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Development of Eco-Friendly Technology of Colloidal Deposit Utilization in Pulp and Paper Industry

Irkutsk National Research Technical University
A.V. Bogdanov, A.S. Shatrova, O.L. Kachor

A.V. Bogdanov

A.S. Shatrova

O.L. Kachor

Development of eco-friendly technology for intensive processing of sludge-lignin deposits, which is based on the best available utilization methods, is one of the urgent tasks to be addressed. The proposed technology to recover deposits in the storage pits of Baikalsk Pulp and Paper Mill on the basis of natural freezing allows reducing the costs and enhancing environmental safety of the project.

Key words: sludge-lignin, sludge storage pits, pulp and paper industry, Baikalsk Pulp and Paper Mill, utilization, freezing, best available technologies.

Today, the management of wastes including waste formation, utilization, and disposal is a critical issue that requires urgent actions. Annually, up to seven billion tonnes of wastes are produced in Russia, only two tonnes being recyclable materials. The waste of pulp and paper industry makes 15% of total waste amount. Sludge-lignin formed as a side product of biological and physico-chemical treatment of waste-water and disposed in sludge storage pits represent the base of the wastes that are not currently recycled. More than 30 million m^3 of sludge lignin is deposited within the territories of the enterprises located in Baikalsk region, near lake Baikal, Bratsk and Ust-Ilimsk Dams. These deposits cause severe damage to the environment. In worldwide practice, there are no data on recultivation of land degraded by sludge-lignin deposits [1, p. 7-8]. This fact is explained by the limited use of physico-chemical treatment in the pulp and paper enterprises and difficulties in understanding the principles of substance interaction during physical, chemical, and biological processes that take place in this anthropogenic substrate. In addition, the impact of environmental conditions (temperature, insolation, ground water, precipitation) on these processes has not been sufficiently studied. The absence of real decisions on sludge-lignin utilization is explained by its complex physico-chemical and dispersion composition, high wetting ability rates basically caused by bound water, and labour-intensive and rather complex treatment technology. The existing methods of sludge-lignin utilization, such as joint grouting, electrosmosis, iron sulfate-treatment, vermiculating, transpiration or simple dumping, are currently not applied.

According to the federal target program "Protection of lake Baikal and the socio-economic development of the Baikal natural territory for 2012-2020", Baikalsk Pulp and Paper Mill is defined as one of the most well-known sources of pollution of lake Baikal. Considering the peculiarities of natural resources development within the basin of lake Baikal, which are defined by the need to conserve its unique ecosystem as a part of the World Heritage, development of eco-friendly technology of colloidal deposit utilization based on the best available utilization methods is one of the critical issues.

Colloidal deposits produced by Baikalsk Pulp and Paper Mill (approx. 8 mill. m3) are stored in the special pits with multilayered hydro-fuge insulation made of natural and synthetic materials and characterized by earthquake resistance up to 9 ball intensity in MSK. The proportion of various substances in deposits is as follows: lignin (40-45%), fiber (15-20%), sludge (15-20%), ash residue (10-20%). Since aluminum oxide and polyacrylamide are used as coagulant in chemical treatment of waste-water, their residual concentrations are found in sludge-lignin deposits [2, p. 60-63]. The deposit sample of 50 g includes: aluminum oxide (expressed as aluminum ion) up to 5 g, polyacrylamide – up to 1.2 g. The storage pits are located in two sites, close to Baikalsk city and Solzan, Babkha settlements. Solzan site covering 105 hactares of land includes storage pits № 1–10 (Fig. 1). The area of Babkha site is 33 hectares and it comprises storage pits № 12–14. Intermediate storage pit № 11 is located in the industrial site of Baikalsk Pulp and Paper Mill.

In order to evaluate the environmental changes within the landfill site where sludge storage pits are located, the samples of soil, plants, ground and above-sludge waters were collected and analyzed during 2009-2016. It was identified that the concentration of benzapyrene exceeds 3 times the MAC value, while concentration of heavy metals – 2-7 times. The toxicity test of soil via Lepidiumsativum, ChlorellavulgarisBeijer, DaphniamagnaStraus revealed that the wastes stored in the sludge storage pits influence the toxicity of soil which is categorized as moderately toxic.

