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TOPICALITY AND POSSIBILITIES FOR COMPLETE PROCESSING OF RED MUD OF ALUMINOUS PRODUCTION

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In the aluminum industry, the largest amount of waste is red mud (RM). that is a solid bauxite residue after hydrochemical processing and extraction of alumina. The topicality of its processing was shown by the ecological catastrophe in Hungary (2010), where the bund wall of the slurry storage was destroyed and the viscous mass of fine red mud fell on thousands of hectares of land.

The risks of a recurrence of such a catastrophe increase due to the increased natural disasters: earthquakes, torrential rains and floods, as well as terrorist attacks. Therefore, it is proposed to exclude the storage of red mud in sludge storages and organize its shipment in transportable form to processing complexes.

The article presents the results of scientific research and the experience of complex processing of red sludge on an industrial scale with the production of new types of marketable products.

Key words: red mud of alumina production, prevention of ecological catastrophe, complete processing, transportability, marketable products, improvement of ecology and economics of consumer enterprises

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Introduction. In the aluminum industry, the largest amount of waste is red mud (RM), that is a solid bauxite residue left after hydrochemical treatment and extraction of alum slate. More than 1.5 billion tons of red mud have been accumulated in the world. Each sludge storage facility occupies 50-100 hectares of land and has a height of 30-50 m, it consists of tens of millions of tons of high-moisture (60-90 %) fine-dispersed and ductile material. The topicality of red mud processing was shown by the ecological disaster in Hungary (2010). With the destruction of the bund wall of the slurry storage facility (Fig. 1), the viscous mass of a fine-grained red mud with high humidity (60-90 %) was found on thousands of hectares of land. People died, under the influence of caustic alkaline sub-slime water, the animal and plant world suffered significantly, the river Danube was polluted.

The risks of a recurrence of such a catastrophe increase due to more frequent 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 complete processing technology. However, the developed processing technologies are not implemented due to the lack of guarantees for the return on investment in the construction of shipping complexes.

The justification of investments requires carrying out representative tests of industrial batches of transportable red mud at processing facilities.

The new, the so-called «dry warehouse storage», does not provide a solution to the problem. The humidity of the red mud remains at the level of 50-60 %. The dustiness of the environment is increasing. At a moisture content of more than 20-30 % this material is not transportable, because it sticks to the walls of cars, bunkers and conveyor belt, clogs overloads and feeders.

Fig.1. Ecological disaster: collapse of the bund wall of the red mud storage in Hungary (2010)

