Artículo de investigación

Comparative Analysis of The Chemical Composition of Bottom Sediments of Freshwater Basins of The Krasnodar Territory for Use as A Raw Material for Agricultural Production

Сравнительный Анализ Химического Состава Донных Отложений Пресных Водоемов Краснодарского Края в Качестве Сырья для Сельскохозяйственного Производства

Análisis comparativo de la composición química de los sedimentos del fondo de las cuencas de agua dulce delterritorio de Krasnodar para su uso como materia prima en la producción agrícola

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Abstract

Recently, there has been more and more demand for effective ways to use different types of natural mineral raw materials in agricultural production. Rivers of the Krasnodar Territory of Russian Federation are over-regulated, silted and have a sluggish flow, and removal of bottom sediments and their waste-free use is necessary. They can be used as a raw material for the production of fertilizers and animal feed additives. A comparative analysis of the river bottom sediments from the Albashi River and sapropel from an artificial lake in the Krasnodar Territory demonstrated that the content of organic substances and all studied macro- and

Аннотация

В последнее время для все большее внимание уделяется поиску эффективных способов применения разных видов природного минерального сырья в сельскохозяйственном производстве. Так как реки Краснодарского края Российской Федерации имеют повышенную зарегулированность, заиленность и вялотекущее течение, возникает вопрос очистки от донных отложений и их безотходного применения, которые возможно использовать в качестве сырья для производства удобрений и кормовых добавок для животных. При сравнительном анализе донных речных

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micronutrients was higher in the river bottom sediments compared to sapropel of the artificial lake. The authors also established that the studied samples can be classified as bottom sediments of the first use-capability class for agricultural production.

Keywords: river bottom sediments, sapropel, chemical composition, fitness class.

отложений реки Албаши и сапропеля озера искусственного происхождения Краснодарского края, установлено, что по содержанию органических веществ и всех изучаемых макро- и микроэлементов, в донных отложениях реки также наблюдалось преимущество, по сравнению с сапропелем искусственного озера. Выявлено, что изучаемые образцы относятся к донным отложениям 1 класса пригодности в сельскохозяйственном производстве.

Ключевые слова: речные донные отложения, сапропель, химический состав, класс пригодности.

Resumen

Recientemente, se presta cada vez más atención a la búsqueda de formas efectivas de utilizar diferentes tipos de materias primas minerales naturales en la producción agrícola. Dado que los ríos del Territorio de Krasnodar de la Federación Rusa han aumentado la regulación, la sedimentación y el flujo lento, surge la cuestión de la limpieza de sedimentos y su uso sin desperdicios, que pueden utilizarse como materia prima para la producción de fertilizantes y aditivos para piensos. Un análisis comparativo de los sedimentos fluviales del fondo del río Albashi y el lago sapropel de origen artificial del Territorio de Krasnodar encontró que el contenido de sustancias orgánicas y de todos los macro y microelementos estudiados en los sedimentos del fondo del río también mostró una ventaja en comparación con el sapropel de un lago artificial. Se revela que las muestras estudiadas pertenecen a los sedimentos del fondo del 1er grado de aptitud física en la producción agrícola.

Palabras clave: sedimentos de fondo de río, sapropel, composición química, clase de acondicionamiento físico.

Introduction

Sapropel is an organic silt material created in the lakes by the natural sedimentation of plant and animal substances for tens of thousands of years. It consists of a combination of fragments of higher plant tissues, pollen, sand, clay, and various mineral solutions (Plotnikov et al., 2018).

Sapropel is a valuable feed additive for farm animals and birds, which includes several specific biologically active substances that increase productivity and other economic traits of animals. Sapropels with a moisture content of not more than 65% can be used in the animal feed industry for the manufacture of all types of animal feed and vitamin premixes, as well as for the production of fertilizers (Perminova, 2008; Lü et al, 2017).

Currently, in Russia, sapropel is used in raw form, which negates the effectiveness of its use. In the production, the most widespread method for drying of sapropelic raw materials is using suspended drying. It is one of the most effective means of production intensification. The use of suspended drying allows reducing the processing time for certain materials using a higher speed of material movement (Perminova, 2008; Lü et al, 2017; Rizhinashvili, 2017).

Activation of the hydrodynamic environment in the drying apparatus allows intensification of the technological process without reducing the economic efficiency of the apparatus and ensuring the high quality of the finished product with the required residual moisture (Drying of sapropel, n.d.).

The upper layers of sapropel look like a yellow jelly, deeper layers are slightly more condensed. Sapropel is rich in macro- and micronutrients, vitamins and biostimulants. In addition to a significant amount of carotene, the sediment of freshwater lakes contains vitamins D, B_1, B_2 and B_{12}, folic acid, and others. It also contains calcium, phosphorus, sulfur and iron, as well as micronutrients such as iodine, cobalt, copper, manganese, molybdenum, bromine, boron, zinc, nickel, titanium, and others. Microorganisms that

produce antibiotics are also found in sapropel; they inhibit the activity of pathogenic microbes. Sapropel is rich in proteins, carbohydrates, lipids, and organic acids.

