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Environmental problems of waste recycling at the Tajik Aluminum Company (TALCO)

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Author’s declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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Tajik Aluminium Company (TALCO) is one of the leading producers of primary aluminum in Central Asia (with design capacity of 517 thousands ton aluminium/year). In the past 30 years, the plant has been producing huge volumes of industrial waste which has had negative environmental impact on soil, groundwater and air quality of it surrounding region. Thus, utilization of this industrial waste as well as reducing it during the production process represents a major ecological issue. Moreover, since this waste also contains significant amount of useful material which can be reused in the production of aluminum or in other industries, it makes the waste utilization also economically attractive.

The present research describes the environmental impact of industrial wastes produced in TALCO and analyzes numerous methods of their utilization. Furthermore, the research makes a comparison of effectiveness, advantages and disadvantages of these methods and their economic cost effectiveness. The required material was collected during the internship at the Research Institute of Metallurgy of TALCO (*Dushanbe, Tajikistan*) and National Library of the Academy of Sciences of the Republic of Tajikistan.

Keywords

Environmental situation, aluminum production, industrial waste utilization, solid and gaseous waste byproducts.

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List of Abbreviations

AS RT - Academy of Sciences of the Republic of Tajikistan

AUSRDIA - All-Union Scientific Research and Design Institute of aluminum

CAM - Cryolite Alumina Concentrate

DCPFAS - Dust Capturing from Production Fluoric acid and its Salts

GAN - Gidroalyuminat sodium

KrAP - Krasnoyarsk Aluminium Plant

MAC - Maximum Allowable Concentration

PROTEC - Production Technology Ecology

SH - Sodium Hydroaluminat

SibVAMI - Siberian Research, Design and Design Institute of the aluminum and electrode industries - Siberian Military District

SWL - solid waste landfills

RT – Republic of Tajikistan

TALCO - Tajik Aluminum Company

TSE – Tajik Soviet Encyclopedia

PMAP – Portal Machines of Alumina Power

CPM – Cryolite Power Machine

INTRODUCTION

Improvement of existing technologies facilitates the solution to urgent problems such as processing of industrial waste from aluminum production and reducing the environmental damage caused by solid and gaseous wastes.

Even more important issue is achieving a waste-free production using the newest technologies and rationale use of resources given their scarcity. Or if there is a byproduct during the production process, then the aim is to find the ways of reusing the byproduct in the same production process. There are hundreds tons of waste stockpiled on the territory of TALCO which contain valuable components such as carbon, alumina, cryolite, fluoride, sulfate and sodium carbonate which occupy considerable space and pollute the environment of that region. Despite the country's substantial reserves of alumina-and fluorine-containing raw materials, due to lack of appropriate infrastructure, these raw materials are not sufficiently exploited. Therefore, the research on utilization of the waste from aluminum production including their re-use is of a great importance.

The main aim of current research is to discuss whether it is feasible to recycle and re-use the waste from aluminum production in TALCO in order to reduce its impact on the environment and if this is technologically achievable. This is achieved through: (i) review of literature available on waste recycling and discussion of various options available; (ii) review of environmental problems caused by TALCO; and (iii) discussion of current ways of waste recycling from aluminium production in TALCO. The current research does not consider the financial aspects of waste recycling options or its use.

REVIEW OF ENVIRONMENTAL ASPECTS OF ALUMINIUM PRODUCTION

To date, humanity has been using technology developed for the processing of geological, environmental and other resources created by nature. The logical negative result of this activity is widespread depletion. However, the amount of resources spent on production of one standard unit of conditional capital depends on the level of technological development of society.

When using the advanced technology for the processing resources provided by the nature, humanity can go even further along the path of evolution. The problem of enhancing the utilization of mineral raw materials (Sazhin *et al.* 1988; Ravich *et al.* 1988; Kitler *et al.* 1962) and secondary resources and improving the quality of products is currently one of the most important problems of chemical and metallurgical industries (Nee *et al.* 1988; Mirsaidov *et al.* 1998; Liner *et al.* 1961; Belyaev *et al.*1970). Its rational and successful implementation will enable complete use of mineral raw materials. Waste recycling can solve a number of economic and environmental problems in the production of valuable products (Mirpochoev *et al.* 1994).

Use of natural resources depends on the pace of socio-economic development, and economic development, and the scale of production. The predominance of extensive methods of economic development led to an aggravation of problems with resources of the national economy, which is closely related to environmental issues. It is therefore necessary to establish the production, providing a full and comprehensive use of natural resources, raw materials, and, at the same time, eliminating the harmful impact on the environment (Azizov *et al.* 2003; Mirsaidov *et al.* 1999; Sheludyakov *et al.* 1985).

