Ecological engineering as a mean to reduce the anthropogenic impact of production on biota

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Abstract. The article deals with the project and implementation of ecological engineering technological measures in practice. As a result, the impact of sub-sludge waters, flooding and pollution of the surrounding area to the sludge storage of alumina plant decreased. Commissioning of a new sludge map with waterproofing screen has reduced the pollution of groundwater and surface water sources. The construction of an interception system of filtration water around the sludge storage reduced the groundwater level by more than 1 m and provided conditions for the restoration of disturbed lands. Technological solutions for the restoration of disturbed lands using substrates made of non-toxic technogenic materials have been developed. It was found that the use of a neutralizer (ammonium sulfate) and sludge from treatment facilities as the main component of the soil substrate leads to a change in the pH value from 9.8 to 7.5 pH. In this case, there was a transition from the strongly alkaline reaction to almost neutral. The use of natural and technogenic sources for recultivation will ensure the creation of an artificial agroecosystem in the area of the existing industrial enterprise and reduce the anthropogenic impact of production on biota.

1. Introduction
As a result of human industrial activity there is a technogenic migration of significant amounts of diverse substances, most of which pollute the environment. The direct consequence of this impact of industrial production is the formation and development of technogenesis processes. In the process of chemical and metallurgical production there is a constant strengthening of diverse anthropogenic impact on biota.

Ecological engineering allows realizing the idea of sustainable development of any industrial enterprise that can simultaneously reduce the harmful effects on the environment and improve the efficiency of technological processes [1].

The use of the principles of ecological engineering as the main vector of industrial development began relatively recently, but is becoming increasingly widespread, both in our country and abroad [2, 3].

JSC «RUSAL Achinsk» is the largest plant of aluminum branch in Russia which is engaged in production of alumina (project capacity: over 1 million tons a year). As a result of the technological process, large amounts of waste are formed, which accumulate in the sludge collectors. Today the release of pollutants into the atmosphere directly from the sludge storage is practically absent, since nepheline sludge and ash and sludge waste are fed through the sludge pipelines in liquid form. Dusting in static storage (wind erosion) from the slopes also remains at the same level, due to the fact that part of the surface of the slopes is more or less cemented, and some have high humidity. Around the sludge
storage of alumina plant as a result of an emergency, there is a contamination of the surrounding area and spills of sub-sludge waters. They are characterized by the following main indicators: pH=11.85, mineralization (dry residue) - 23 g/l, oxidation by O2 – 1.072 g/l, total hardness - 15 mg-EQ/l, carbonate hardness - 2120 mg-EQ/l, chlorides - 590 mg-EQ/l, sulfates - 40 mg-EQ/l, ammonium nitrogen, iron – less than 1%. Since the sludge storage facility was put into operation almost 50 years ago, its project solutions do not meet modern environmental requirements. Thus, the sludge map No. 1 has no waterproofing screen; therefore, during the storage of waste, drainage and filtration waters actively pollute the surrounding area and cause the formation of an "alkaline" crust on the soil surface [4, 5].

Currently, the sludge map No. 1 is almost filled, and it is necessary to withdraw it from service with subsequent conservation and recultivation.

It was decided to carry out its reconstruction using the techniques of ecological engineering to reduce the negative impact of sludge storage of alumina plant on the environment.

2. Purpose of research
The aim of the study was the development and practical implementation of technological measures of ecological engineering. They provide reduction of harmful effects of sludge storage on the surrounding area with the reconstruction and construction of new facilities. They meet the regulatory requirements of the current legislation and the introduction of technology for the restoration of disturbed lands in the area of the current chemical industrial production.

3. Obtained results
The sludge map No. 3 was designed, built and put into operation to reduce the negative impact on the environment from production waste of JSC "RUSAL Achinsk", using the principles of ecological engineering «figure 1». The map has an anti-filtration screen made of a polymer membrane based on high density polyethylene and is laid on the foundation of the sludge map and on the inner slope of the enclosing dam.

![Figure 1. Laying the anti-filtration screen at the foundation of the sludge map.](image1)

These engineering works were aimed primarily at reducing the load on the components of the environment. Local exceedances of background values in the soil cover in the area of sludge storage are mainly associated with soil contamination in technogenic accidents. A characteristic feature of the land from the surveyed area around the sludge storage of alumina plant is the alkaline reaction of the soil environment. PH value of aqueous extract from different sites ranged from 8.1 to 10.7 pH. Alkaline soil environment prevents the assimilation of micro- and macronutrients for plant development. The alkalinity of the soil in the surrounding area to the sludge storage is mainly due to the pollution of its sub-sludge waters containing high concentrations of potassium alkali. However, it is known that potassium is one of the main nutrients that affect the number of plants. With optimal potassium content in the tissues, plants better retain water. They are easier to tolerate drought and
frost, increases resistance to various diseases. The study of features of functioning of agroecosystem in various ecological conditions is essentially important for creation of productive and steady soil objects in the conditions of technogenesis. In case of technogenic contamination of biosphere components, soil biota is able to detoxify various compounds presenting in the soil and affecting the environment and the quality of cultivated plants [6,7].