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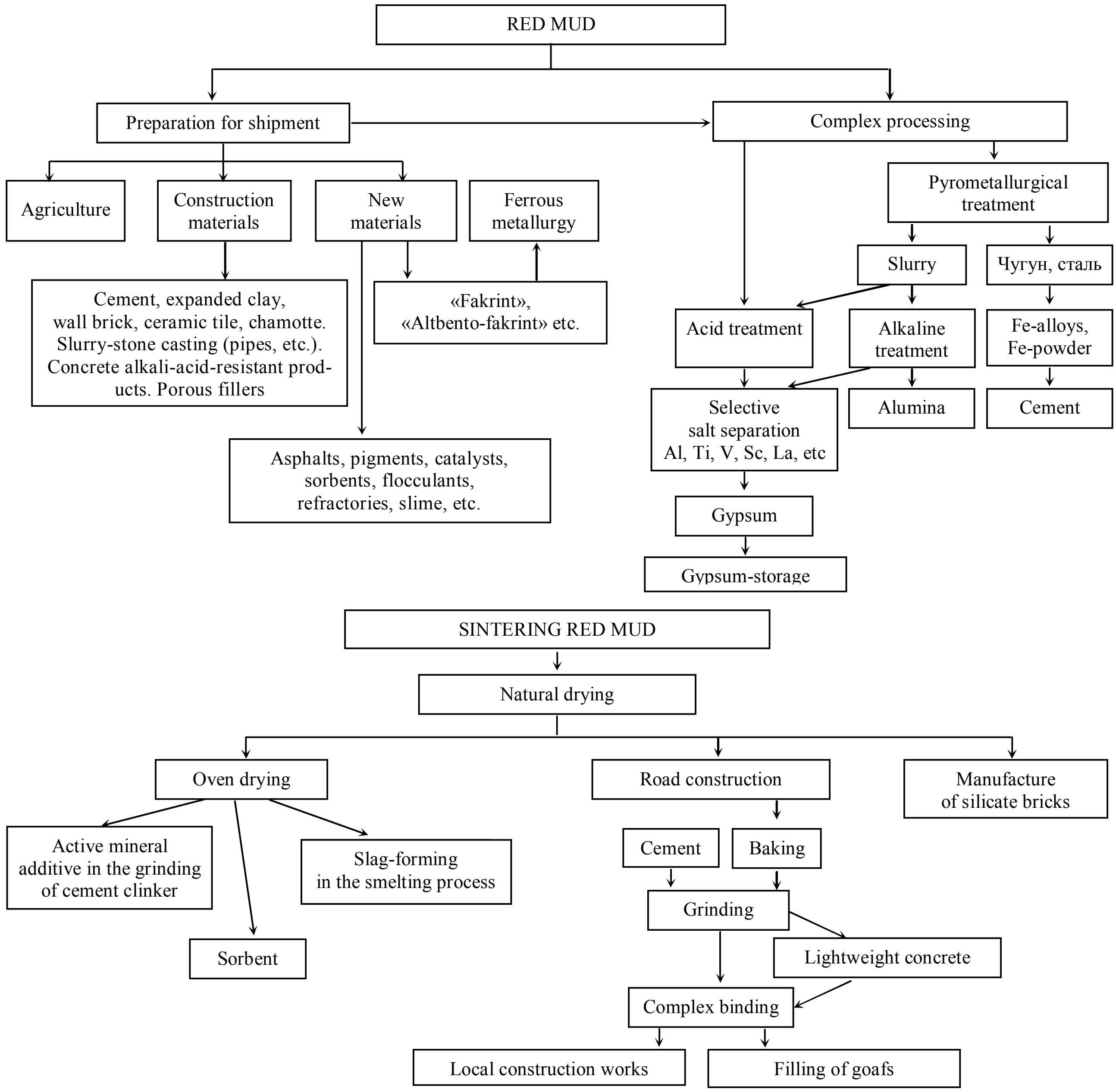

Fig.2. The most promising and proven ways of processing red mud

Fig.2 shows the options for processing red mud, developed by specialists of the Mining University, tested in recent years [5, 7, 9-19] in pilot plant conditions using small samples of red mud.

The tested options for the preparation of red mud for pilot trials. *Option A*. Preparation of a sandy red mud which sediments near the mud discharge nozzles located along the perimeter of the slurry storage. The advantages of the appropriate liquid slurry tankers are the topping of the bund wall without any imported materials. Sandy sludge is obtained with the use of hydrocyclones. The disadvantage of these slurries is that they are not representative of the chemical composition compared with the bulk of the red mud.

Option B. Obtaining a more representative red mud from the initial maps, which turned out to be outside the boundary of the common raised damming up of the slurry storage. Over time, the red sludge of small open maps dries up. In tests, it was selected with a bucket of an excavator, loaded into dump trucks and placed in small stacks on an open platform. Later stacks were moved periodically. Two years later, it lost moisture on average to a transportable condition. But inside the stacks were clods of high-moisture red mud, which hampered its conveyor transportation and industrial dosage.