We know that throughout the history of mankind, science was the engine of development and contributed to the effective use of mineral resources. Now science is beginning to seek protection from the consequences of their own discoveries (Derevyankin *et al.* 1972; Ruziev *et al.* 1998; Mirsaidov *et al.* 1994). In terms of environmental degradation, depletion of mineral resources and population growth of particular importance is the introduction of low-waste and waste-free processes (Abdulloev *et al.* 2000; Pustilnik *et al.* 1978; Nee *et al.* 1975; Liner *et al.* 1976; Ismatov *et al.* 1974).

Resolving this problem requires improvement of the entire economic mechanism. Therefore, new approaches are being developed for resource conservation, improved efficiency of production processes and evaluation methods of economic analysis. There are also many researches being undertaken for the formation of regional and inter-industrial complexes based on management of material flow (Mirsaidov *et al.* 1998; Mirpochoev *et al.* 1994; Ganiev *et al.* 2001).

There has been considerable research done on the economic consequences of environmental pollution and unsustainable use of natural resources. Accounting for damage from environmental pollution by industrial emissions significantly expands the economic border of implementing waste-free manufacturing processes. Waste-free production becomes effective even in cases where the cost of the products obtained is higher than the competing options, as the overruns on capital expenses is less than the savings from reducing the impact of environmental pollution (Mirsaidov *et al.* 1999; Felinberg *et al.* 1997; Mirsaidov *et al.* 2001; Ganiev *et al.* 2001; Safiev *et al.* 1991; Marakushev *et al.* 1998; Trubeckoy *et al.* 1998; Kondratev *et al.* 1998).

As per analysis of a large statistical material, the volume of world industrial production is increasing exponentially. In turn, the amount of raw material and the resulting waste also is increasing exponentially. This means that humanity is increasing the production of waste, since only about 3-5% of raw materials turns into the final product, and the rest is a waste. Never before humans exploited so much of raw materials as it is doing now (Sokolov *et al.* 1996; Goyakov *et al.* 1989).

It is estimated that, in developed countries, every person already accounts for more than 20 tons extracted minerals per year. Even more remarkable is that the costs of disposal and recycling also increasing exponentially and accounts for 8-10% of the cost of production.

Development of technological production processes can not rely on historically established traditional processes but rather requires a fundamentally new approach. This new approach, called "non-waste technology" is prompted by the nature itself. Under natural conditions, the waste of some organisms is absorbed by others, and generally consists of biogeochemical cycle of substances. Particular importance of this approach was emphasized by V.I. Vernadsky, who highlighted that the transition "to a new evolutionary state of the biosphere is only possible while maintaining the cycles of matter and energy existing in the biosphere" (Trubeckoy *et al.*1998, Kondratev *et al.* 1998; Sokolov *et al.* 1996; Goyakov *et al.*1989).

At the present time, the idea of cyclic reuse of material resources is being widely discussed throughout the world. With technologies and processes developed to date, it is possible to re-use only 2 / 3 of the waste produced, but in the very near future, industry will largely rely on renewable and secondary material resources, and only expanded reproduction will rely on primary resources.

Re-use of resources (recycling) is crucial in terms of maintaining or extending the exploitation time of scarce natural resources. [Trubeckoy *et al.* 1998]. If the stocks of recycled materials will increase by 10 times, then the supply of raw material production will increase only 2,5-3 times. If 50% of used metals are brought back into production cycle, it will meet the demand for metals by 3-3,5 times, and in the case of 100% recycling by 5-7 times.

Solution to the waste problem lies in substantial increase of the role of secondary resources and organizing local, regional and eventually global (across states) cycle of materials in which the primary raw materials will be only used to fill in for the losses and increased production volumes. Ultimately, industrial production shall only rely on secondary raw materials (Felinberg *et al.* 1997; Mirsaidov *et al.* 2001; Ganiev *et al.* 2001; Safiev *et al.* 1991).

All unused or underutilized raw materials, still a small part of it, ends up in the environment, which has a very adverse impact on living organisms, including on human being. Over the past decade, disposal of industrial, agricultural and domestic waste into the atmosphere, hydrosphere and lithosphere has reached such magnitudes that it became commensurate with the natural components of global biogeochemical cycles of substances (Kondratev *et al.* 1998).

But even now, discharging of industrial waste into the environment is still the most economical (obviously if there is no harm to the environment) way of getting rid of them. It is known that approximately 50 metals have a direct economic value, while half of them are highly toxic. Just burning coal in the power plants produces antimony, mercury, lead, cadmium, selenium, beryllium, which is ten times more than what is produced in the natural biogeochemical cycles on Earth during the comparable period of time. In recent years, industry and transport emitted more lead than ever in history (Kondratev *et al.* 1998; Snakin *et al.* 1998).

Not less serious is the problem of environmental pollution by liquid waste from industry, agriculture and public sector. Since water plays a critical role in the formation and organization of biogeochemical cycles, its pollution has a significant impact, both direct and indirect, on the cycling of matter in nature. The main cause of water pollution is the discharge of untreated or inadequately treated wastewater from (Pushkarev *et al.* 1975; Zapolskiy *et al.* 1987; Tkachev *et al.* 1978) industry.