In the samples collected in the observation wells of water intake, the concentration of the substances mentioned below exceeds MAC for fishery water: formaldehyde up to 1.3-2.9 MAC, petroleum products up to 6.2 MAC, aluminum 3.2-19.7 MAC, iron up to 8.9 MAC [3, p. 192-193]. The obtained data on the environmental conditions do not significantly differ from that obtained 5 years ago (average deviation does not exceed 5-8%). The analysis of plant samples (needles of Siberian pine (Pinussibirica Du Tour)) collected within the study area revealed that the concentration of heavy metals does not exceed the normative values.

Fig. 1. Location of Baikalsk Pulp and Paper Mill storage pits

Thus, the data obtained on environmental condition monitoring have revealed that concentration of pollutants in Solzan site has remains unchanged over the past 5 years, which, in its turn, shows that the pollution level has achieved a critical value. However, this fact does not indicate stability in ecological balance as it can be easily disturbed by various natural and technogenic phenomena (mudflow, earthquake more than 9 ball intensity in MSK, accidents caused by inadequate technological decisions, etc.). The results of the field work showed that deposits accumulated in Solzan site have different morphological and physico-chemical composition. The index of wetness ranges from 74% (storage pit № 5, average value) to 86% (storage pit № 8, average value). Based on the obtained data, 3-D image of colloidal deposit (storage pit № 2 with aluminum oxide) was created using software Surfer (Fig. 2). A great amount of aluminum oxide allows using ash of sludge-lignin as a sorbent to treat waste waters of different composition. In addition, it can be used as a component of raw material for water cement production [4, 5]. As shown in Fig. 2, concentration of aluminum oxide increases up to 25% with depth.

Fig. 2. Concentration of aluminum oxide (%) in sludge-lignin deposits (storage pit № 2)

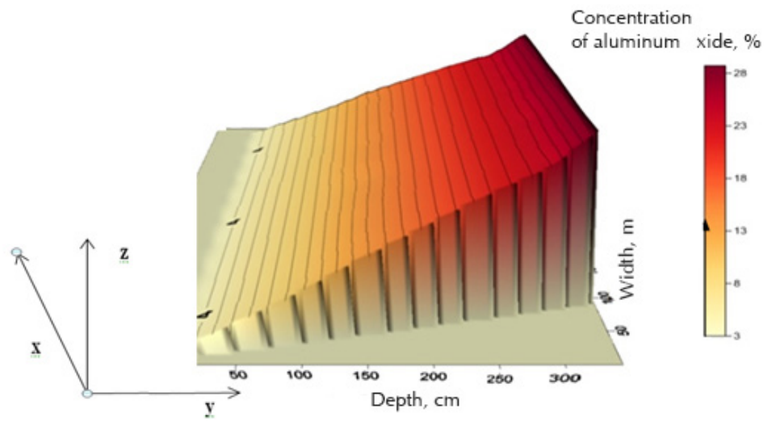
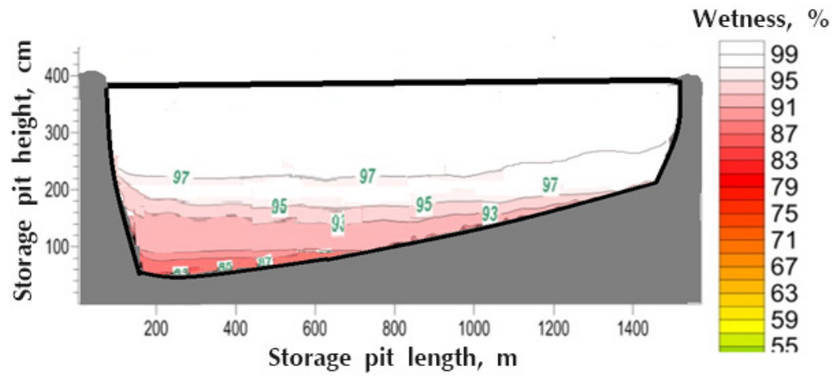


Fig. 3 shows 2-D image of deposit accumulation in storage pit № 2. As shown, the wetness index decreases from 98% to 83% with depth, which is certainly a natural result of compaction. Vertically, the wetness index of deposit is not homogeneous as well. Such a wetness profile and distribution of minerals are due to the pit filling technology used in Baikalsk Pulp and Paper Mill, i.e. liquid sludge is poured at the east side of the pit, and as it moves along an inclined bottom to the west side of the pit, it gets compacted.

Based on the existing and obtained data on morphological and physico-chemical composition, lignin deposits accumulated in the pits of Baikalsk Pulp and Paper Mill were classified. This allowed defining the utilization technology in accordance with NDT GOST R 55827-2013: "with regard to resource potential, need to protect environment and human health".