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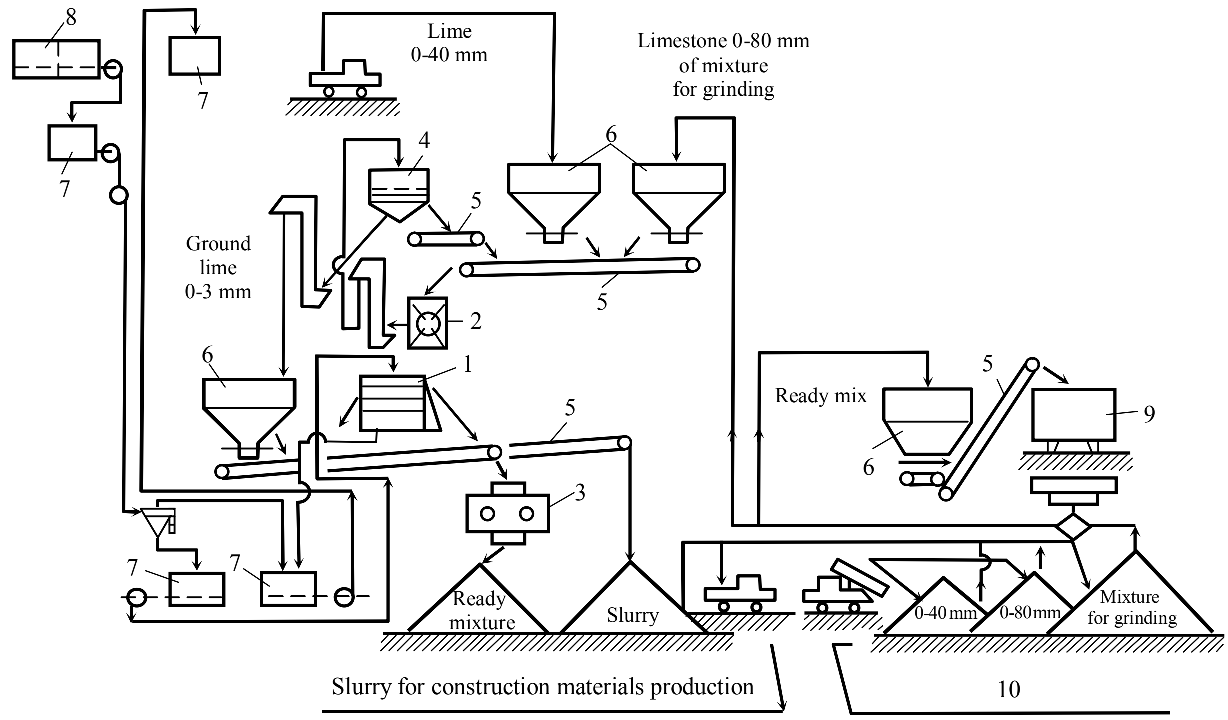

Fig.3. Equipment-technological scheme of the main industrial plant
for production of transportable red mud product with capacity more than 20 thousand t/year

1 – filter press; 2 – crusher; 3 – mixer; 4 – screener; 5 – conveyors; 6 – bunkers; 7 – agitators;
8 – washer of alumina shop; 9 – railway car; 10 – pile

Option C. Preparation of red sludge by passing through a belt filter press FPAKM-25. The resulting red mud cake had a moisture content of about 25 % and had the required transportable properties.

The results allowed to justify the construction of an industrial plant of GPU (Fig. 3) with a capacity of 20 thousand tons/year, and then a shipping complex designed for the full capacity of the alumina plant.

Assessment of the tested options for the red mud processing. Depending on the method of alumina production, the red mud may be Bayer or caking. The first one requires presence of press-filtration for later shipping, the latter variant provides product ready for shipment without any special preparation [9]. The chemical composition (except REM) and the size of the red mud are given in Table 1.

Table 1

Chemical composition and coarseness of red mud

Production method	Chemical composition, % by mass						Coarseness, μm
	Fe_2O_3	SiO_2	Al_2O_3	CaO	$Na_2O + K_2O$	LOI	
Bayer	42-55	5-8	12-17	8-13	4-9	6-10	0-0.05
Caking	20-25	16-20	8-10	37-42	2-3	4-5	0-10.00

Complex processing. Some part of the red mud contains elements of almost the entire table of D.I. Mendeleev. Therefore, a large number of studies are devoted to the complex processing of red mud [5, 11-14, 16-19], which are especially relevant with the extraction of the REM [7, 10]. With rare exceptions [6], acid technologies are most often used for complex processing, the storage of waste products is incompatible with alkaline red mud. Alumina refineries have adopted a closed water cycle. Acid slurry sludges require separate slurry tanks, often much larger in size in proportion to their formation.

Much attention is paid to Russian and foreign research on reduction smelting of red mud, which can be organized at metallurgical enterprises of ferrous metallurgy. There is an experi-

Fig.4. The view of the industrial complex for red mud filtering for shipment to consumers

ence of smelting high-quality foundry pig iron. The formation of self-dusting belite sludge makes it possible to produce, according to Russian experience, a cement clinker with a significant reduction in fuel consumption and greenhouse gas emissions (Fig. 4).

