sludge and soil is in a ratio of 1:3.

Utilization of newly formed and stockpiled wastewater sludge of wastewater treatment plants as soil component in landscaping will improve sanitary conditions and will reduce human pressure on the environment, will gain valuable commercial product, suitable for implementation in the municipal facilities.

References

[1] Vatin, N.I., Chechevichkin, V.N., Chechevichkin, A.V., Shilova, Y., Yakunin, L.A. [Application of natural zeolites for aquatic and air medium purification] (2014) Applied Mechanics and Materials, 587-589, pp. 565-572.

[2] Chechevichkin, V., Vatin, N. [Megacities land drainage and land runoff features and treatment] (2014) Applied Mechanics and Materials, 641-642, pp. 409-415.

[3] Kofman, V.Ya. Kak postupayut v Evrope s osadkami ochistnyh sooruzheniy kanalizatsyi (obzor zarubezhnyh izdaniy) [Wastewater sludge handling in Europe (review of foreign publications)] (2013) Water supply and sanitary technique, 4, pp. 18-23.

[4] Sokolov, L.I. Ispolzovaniye osadkov stochnykh vod pri proizvodstve stroimaterialov [Utilization of sewage sediments for manufacture of construction materials] (2006) Ekologiya i promyishlennost Rossii, 2, pp. 18-21. (rus)

[5] Sokolov, L.I. Ispolzovaniye osadkov stochnykh vod pri proizvodstve stroimaterialov [Utilization of sewage sediments for manufacture of construction materials] (2006) Ekologiya i promyishlennost Rossii, 4, pp. 18-23. (rus)

[6] Gubanov, L.N., Boyarkin D.V. Utilizatsiya osadkov stochnykh vod v kachestve istochnika povysheniya plodorodiya pochv [Utilization of sewage sludge a source of improvement of soil fertility] (2014) Privolzhsky scientific journal, 4, pp. 230-236. (rus)

[7] Gavrilin, A.M., Kevbrina, M.V., Grachev, V.A., Vanyushina, A.Ya., Agaryov, A.M. Utitltzatsiya osadkov stantsiy vodopodgotovki i ochistnyh sooruzheniy dlya vyrashchivaniya sazhentsev dekorativnyh drevesnyh kultur [Recycling of deposits of water treatment plants and sewage treatment plants for growing seedlings of decorative tree crops] Scientific and Technical Conference "Treatment of urban and industrial wastewater and sludge treatment: technological standardization, calculation, design, commissioning" [Electronic resource] (2013). (rus)

[8] Meshengisser, Yu.M., Esin, M.A., Zinchenko, D.B. Perspektivnye napravleniya obrabotki osadkov hoziaystvenno-bytovyh stochnykh vod [Perspective directions of sludge treatment of domestic sewage] Scientific and Technical Conference "Treatment of urban and industrial wastewater and sludge treatment: technological standardization, calculation, design, commissioning" [Electronic resource] (2013). (rus)

[9] Drozd, G.Ya., Bizirka, I.I. Vovlecheniye deponirovannyh osadkov stochnykh vod v hozhiaystvenniy oborot [Commercialization of landfilled sludge] (2013) Water supply and sanitary technique, 4, pp. 11-17. (rus)

[10] Lotosh, V.E. Pererabotka otkhodov prirodopolzovaniya [Recycling of natural management wastes] (2007) 503 p. (rus)

[11] Kulikova, Yu.V., Zavizion, Yu.V. Ekologo-ekonomicheskaya otsenka napravleniy ispolzovaniya produktov pererabotki osadkov stochnykh vod [Ecological and economic estimation directions of using processing products of sewage sludge] Scientific and Technical Conference "Treatment of urban and industrial wastewater and sludge treatment: technological standardization, calculation, design, commissioning" [Electronic resource] (2013). (rus)

[12] Krymskaia, E.Ya., Chukalina, E.M., Ivanov, V.A. Polucheniye modifikotora pochv putem pererabotki bioshlamov [Soil modification through bioslime processing] (2014) Servis v Rossii i za rubezhom, 4, pp. 94-101. (rus)

[13] Dovgan', S.A. Ekologicheskiye, technologicheskiye i ekonomicheskiye aspekti ispolzovaniya osadkov stochnykh vod [Environmental, technological and economic aspects of sewage sediments utilization] (2012) Ekologiya i promyishlennost Rossii, 5, pp. 28-30. (rus)

[14] Gulyaeva, I.S., Dyakov, M.S., Savinova, Ya.N., Rusakova, V.A., Glushankova, I.S. Analis i obosnovanie metodov obezvrezhivaniya i utilizatsyi osadkov stochnykh vod biologicheskih ochistnyh sooruzheniy [Analysis and substantiation of the methods neutralization and utilization of of sewage sludge biological treatment plants] (2012) Transport. Transportnye sooruzheniya. Ekologiya, 2, pp. 18-32. (rus)

[15] Storchak, T.V. Otsenka stepeni zagryazneniya pochv goroda Nizhnevartovska [Estimation of the degree of soil pollution in Nizhnevartovsk] (2012) Vestnik NGGU, 1, pp. 62-68. (rus)

[16] Kozlov, M.N., Grachev, V.A., Khramenkov, S.V., Shchegolkova, N.M., Vanyushina, A.Ya., Agaryov, A.M. Ispolzovaniye pochvogruntov s vneseniyem osadkov sooruzheniy ochistki stochnykh vod i vodopodgotovki dlya vyrashchivaniya tehnicheskih kultur [The use of soils with addition of water and wastewater sludge for industrial crop cultivation] (2012) Water supply and sanitary technique, 10, pp. 72-77. (rus)

[17] Belyaeva, S.D., Korotkova, E.V. Novye natsionalnye standarty po ispolzovaniyu i razhmeshcheniyu osadkov stochnykh vod [New national standards for the wastewater sludge utilization and disposal] (2013) Water supply and sanitary technique, 4, pp. 5-9. (rus)

[18] Kirkham, M.B. Disposal of sludge on land: effect on soils, plants, and ground water (1974) Compost Science, 15(2) pp. 6-10. (rus)

[19] Bernadiner, I.M., Stepanova, T.A., Khoreva, P.V., Chevychelov, D.D., Neekolayev D.A., Bernadiner, M.N. Vybor optimalnykh napravleniy pererabotki i obezvrezhivaniya osadkov stochnykh vod [Selection of optimal trends of processing and neutralization of sewage sediments] (2012) Ekologiya i promyishlennost Rossii, 6, pp. 44-45. (rus)

[20] Smagin, A.V. Teoriya i praktika konstruirovaniya pochv [Theory and practice of designing soil] (2012), 544 p. (rus)

[21] Nefedov, B.K., Yermilov, V.V., Polyakov, V.S. Ispolzovaniye osadkov stochnykh vod v kachestve organomineralnogo udobreniya [Using of sewage sludge as organic mineral fertilizer] (2007) Ekologiya i promyishlennost Rossii, 11, pp. 42-45. (rus)

[22] Government standard 17.4.3.07-2001. Ohrana prirody. Pochvy. Trebovaniya k svoystvam osadkov stochnykh vod pri ispolzovaniy ih v kachestve udobreniy [Nature protection. Soils. Requirements for sewage sludge use for fertilization] (2001), 20 p. (rus)