It should be noted that sapropel in different freshwater basins differs in qualitative composition; therefore, its chemical properties must be evaluated before use (Martyshev, 1973).

The steppe rivers of the Krasnodar Territory include rivers that flow through its territory north of the Kuban River. They fall directly into the Sea of Azov, or into a network of associated firths. The largest steppe rivers of the region include Eya, Chelbas, Beysug, Kirpili, Ponura, Sengeli, Ash, Albashi. Currently, all steppe rivers are divided by dams into many separate basins (small reservoirs), and there is practically no single stream from the upstream to the estuary. The layer of bottom silt deposits in some locations reaches a thickness of five m, and the underground nourishment is completely disrupted. Silting reduces the depth of steppe rivers, contributing to their overgrowing by aquatic vegetation. In many locations of these rivers, the areas occupied by reed, bulrush, and cattail thickets exceed 80% of water surface. Under conditions of low flowage, organic substances quickly accumulate in rivers, causing the eutrophication of their waters (Belyuchenko, 2015; Mamas, Ryabtseva, Solodovnik, 2012; On the problems of the steppe rivers of the Krasnodar Territory, n.d.).

The bottom sediments of the Krasnodar Territory steppe rivers are characterized by high sorption properties. Many aerobic microorganisms live in river silt, which includes the remains of aquatic organisms that have not been decomposed in the water column and mineral particles that gravitate to the bottom, which creates a zone rich in organic matter and favorable for the development of various groups of microorganisms. Spore-forming bacteria prevail in bottom sediments (about 75%). Cellulose-fermenting, pectolytic, methane-producing, and putrefactive bacteria and other groups are also common. Ammonifying, aminoautotrophic, thionic, sulfate-reducing microorganisms and micromycetes have been also isolated from samples of bottom sediments. Bacteria mineralizing protein compounds predominate in river silt. Various members of the genus *Pseudomonas* take part in the mineralization process, and spore bacteria are mineralized in inaccessible substances (Belyuchenko, 2015).

Silt deposits of the Krasnodar Territory steppe rivers are also characterized by a high content of humic acids. The flow rate of the steppe rivers is low – no more than 0.1 m per second due to over-regulation, therefore at the present time there are humified sediments 30-40 cm thick on the bottom of those rivers, and in several cases, the silt layer is 5-7 m thick (Mamas, Ryabtseva, Solodovnik, 2012).

The eutrophication of water basins has become one of the most serious threats to aquatic ecosystems in the world; it is especially harmful to water quality, and in the future may have a negative impact on public health (On the problems of the steppe rivers of the Krasnodar Territory, n.d.). Combined with the factors of climate change and human activity, eutrophication has expanded from small lakes in the temperate zone to water lakes in cold areas (cold water lakes). Due to the natural eutrophication of lakes and rivers, as well as anthropological activity, a large amount of silt deposits is formed, water basins decompose and turn into swamps. There are many ways to reduce the silting of lakes and rivers – for example, mechanical cleaning. However, currently, the utilization of sapropel and silt from the rivers is problematic. Therefore, the use of bottom sediments for feeding purposes is a very relevant topic (Blair et al., 2018).

Recently, there is more and more demand for effective ways to use different types of natural mineral raw materials to increase soil fertility. It is possible to produce fertilizers for cultivated plants using sapropel, both in solid and liquid form. As a high-quality mineral-organic fertilizer, sapropel can be used for many types of soil and plants. Sapropel is classified as an environmentally friendly and effective agricultural product of natural origin. Therefore, one of the most promising methods of bottom sediments use is processing and production of effective plant growth biostimulants. The best results are usually achieved using liquid forms of sapropel fertilizers (Plotnikov et al., 2018; Agafonova et al., 2018).

Several researchers have found that sapropel fertilizers increase the yield of agricultural plants by 9-16% and protect them from the effects of soil salinity (Agafonova et al., 2018; Zaimenko et al., 2018).

N. Naumova et al. have found that sapropel had no effect on fruit yield of tomato, but the lycopene content in fruits with the use of sapropel was 80% higher (34 mg/kg vs 19

mg/kg), thus the quality of the fruit was improved (Naumova et al., 2017).
N.A. Yurina et al. (2018) have also discovered a positive effect of the use of lake bottom sediments as a feed additive for poultry: a 2.5-3.0% increase in the growth rate of young laying hens, a 2.0-3.3% increase in egg productivity, and a 2.2-4.0% decrease in the feed cost per unit of production (Yurina et al., 2018).