In order to prevent contamination on the surrounding area to the sludge storage, the system of interception of filtration water was projected and put into operation in 2017. For this purpose, a channel with a depth of more than 4 m and a width of 20 m was built with the installation of pumps for pumping the filtrate into the bypass channel of the sludge map. These engineering and technological measures allowed the elimination of infiltration of sludge water in the underground water, their drainage to surface waters and territory flooding with polluted water. The effectiveness of eco-engineering techniques use is also confirmed by monitoring of the groundwater quality in terms of pH. Thus, with the beginning of the construction of map No. 3 (2014) and, especially, with the beginning of the construction of the drainage interception system (2016), there is a decrease in the pH in groundwater from map No. 3 from 10.5 to 9.5 pH. The withdrawal from the work of map No. 1 and its further planned conservation and remediation should contribute to a further reduction in the volume of filtration and the impact on groundwater pollution.

Ecological engineering measures have shown the following results. Laying of the anti-filtration screen on the foundation of the sludge map and commissioning of the system of interception of filtration water of the sludge storage in the form of a drainage ditch, laid along the contour of the sludge maps, lead to a positive result and further flooding of the territory of the recultivation area is excluded. The water level in the channel in September 2018 was at the lower level.

A survey of the surrounding area to the sludge storage on the north side, conducted in May-June 2018, indicates the drainage of previously flooded sludge water areas, the water level of which fell by 1.05 m during the year. The technical measures carried out for the construction of the water level lowering system have led to the leveling of technogenic intervention and created favorable conditions for the return of land to agricultural use, ensuring the stability of the agroecosystem.

The restoration process of ecological integrity of territories includes management of all kinds of physical, chemical and biological soil disturbances, such as soil pH, fertility, microbial community and various soil nutrient cycles [8].

The localization of land areas and their technical and biological recultivation with the replacement of contaminated soils with non-toxic ones is possible for implementation in the short term from the complex of engineering measures for the restoration of disturbed lands. The task number one in this part of the research was the search of successful experience in Russian and foreign researches on the preparation of such "artificial soil" [9, 10].

The experimental area, the most exposed to pollution by the sub-sludge waters, was chosen to assess the change in soil indicators from the contaminated area in the surrounding area to the sludge storage of JSC “RUSAL Achinsk” from the north side figure 1. In summer, the components of the substrate were brought to this experimental area and preparatory work was carried out for its preparation. Taking into account the formation of potassium-sodium alkaline "crust", with deep plowing of the substrate components and when plowing the surface layer of the soil on the experimental area, preliminary neutralization of the soil contaminated with alkaline waters with ammonium sulfate was carried out. The technology with preliminary neutralization with ammonium sulfate and with the subsequent introduction of overburden sand extraction with a layer of at least 20 cm received quite good results on the germination of perennial grass.

Monitoring pH research of water extraction from soil samples with potentially fertile soil layer after neutralization with chemical reagents showed that after soil neutralization with ammonium sulfate the index decreased from 9.82 (10.07.2017) to 8.12 pH (01.10.2018). The dynamics of changes in the pH of soil samples after neutralization with ammonium sulfate showed that this technique is quite effective and at the same time is easy to implement. This technology can be promising and, as shown by field tests, leads to a satisfactory germination of green mass.
In further researches, the scheme of recultivation of the disturbed land was used «figure 2».

**Figure 2.** Recultivation scheme of disturbed land.

From the substrates of soil samples taken from various plots of the experimental area, satisfactory results on the normalized pH of the soil showed a mixture of substrates from contaminated soil with sludge from the left-bank treatment facilities of Achinsk and soil-plant layer from the sand quarry. Industrial tests on the formation of substrates on various plots of the experimental area showed good germination and productivity of the grass cover «figure 3 and figure 4».

**Figure 3.** The territory of the experimental area before the ecological engineering activities (September 2016).

**Figure 4.** The territory of the experimental area after the recultivation works (September 2018).

There is a clear advantage of substrates from the soil-plant layer in comparison with technogenic-contaminated soil, according to the results of agrochemical and chemical-toxicological analysis carried out in the accredited laboratory of the FSBI "Krasnoyarsk reference center of the federal service for veterinary and phytosanitary control". In the formation of the substrate, the soil was used, obtained in the process of sand extraction in the floodplain of the Chulym river and sludge from the left-bank treatment facilities of Achinsk 5-year shelf life.

As a result of the work carried out, there is a decrease in pH to 7.5 units, a decrease in the concentration of potassium and sodium exchange and an increase in the content of organic matter. It is also established that the use of sludge from treatment facilities as the main component of the soil substrate leads to a significant change in the pH value. There is a transition from a highly alkaline reaction of the medium to a practically neutral one. The presence of heavy metal compounds in the prepared substrates was not observed.

**4. Conclusion**

The technological measures of ecological engineering in the construction of a new sludge map with the installation of a waterproofing screen, and the introduction of a system of interception of drainage
water provided a reduction in the harmful anthropogenic impact of sludge storage of non-ferrous metallurgy on the environment. The conducted industrial tests are confirmed by the data of agrochemical and chemical-toxicological analysis of soil samples and indicate the suitability of the proposed scheme of recultivation and sanitation of the polluted area with sub-sludge waters near the sludge storage. Tests of the technology have shown that one of the options for the restoration of disturbed lands can be the use of substrates prepared from non-toxic technogenic materials. The use of sources of natural and technogenic origin will not only increase soil fertility, but also will return at least partially removed elements in the biological cycle of substances.

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