In our opinion, regardless of the technology used, first of all, it is essential to reduce the amount of sludge lignin, which, in its turn, will proportionally cut technical-and-economic costs [6, p. 99-107]. The conducted study has revealed that natural freezing is the most effective method to reduce the amount of sludge-

Fig. 3. 2-D image of wetness profile in storage pit № 2



lignin. Precisely, the amount is reduced due to the removal of snow cover from the storage pits (for example, via gas-jet wind machines) as it serves as a special screen that prevents complete freezing. In addition, various biological processes which are exothermal take place in sludge-lignin deposits.

The conducted office and field work has shown that freezing destroys the colloidal structure of the deposits and reduces the amount of sludge-lignin by 30-40% depending on the composition and wetness index by 6-11%. Besides, the technology contributes to reducing specific resistance of the deposits and leads to 4–7-fold decrease in the concentration of benzapyrene, the main toxic element.

The proposed utilization technology allows reducing the amount of sludge lignin produced by Baikalsk Pulp and Paper Mill due to the destruction of its colloidal structure. As a result of lignin degradation, three types of materials can be obtained: destroyed colloidal percipitate (35%), mineralized above-sludge waters (5%), demineralized above-sludge waters (60%), which flow into the prepared-in-advance storage pit № 2 (clarifier) due to the gravity force. Have residual pollutants precipitated, purified water is transported to the pond-aerator of Baikalsk Pulp and Paper Mill and, then, to Lake Baikal. The destroyed colloidal precipitate and mineralized water are pumped in cascade from pit № 7 to the downstream pits until the pits are full. In order to obtain eco-friendly concrete, ashes mixed with 10% concrete M400 are added to the precipitate from pits № 11,13,14 through the sluice-discharge line. Ash and concrete are mixed. Finally, eco-friendly engineering constructions – confinement – are built. To ensure gravity-driven flow of storm water, the surface of confinements should be inclined at an angle of 2 degrees. They should be also fitted with a system of drain pipes to drain water to pit № 2 for the preliminary treatment under natural conditions. Within the territory where confinements are located, such light constructions as hothouses, recreational sport facilities can be built. In addition, the empty pits can be used as ponds for fish farming and sport activities.

The proposed technology to recover deposits in the storage pits of Baikalsk Pulp and Paper Mill on the basis of natural freezing allows reducing the costs and enhancing environmental safety of the project. The expected ecological effect is projected to reach 6.5 billion of rubles.

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Formation of Professional Competences for Future Environmental Engineers Based on the Interdisciplinary Approach

Kazan National Research Technological University
A.E. Irismetov

The article discloses new requirements towards future environmental engineers, who will be conducting environmental protection under new socio-economic conditions. The definition of professional competency of an environmental engineer is determined.

Key words: professional competency of environmental engineers, World Trade Organization, international trade, ecological problems.

In the framework of Russia's accession to the World Trade Organization (WTO) the new rules concerning the process of international trade, new standards for trading products, norms and principles, requirements for ecolabelling of goods and products have been introduced. These changes concern the issues of international relations' regulation in the sphere of environmental protection with an aim to preserve rational management of natural resources. This is strongly tied with the fact that current ecological situation can be characterized by a high level of ecological disaster risks, an increase of anthropogenic influence on nature, that require constant attention to the ecological problems and their efficient solution [1, pp. 216-218]. The most essential part of ecological problems' solution is the interdisciplinary approach to those phenomena of material world that are based on the biological laws, but are getting more and more involved in the spheres of social, technological, economical and political interests.

The accession of Russia to the WTO sets new requirements towards specialists, who are working for the environmental protection and are assuring environmental control of goods and products. These specialists are prepared by engineering universities, among which is the Kazan National Research Technological University. The topical issue of training environmental engineers is the need to foster professional competency as a holistic integrative ability of a specialist that ensures his/her readiness for the efficient resolving of appearing problems.

In order to follow the new requirements set by the WTO, environmental engineers have to focus on the new standards, norms, by-laws, statutory regulation of the environmental state, methods and means for assessing the current state of the environment and its protection from anthropogenic influence. Thus, their professional competency has to include new knowledge, skills and professionally important personal attitudes that ensure efficient professional activities under the new conditions and allow for the environmental engineers to constantly develop their competency in the framework of dynamically changing conditions of the professional activities.

The World Trade Organization guides countries to follow and implement international standards – International Organization for Standardization (ISO), which assure an integrated international system of requirements towards the quality management of goods and services. One of the most important international

A.E. Irismetov