Processing red mud as a factor of removing the risk of environmental disasters: RUSAL experience

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Abstract. The paper considers the current problem of waste management of aluminum production in the Krasnoyarsk Territory. The negative consequences of the existence of sludge collectors of aluminum production for the natural environment and the population of the region are shown. The analysis of the consequences of environmental disasters, such as cancer in the population, chemical pollution of groundwater and surface water caused by leakage of hazardous substances, is presented. The experience of RUSAL, as well as international experience in the field of waste processing is presented.

1. Introduction.
Currently, one of the pressing environmental problems in Russia is the problem of waste management. The composition of production waste becomes more componential, new substances appear that also have a negative impact on the environment, on human life and health. In order to reduce the amount of waste generated and reduce its negative impact on the environment, on human well-being and health, as well as in order to obtain secondary raw materials, energy or products with certain consumer properties, various methods of waste disposal are used.

The significant problem is the waste of aluminum production, which today is especially acute and, in fact, unpredictable in the Krasnoyarsk Territory, where there are aluminum giants that produce semi-finished products, both for their own needs and for further deeper processing. Among them are RUSAL Krasnoyarsk (primary aluminum) and RUSAL Achinsk (alumina production). A huge problem is the sludge accumulated over the entire period of their activity and already estimated in million tons. Their impact on the environment is enormous and is already comparable to a delayed environmental disaster. This is compounded by the fact that the disposal processes of these hazardous accumulations over decades of operation are only at the level under discussion. Due to the lack of efficient processing technologies, the bulk of the red mud is not used and is stored in special collectors. They have a negative impact on the environment [1].

The purpose of the paper is to draw attention to solving the acute environmental problem that arose in the Krasnoyarsk Territory in connection with the activities of aluminum production enterprises.

Placing storages of large-tonnage waste generated during the production of aluminum in large cities of the Siberian region (Krasnoyarsk, Bratsk, Irkutsk, etc.) poses a serious threat to the population and natural resources in the absence of effective methods for their disposal. In the aluminum industry, red mud (RM), the solid residue of bauxite and nepheline after hydrochemical processing and extraction of alumina, is the largest in terms of the amount of waste.
The world has accumulated more than 1.5 billion tons of red mud. Each sludge repository occupies 50-100 hectares of land 30–50 m high, contains tens of millions of tons of highly moist (60-90%) finely dispersed and plastic material [2].

Red mud is formed during the purification of bauxite (the main raw material for the production of aluminum) in the production of alumina in the so-called Bayer process (the process for producing pure aluminum oxide). The red mud, from which aluminum oxide is removed, is contaminated with alkali and therefore poses a danger to the environment and humans: when it comes into contact with the skin, it begins to corrode. For each ton of aluminum oxide produced, 360 to 800 kg of sludge is produced [3].

The existence of the OAED facilities (objects of accumulated environmental damage), which are also the sludge collectors of aluminum production, is fraught with serious negative consequences for the natural environment and the population. Adjoining lands and surface water bodies, as well as waters under objects, are polluted by a wide variety of organic and inorganic substances, dangerous microorganisms, the set of which determines the type of activity that generated these objects. Among the pollutants of organic and inorganic nature are for example, heavy metals, petroleum hydrocarbons of various degrees of transformation, as well as poorly soluble chemical compounds in water, among which the most dangerous are polycyclic aromatic hydrocarbons, polychlorinated aromatic compounds [4].

2. Materials

Currently, Russian aluminum smelters generate a significant amount of solid waste that is hydraulically directed to sludge fields. The latter are hydraulic structures, inside the dams, the wastes are washed, and the liquid part of the pulp is separated and returned to the sludge disposal system. It is known that the consequences of the placement and storage of waste in sludge fields and landfills lead to high costs in the operation of sludge fields, cause the loss of valuable components for electrolysis (F, Al, etc.), and also require compensation for significant environmental damage. Environmental damage is caused, first of all, by chemical pollution of groundwater, which occurs as a result of filtration losses of industrial water, introduced into natural aquifers. During the operation of aluminum smelters, each of them has accumulated gigantic volumes of finely dispersed fluorine, sulfate and carbon-containing wastes, which are a mechanical mixture of finely dispersed dust from electrostatic precipitators, gas treatment sludge and flotation tailings [5].