It has been established that the process of reducing iron from red mud in electric furnaces is the most technologically advanced. In a rotary kiln the hard-to-remove build-ups are formed.

Thermal agglomeration of red mud is one of the most effective stages of its metallurgical complex processing. The study of this process was carried out in laboratory and industrial conditions [1]. Agglomeration of red mud allows to remove more than 50 % of sulfur, phosphorus and alkalis from it. Sintered red mud is advantageous for use in the smelting of steel, replacing mineral resources with iron ore, bauxite and fluorspar.

Use of red sludge in ferrous metallurgy. About 50 % of the real mass of red mud is represented by iron oxide, so it is logical to consider the possibility of using red mud in the composition of the charge to obtain a blast-furnace agglomerate. However, one must take into account that this material is considerably inferior to the processed iron ores by the iron content. Its application undoubtedly reduces the productivity of blast furnaces and increases the specific consumption of coke.

The novelty of this research is that the described disadvantage, as established by our studies, is overlapped by the advantages from the substantial hardening of the agglomerate [8]. The ability of red mud to prevent the polymorphism of dicalcium silicate found in the structure of agglomerates is revealed. It leads to the elimination of agglomerates destroying internal stresses. Reducing the amount of fines of fractions of 0-5 mm by 1 % contributes to the increase in the productivity of the blast furnace, also by 1 %, with the same saving in expensive furnace-size coke.

In addition, binding properties of red mud have been identified. Pelletization of the charge and its gas permeability are improved as well. The productivity of agglomeration machines increases without capital costs by 5-10 %. If the amount of fines in the agglomerates is reduced by 3-5 %, and the iron content is reduced by an average of about 0.5 %, the total technological efficiency in blast-furnace production is: 1.2-2.5 % for pig iron production, and for economy of furnace-size coke – 1.5-1.8 %.

The technological efficiency of the use of red mud was confirmed by 10 industrial tests of 30 different raw material variants (Table 2).

Table 2

Results of the use of red mud in agglomeration and blast-furnace industries

Проведенные работы	NEIT	PG, %	DYA, % (% rel.)	STF, %
Large-batch sintering on a grate	Over 130 (21)	8-15	3-5 (7-20)	4-15
Tests in agglomeration plants	8 (6)	4-10	2-5 (8-16)	8-12
Guaranteed indicators in agglomeration production		5-10	3-5 (10-15)	8-10
Tests in furnace production	4 (4)	1.15-1.25	2-6 (8-16)	1.2-1.8
Guaranteed indicators in furnace production		1.2-2.5	4-6 (12-17)	1.5-1.8

Note. NEIT – the number of experiments or industrial tests (raw options); PG – productivity growth; DYA – decrease in yield of fines of agglomerate after tests for strength; STF – saving of technological fuel.

It is additionally determined that the introduction of the red mud into the agglomeration blend composition forms a reinforcing alumina-ferruginous bunch of agglomerates and pellets. The yield of the fraction 0-0.5 mm with heating and reduction of agglomerates and pellets in blast furnaces is reduced by 20-40 %. As a result, iron losses with dust removed from blast furnaces are reduced and, accordingly, their productivity increased.

The most important economic part of the industrial tests carried out is the research is getting the mutually agreed beneficial price for salable red mud product, which was produced at one of the largest metallurgical plants, and this case is the first one on global practice. It compensates about 50 % of the cost of the original bauxite and therefore enables to return the investments allocated for the construction of the shipping complex in 2 or 3 years.

The use of red mud as a salable product in ferrous metallurgy is most promising for industrially developed countries (Germany, China, Russia, USA, Sweden, Japan, etc.).

Peculiarities of using red mud in the production of construction materials. The use of red mud in the production of cement clinker, chamotte, expanded clay and ceramics has long been theoretically substantiated and widely known in the world practice (Hungary, Germany, India, Ukraine, Yugoslavia, etc.). For this purpose, the sludge is taken from abandoned sections of small sludge piles or storage areas or from beach active zones.