Rivers of the Krasnodar Territory of Russian Federation are over-regulated, silted and have a sluggish flow, and removal of bottom sediments and their waste-free use is necessary. Therefore, a comparative analysis of the chemical composition and content of humic acids in lake and river silt sediments of the Krasnodar Territory is required.

The aim of the research was to assess the suitability of river silt as a raw material for the production of fertilizers and feed additives for animal husbandry.

Materials and methods

Lake silt (lake of artificial origin in Elizavetinskaya village of Krasnodar Territory with an area of 7 ha) and river silt from a section of regulated flow at a distance of 54.0-58.5 km from the estuary of the Albashi River in the Leningrad district of the Krasnodar Territory (area of 7 ha) were sampled for laboratory studies.
Bottom sediments were sampled for analysis from control points using bottom samplers and the envelope method and later combined into a laboratory sample. Sediments were collected from a depth of 1.0-1.2 m from the surface.

In the course of the research, the following was determined in the samples: mass fraction of moisture, total nitrogen, raw fiber, crude ash, calcium, phosphorus, sodium, magnesium, potassium, iron, zinc, manganese, copper, cobalt, lead, arsenic, cadmium, mercury using the test methods described in State Standards and Methodical Guidelines in the "Argus" test center, Krasnodar.

Albashi is a steppe river flowing through the Azov-Kuban plain. It flows through the Leningrad and Kanevskoy Districts of the Krasnodar Territory from east to west. Its sources are located at absolute altitudes of no more than 50 m, 5 km west of the of the Leningradsky village of the Krasnodar Territory. From the riverhead to Albashinsky estuary, the length of the river is almost 57 km.

At its source, the Albashi River is a creek (galley) overgrown with bulrush and has a sluggish flow. During the drought season, the river often dries up in several locations, splitting into separate reaches. The main sources of river nourishment are thawed snow and rainwater. The river bottom is heavily silted and requires urgent removal of sediments. The hydrochemical regime is favorable for the use of the river for fish farming.

Feed resources are typically freshwater forms of plants and animals: macrophytes, phytoplankton, zooplankton, and zoobenthos. All of these groups have a wide range of adaptability and a relatively stable level of growth throughout the vegetation period, which allows classifying the feed resources as formed.

The artificial lake in Elizavetinskaya village of the Krasnodar Territory is a small reservoir with an area of 7 ha. The purpose of its use is the stocking of commercial fish. However, a high degree of bottom silting encumbers this.

Federal State Budgetary Scientific Institution Krasnodar Research Center for Zootechnology and Veterinary Medicine at the Krasnodar Regional Scientific Research Center is actively developing the methods of use of bottom sediments of the lakes of the Krasnodar Territory as ingredients for feed additives. In this regard, we decided to conduct a comparative chemical analysis of the silts from the reservoirs under study.

Results

The chemical composition of bottom sediments calculated as natural substances is presented in Table 1.

Content	Sample № 1 Lake bottom sediments	Sample № 2 River bottom sediments
Mass fraction of total nitrogen, %	0.40	0.82
Mass fraction of raw fiber, %	7.8	4.0

Mass fraction crude ash, %	40.78	50.34
Mass fraction calcium, %	0.29	1.33
Mass fraction phosphorus, %	0.20	0.27
Sodium, mg/kg	36.6	82.6
Magnesium, mg/kg	148.2	464.4
Potassium, mg/kg	326.3	662.4
Iron, mg/kg	7859.3	8549.3
Zinc, mg/kg	21.3	22.0
Manganese, mg/kg	74.9	188.0
Copper, mg/kg	4.40	5.68
Cobalt, mg/kg	1.75	4.06
Lead, mg/kg	2.05	2.65
Cadmium, mg/kg	0.05	0.05
Mercury, mg/kg	0.005	0.006

It was established that the mass fraction of total nitrogen was almost two times higher in river bottom sediments than in lake sapropel. By contrast, lake bottom sediments had higher raw fiber content, which is most likely due to the smaller area of the lake and greater the amount of vegetation on its shore. Crude ash content in the bottom sediments from the regulated area of Albashi River was 23.4% higher, calcium content was almost 4.8 times higher, phosphorus content was more than two times higher. The river bottom sediments were also higher in the content of all studied macro- and micronutrients compared to the sapropel of the artificial lake.

According to State Standard R 54000-2010, sapropel of the first use-capability class for use in agricultural production should contain (not more than): cadmium – 3 mg/kg, zinc – 300 mg/kg, lead – 50 mg/kg, copper – 100 mg/kg, mercury – 1.0 mg/kg, manganese – 500 mg/kg, cobalt – 20 mg/kg. Consequently, the studied samples can be classified as the bottom sediments of the first use-capability class for agricultural production.