Enormous environmental damage is also caused by disasters such as in Hungary near the town of Ajka, where one of the largest man-made disasters occurred in the 21st century and in the history of the country. As a result of the destruction of the toxic waste tank at an aluminum plant 160 km west of Budapest, about 700 thousand cubic meters of red mud were spilled [6].

The sludge, which is waste produced during aluminum manufacture, swept cars off roads and damaged bridges and homes, forcing the evacuation of 400 residents. About 7,000 people have been directly affected by the spill.

So far, about 1m³ of sludge has leaked from the reservoir. Seven towns, including Kolontal, Devecser and Somlovasarhely, have been affected.

Doctors said that the injured were being closely monitored because the chemical burns caused by the sludge could take days to emerge and what could seem like superficial injuries could later cause damage to deeper tissue [7].

The government declared a state of emergency in three areas.

Hundreds of millions of tons of toxic aluminum waste, similar to those that fell into the Hungarian rivers and literally poisoned the lives of tens of thousands of people, have been accumulated in Russia to date. This waste, the so-called red mud, according to environmentalists, makes the aluminum industry the most dangerous industry in the world [8].

The risks of a recurrence of such a catastrophe increase due to increased natural disasters: earthquakes, torrential rains and floods, as well as terrorist attacks. But they can be completely eliminated by replacing the storage of red mud with its full processing. However, the developed
processing technologies are not implemented due to the lack of guarantees of the return on investment in the construction of shipping complexes. Until the processing problem is resolved, disasters will continue.

On January 31, 2013, an emergency occurred at the Achinsk Alumina Refinery. Due to the breakthrough of the sludge "lake" of the Achinsk Alumina Refinery (AAR) - the RUSAL plant and the increase in the drainage water level in the bypass channel of the AAR sludge maps, a short-term overflow of water onto the adjacent territory occurred. The incident occurred on the evening of January 31, but the information about it became known only a few days later. According to the information of the Krasnoyarsk news agency Press-Line, the management of the plant until the last did not allow representatives of the Ministry of Emergencies or employees of Russia’s Ros Prirod Nadzor environmental watchdog to the accident site. At the same time, according to the publication, the breakdown of the sludge pipe and overflow of the bypass channel of the AAR led to flooding of the area around the sludge fields of the plant with alkaline filtrate. Emergencies at the AAR happen regularly. A year earlier there was an explosion, even earlier - the fish had a rest in the nearby body of water, now - the leak of alkaline solution from the sludge fields. The last incident was dangerous in that the alkali destroys all life in the territory where it has already entered, and there was also a threat of getting into the Chulym River [9].

Speaking about the Krasnoyarsk Territory, scientists at the Siberian Federal University recall that the most catastrophic situation with waste from the metallurgical industry has developed in Achinsk. Over the decades, a huge slurry mountain has formed there. The main danger of these slurges is that they are highly alkaline. The pH factor is 10-13 units. When it enters water, a process such as an increase in the alkaline factor of water occurs. This can cause burns, death of plants, microorganisms and even animals. As a result of the spill of slurry fields, the lands become lifeless, resembling a Martian landscape. Achinsk spends a lot of money on the reconstruction of sludge fields, maintaining their performance, but leaks occur periodically. The last leak was in 2015. The accident is not major, but the consequences are quite serious. And according to the results of the investigation, the environmental prosecutor's office fined Achinsk alumina refinery for 408 million rubles. The problem is that a huge amount of waste is generated in alumina refining, much more than in aluminum production. According to RUSAL, this is about 12 million tons of waste. It is processed no more than 10%. Most of the waste is stored in sludge fields. Stimulation of the processing of slurges begs, because around Achinsk there is already not enough agricultural land, because many of them are occupied by landfills, by sludge cards.

The second problem is the sludge fields of the Krasnoyarsk aluminum smelter, the sludge of which is harmful because of fluorine. Fluorine intoxication leads to cancer, thyroid disease, and a number of other serious diseases. Despite the fact that special measures are being taken to retain sludge, studies by the Siberian Federal University scientists have shown that the fluorine content is very high in snow. The studies were conducted in 2015. Fluorine contaminated most of the Sovetsky district of Krasnoyarsk, part of the Central district of Krasnoyarsk, and the right bank of the Yenisei River. The fluorine content is much higher than permissible.