Attempts are being made to produce and consume special colored decorative or acid and alkali-resistant concretes for chemical shops and offshore structures.

The production of calcined construction bricks from the raw mix containing red mud was cancelled because of the appearance of alkaline salt efflorescence on the surface of bricks, increased weight of bricks and, accordingly, transport costs.

The production of bricks from red sludge on a cement binder proved to be unsuccessful, since the buildings built from them spontaneously destroyed themselves from ettringite corrosion. The use of red mud having a bright reddish-brown color did not work as a coloring pigment because of the low durability of the colors due to the presence of alkali and calcium oxide in the red mud. The high costs for a complete washing of them make us return to traditional materials and technologies.

Use of red mud to improve the ecological situation. The ability of red mud to bind heavy metals dissolved in industrial wastewater is revealed.

The deodorizing ability of red mud is established in contact with livestock and poultry organic waste and sewage.

A sufficiently high sorption capacity of red mud has been established when sulfur and nitrogen compounds (without catalysts) are collected from industrial gases from TPP plants on the basis of pilot-industrial tests (for example, TPP-2 of sintering plant and steel-smelting workshop of «Severstal»).

Laboratory and industrial tests were conducted on the use of red mud in the granulation of blast furnace slags. The content of hydrogen sulfide on the working site of the pool could be reduced by two orders, while the quality of the slag does not decrease.

Correspondingly, the prepared red mud replaces expensive limestone and lime during cleaning from harmful impurities of furnace gases at TPP and boiling units.

It is effective to replace a large amount of lime with red mud for the neutralization of contaminated emergency drains and reservoirs, while excluding the release of toxic dust from spontaneous hydration of lime and the formation of large quantities of greenhouse gases formed during its production.

Especially practical for solving these problems is red mud of caking origin. It is transportable without filtering. This makes it easier to solve the problem of processing this waste, in particular, stored in the city of Boksitogorsk Leningrad region (15 million tons). Technical specifications for industrial production of salable red sludge have already been developed. The toxicological studies, radiation and technological tests for a large number of consumers have been successfully carried out.

Obtaining new types of marketable products. The concept of «red mud» is suitable only for red sludge located in the sludge dump areas. Sludge is a suspension, a liquid substance with suspended fine particles of a solid material.

The Bayer red mud, suitable for use in sintering production of ferrous metallurgy, received the advertising commodity name «Fakrint» – ferro-alumina-calcium reagent – intensifier of the sintering process.

For the production of iron ore pellets, the material «Altbento-fakrint», which is a cognate material for natural expensive bentonite and can be used as its substitute. Unlike the fakrinit, it has some competitors. This is the usual bentonite and new organic binders. Their advantage is a much smaller specific consumption rate. But the disadvantages are extremely important: the inability to increase the mechanical and hot strength of pellets and the high cost. Natural bentonite is more expensive than red mud in 4-5 times. In addition, it contains 6-8 times less iron and almost 10 times more unnecessary silicon oxide.

The use of red mud for various ecological purposes allows the release of a series of specific names from the original «Fralsorbent». We can replace expensive limestone and lime with red mud products and profit up to $ 100 per ton.

The red mud can be used to obtain deodorized mineral complex granulated fertilizer «UMODKgr». Technologies for their preparation for introduction into soils using the existing technology have been developed.

For the sintered red mud, there has been chosen the commodity name «Granulated Universal Slag» (GUS), which has minimum tariffs for rail transportation. The expansion of the nomenclature of marketable products can be achieved through joint work with interested organizations [2].

Conclusions

1. Red mud processing removes the risks of major environmental disasters in alumina refineries and their environment.

2. Saint-Petersburg Mining University has practical experience and technologies of ecologically and economically efficient complete processing of bauxite waste red mud for alumina refineries.

3. The most difficult are the work on the justification of the return on investment for the construction of shipping complexes, including the organization and successful conduct of representative industrial tests of new technologies for obtaining and using red-sludge products from consumers.

4. By introducing new technologies consumers of red sludge get an economic effect by saving mineral raw materials and technological fuel, and also reducing greenhouse gas emissions.