Physical-chemical indicators of these sediments allow to classify them as organic-calcareous. The content of particles in samples of more than 10 mm in size did not exceed 20%, the content of ballast mechanical inclusions did not exceed 1.0%, the pH of the salt extract 6.0 in the first sample was, and 6.1 in the second sample.

No pathogenic bacteria (including E. coli, enterococci, staphylococci, clostridia) and viable eggs or larvae of helminths were found in the samples.

Conclusion

Both sapropel from the artificial lake and bottom sediments from the regulated flow of the Albashi River can be attributed to the first use-capability class for the agricultural production and it is desirable to use them as raw materials for the production of feed additives (as sources of mineral substances), as well as fertilizers for crop farming.

References

Agafonova, L., Alsina, I., Sokolov, G., Kovrik, S., Bambalov, N., Apse, J., Rak, M. (2018). New Kinds of Sapropel and Peat Based Fertilizers. Environment. Technology. Resources. Proceedings of the International Scientific and Practical Conference, 2(1), 20-26. Retrieved December 17, 2018 from:

http://journals.rta.lv/index.php/ETR/article/view/271/648

Belyuchenko, I.S. (2015). Malye reki Kubani, sostoyanie i perspektivy razvitiya ikh bioty [Small rivers of the Kuban, the state and prospects of development of their biota]. Nauchnyi zhurnal KubGAU, 106(2), 22.

Blair, N.E., Leithold, E.L., Thanos Papanicolaou, A.N., Wilson, C.G., Keefer, L., Kirton, E., Vinson, D., Schnoebelen, D., Rhoads, B., Yu, M., Lewis, Q. (2018). The C-Biogeochemistry of a Midwestern USA Agricultural Impoundment in Context: Lake Decatur in the Intensively Managed Landscape Critical Zone Observatory. Biogeochemistry, 138(2), 171-195.

Drying of sapropel. Retrieved December 9, 2018 from: http://www.parmatech.org/sapropel1.html

Lü, X.T., Lü, Y.L., Song, S., Wang, T.Y. (2017). Eutrophication in Cold-Water Lakes Driven by Combined Effects of Climate Change and Human Activities. Acta Ecologica Sinica, 37(22), 7375-7386.

Mamas, N.N., Ryabtseva, O.V., Solodovnik, E.V. (2012). Studies in the floodplains of the steppe zone of the Krasnodar Territory [Issledovaniya v poimakh rek stepnoi zony Krasnodarskogo kraya]. Nauchnyi zhurnal KubGAU, 83(9), 15.

Martyshev, F.G. (1973). Pond Fisheries. Moscow, 235.

Naumova, N., Nechaeva, T., Smirnova, N., Fotev, Yu., Belousova, V. (2017). Effect of Sapropel Addition on Selected Soil Properties and Field Tomato Yield in South West Siberia. Asian Journal of Soil Science and Plant Nutrition, 1(1), 1-11.

O problemakh stepnykh rek Krasnodarskogo kraya. [On the problems of the steppe rivers of the Krasnodar Territory]. AzNIIRKh [Azov Scientific-Research Institute of Fishing Industry]. Retrieved September 12, 2018 from: http://azniirkh.ru/novosti/o-problemah-stepnyih-rek-krasnodarskogo-kraya/

Perminova, I.V. (2008). Guminovye veshchestva – vyzov khimikam XXI veka [Humic substances – a challenge to chemists of the XXI century]. Khimiya i zhizn, 1, 50-55.

Plotnikov, A.M., Balueva, N.A., Sozinov, A.V., Vafin, N.N. (2018). Vliyanie trepela, sapropelya i mineralnykh udobrenii na urozhainost i kachestvo zerna pshenitsy v zvene sevooborota [The yield of tripoli, sapropel and mineral fertilizers on the yield and quality of wheat in a stage of crop rotation]. Bulletin of Kurgan State Agricultural Academy, 2(26), 49-51.

Rizhinashvili, A.L. (2017). Small and Shallow Previously Unstudied Lakes: Land-Use, Overgrowth and Eutrophication. Management of Environmental Quality: An International Journal, 28(1), 120-136.

Yurina, N.A., Kononenko, S.I., Vlasov, A.B., Danilova, A.A., Gneush, A.N. (2018). Natural Feed Additive in Rations of Laying Hens. Journal of Pharmaceutical Sciences and Research, 10(7), 1860-1862.

Zaimenko, N.V., Didyk, N.P., Pavliuchenko, N.A., Ivanytska, B., Kharytonova, I.P., Rositska, N.V. (2018). Natural Silicates Mixed with Organic Fertilizers Enhance Corn Adaptation to Salt Stress and Improve Physical Characteristics of Sandy Soil. Journal of Crop Improvement, 32(2), 188-207.