The conclusion suggests itself that fluorine from sludge fields is spread with the help of the wind, which leaks and enters the atmosphere in the form of a dust fraction. Unfortunately, this issue is poorly researched. Initial studies show that the situation is quite dangerous. The 4-5 times excess was fixed at such districts of Krasnoyarsk as Severny and Vzlyotka. This is quite a serious and a dangerous factor. An increase in the incidence of cancer occurs every year, and oncology appears not only in the older generation, but also among young people and children. Then there are diseases of the endocrine system and blood circulation. Statistics show that residents of areas adjacent to the plant are often sick.

3. Results and discussion
Despite the rather long-term operation of aluminum production in the Krasnoyarsk Territory (RUSAL Achinsk and RUSAL Krasnoyarsk), the issue of disposal of accumulated hazardous waste in sludge storage facilities has not yet been resolved. At AAR, about 100 million tons of nepheline sludge is
currently stored on sludge collectors, with an annual increase of 4 million tons. At the Krasnoyarsk aluminum smelter, another sludge program No. 5 has been launched, which is ready to accommodate about a million tons of hazardous waste. These waste disposal sites carry a dangerous technological pressure on the environment, since they are located in the urban areas of the cities of Krasnoyarsk and Achinsk. It is necessary to introduce technologies for the deep processing of these wastes. In fact, sludge fields should be completely removed from Krasnoyarsk.

Krasnoyarsk chemists, technologists have already found how to recycle and where to use recycled waste from the Krasnoyarsk aluminum smelter. Research and calculations were carried out on their own initiative, without the support of RUSAL. Doctor of Chemistry, professor of Siberian Federal University Boris Kulikov said that from the sludge it is possible to obtain additives necessary for the production of cement - suitable in construction and absolutely safe for human health. The construction of a processing plant requires 15-20 million dollars. This will allow Krasnoyarsk aluminum smelter to enter non-waste production [10].

RUSAL Krasnoyarsk Company pays great attention to reducing the negative impact of the operation of slurry storage facilities on the environment. In recent years, reconstruction of hydraulic structures and screening of sludge maps has been carried out, as well as the reconstruction of a system for the removal of sludge water, which allows withstanding sludge moisture in the range that reduces the filtration of contaminated industrial water into groundwater. Simultaneously with the reconstruction, monitoring of the status of groundwater is carried out. The existing operational network of ecological monitoring wells allows to control the impact of waste disposal sites on groundwater.

The technical director of RUSAL, Viktor Mann, said that the creation of a technology for the recycling of waste was an important area of work. So, at the Krasnoyarsk aluminum smelter (KrAZ), a two-stage gas purification section was commissioned to produce sodium sulfate in the first phase. It is used in the production of cellulose, glass, detergents, as well as building materials. Investments in this project amounted to $ 1.14 million. The new technology developed by the RUSAL Engineering and Technology Center surpasses foreign analogues in a number of ways: there is no discharge of liquid and solid wastes. In addition, this installation, which removes the substance from the gas treatment, reduces the maintaining equipment cost. “The two-stage gas purification with the removal of sulfur in the form of a commercial product at the Krasnoyarsk aluminum smelter has no world analogues. The effectiveness of the technology is above 99.5% for fluorine and 96.7% for sulfur, while world analogues do not exceed 92%. We have already launched the same project at the Novokuznetsk aluminum plant. The plans are to start using this technology at the Irkutsk and Bratsk factories,” said Viktor Mann. The introduction of the new technology will allow RUSAL to abandon the construction of new slurry fields at KrAZ, which will save up to $ 1.39 million per year. The plant management understands that the methods for handling sludge - slag-like waste from electrolysis production - are one of the most pressing environmental problems in the production of aluminum [11].

4. Conclusion
Taking into consideration above information, processing red mud could remove the risks of major environmental disasters in and around alumina refineries. In recent years, a number of proposals have been made and technical developments have been completed on the technologies for utilizing both sludge accumulations and sludge coming from the process stream. In laboratory conditions, technologies for pelletizing fine sludge with transfer to the iron and steel industry and cement production were developed and tested on small pilot plants. They gave positive results, but, unfortunately, RUSAL did not rush to invest in large-scale production of sludge utilization. It is easier and cheaper to build new maps, to reclaim waste sludge collectors, and to pay fairly small environmental fees for negative environmental impacts. There is practically no incentive for recycling, but not the accumulation of hazardous waste from the authorities. Agricultural land is contaminated, hazardous substances get into groundwater. Unfortunately, this dangerous impact on the environment
and human health is currently underestimated. This is an environmental time bomb, set aside for future generations.

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