REFERENCES

1. Besedin A.A., Utkov V.A., Brichkin V.N., Sizyakov V.M. Agglomeration sintering of red sludge. *Obogashchenie rud*. 2014. N 2, p. 28-31 (in Russian).

2. Alekseev A.I. Complex processing of apatite-nepheline ores based on the creation of closed technological schemes. *Zapiski Gornogo instituta*. 2015. Vol.215, p. 75-83 (in Russian).

3. Bratygin E.V., Gazaleeva G.I., Dmitrieva E.G., Kalugin Ya.I. Investigation of enriched red muds in the production of high-fluxed agglomerates for further processing in blast furnaces. Metallurgiya –INTEKhEKO – 2012: Sb. dokladov Pyatoi mezhdunarodnoi konferentsii. Moscow, 2012, p.63-67 (in Russian).

4. Rebrik I.I., Utkov V.A., Smola V.I., Sizyakov V.M. Criteria for processing red sludges as technogenic raw materials. *Ekologiya i promyshlennost' Rossii*. 2008, noyabr', p. 26-28 (in Russian).

5. Korshunov E.A., Burkin S.P., Loginov Yu.N., Loginova I.V., Andryukova E.A., Tret'yakov V.S. RF Patent N 2245371. Method of processing of red mud of alumina production. Opubl.12.04.2005. Byul. N 32 (in Russian).

6. Pyagai I.N., Yatsenko S.P., Pasechnik L.A. RF Patent N 2483131. Method for obtaining scandium oxide from red mud. Opubl. 27.05.2013. Byul. N 15 (in Russian).

7. Kozhevnikov G.N., Vodop'yanov A.G., Pan'kov V.A., Kuz'min B.K. Joint processing of bauxite and red sludge. *Tsvetnye metally*. 2013. N 12, p.36-38 (in Russian).

8. Utkov V.A., Leont'ev L.I. Increase the strength of agglomerates and pellets with bauxite red mud. Stal'. 2005. N 9, p. 2-4 (in Russian).

9. Utkov V.A. Processing of dump slurries as an element of high-tech low-waste technology for the production of alumina from bauxite and nepheline. *Tekhniko-ekonomicheskii vestnik RUSALa*. 2007. Iss.18, p. 51-56 (in Russian).

10. NGZ is 20 years old. Nauchno-tekhnicheskaya konferentsiya: Sb. nauchnykh dokladov. Nikolaevskii glinozemnyi zavod. Nikolaev, 2000, p. 177 (in Russian).

11. *Atasoy A.* The comparison of the Bayer process wastes on the base of chemical and physical properties. *J. Therm. Anal. Calor*. 2007. Vol. 90. N 1, p.153-158.

DOI: 10.25515/PMI.2017.5.547

12. Ercag E., Apak R. Furnace smelting and extractive metallurgy of red mud: Recovery of TiO_2, Al_2O_3 and pig iron. *J. Chem. Technol.* Biotechnol. 1997. Vol.70. N 3, p.241-246.

13. Horvath G. Red Mud Smelting Experiments. *Acta Technica Academiae Scientiarum Hungaricae*. 1974. Vol.79. N 3-4, p.413-449.

14. Jamieson E., Jones A., Cooling D. et al. Magnetic separation of Red Sand to produce value. Min. Eng. 2006. Vol. 19. N 15, p. 1603-1607.

15. Klauber Craig, Gräfe Markus, Power Greg. Reviewof Bauxite Residue «Re-use» Options. CSIRO-2009. Document DMR-3609. USA. Los Angeles, 2009, p.66.

16. Mishra B., Staley A., Kirkpatrick D. Recovery of value-added products from red mud. Min. Metallurg. Process. 2002. Vol.19. N 2, p. 87-94.

17. Piga L., Pochetti F., Stoppa L. Recovering metals from red mud generated during alumina production. *J. Metals*. 1993. Vol. 45. N 11, p. 54-59.

18. Paradis – Application of Alcans deep bed thickener technology. *Travaux ICSOBA*. Milan, 1997. Vol.24, p. 82-89.

19. Paramguru R., Rath P., Misra V. Trends in red mud utilization – A review. Min. Process. Extract. Metall. Rev. 2005. Vol. 26. N 1, p.1-29.

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