Environmental management encompasses a range of different problems. That's when the new research areas have emerged, such as industrial ecology, which studies the interdependence of production and the environment. Social, economic, technological and biological processes in the environment are now so closely linked and interdependent, that there is an objective necessity to consider the production as a component of a complex ecological-economic system, which includes material production and the environment as a sub-social system.

At the present time, the idea of repeated, cyclic use of material resources has been widely discussed throughout the world. Now technically possible (we have developed processes and related equipment) to re-use 2 / 3 of waste, and in the near future, industry will be largely based on renewable and secondary material resources, and only on the expanded reproduction of the primary need is not a renewable raw material.

Therefore, reducing the negative anthropogenic impact on the environment through management of natural resources – is of prime importance for the governments[1].

[1] State Environmental Programme for the period 1998-2008 years. Ministry of Ecology of the Republic of Tajikistan 1998, page 159.

CHAPTER I

ENVIRONMENTAL IMPACTS GENERATED BY TALCO

Among all other industrial enterprises in Tajikistan, the Tajik Aluminium Company - TALCO´s environmental performance is of special importance in the country. TALCO is one of the largest industrial plants in Central Asia. The latest technologies available at that time were used in its construction. The plant uses a high-performance air and gas treatment processes. TALCO has undertaken numerous measures aimed at preventing air pollution. However, from time to time, high concentrations of toxic substances, often exceeding the maximum permissible levels were recorded around the plant’s area.

1.1.1. General information about TALCO

TALCO is located in the western part of the Hissar valley, 56km from the capital city of Dushanbe and within 10 km from the border of the Republic of Uzbekistan. The climate around TALCO is very continental with very hot and dry summer. The average temperature in July (the hottest month) is +32 °C, and the maximum goes up to + 45 °C. Humidity in winter is about 65-70%, and in summer 40-45%. Annual average rainfall is 120-200 mm a year; it mainly rains in winter and spring. Summer is usually characterized with very high solar radiation (TSE 1986).

The plant employs about 13,000 people and includes the following main and auxiliary workshops:

1) Aluminum electrolysis plant;
2) Mixing and pressing shop;
3) Roasting shop;

4) Shop for production of electrodes;

5) Shop for equipment overhaul;

6) Shop for dust collection from production of fluoric acid and its salt;

7) Steel and iron casting shop;

8) Construction and repair shops # 1,2,3.

9) Repair and mechanical shops # 1 and 2;

10) Motor shop # 1 and 2;

11) Energy shop;

12) Central warehouse;

13) Shop for production of aluminum products;

The main products are:

- Raw aluminum and products based on it (aluminum ingots, wire rod and aluminum sheets);
- Deification anodes;
- Consumer goods made of aluminum[2];

1.1.2. The scale of atmospheric fluorides pollution

Table 1: Background contamination of the atmosphere by types of pollutants

#	Name of index	Unit	Index value
1.	Alumina	mg/m^3	0.00002
2.	Oxide	mg/m^3	0.00007
3.	Nitrogen dioxide	mg/m^3	0.00006
4.	Sulfur dioxide	mg/m^3	0.00003
5.	Hydrogen sulfide	mg/m^3	- (trace)
6.	Carbon monoxide	mg/m^3	0.0001
7.	Gaseous fluoride	mg/m^3	0.00003
8.	Solid fluorides	mg/m^3	0.0001
9.	Resinous substances (sublimate of stone coal pitch)	mg/m^3	0.002

[2] Data of the library of the Technical Deparment of TALCO, 2010;

10.	Formaldehyde	mg/m^3	- (trace)
11.	Chlorine	mg/m^3	0.0005
12.	Suspended substance	mg/m^3	0.002
13.	Inorganic dust containing	mg/m^3	0.0003
14.	Wood dust	mg/m^3	no data
15.	Annual and seasonal mean values of concentrations	mg/m^3	no data
16.	Repeatability of the pollutant concentration is greater than 1 MAC, 5 MAC and 10 MAC	mg/m^3	5
17.	Major sources of atmospheric pollution in the area of construction	mg/m^3	Auxiliary production

Source: Statistical data of TALCO, 2010

Emissions of TALCO have significant impact on health and environment of Tursunzade and nearby regions of Tajikistan and Uzbekistan. Emissions of TALCO are spread mainly depending on the meteorological characteristics of the environment and environmental factors in Sariasiysk, Denau, Shurchi, Altinsk areas and Surkhandarya region of Uzbekistan[3].

Data analysis of statistical reporting for 2002-2009 reflects the tendency of reduced emission on all major pollutants.

Table 2: Emissions of harmful substances in the country for the period of 2002-2008

Years	Emissions of harmful substances in the Republic (thousand tons)	TALCO's contribution to the total amount of harmful emissions in the Republic
2002	69.9	42.1
2003	43.8	66.7
2004	30.1	80.96
2005	31.8	73.6
2006	24.2	75
2007	23.3	80
2008	21.4	79
2009	22.1	80

Source: Statistical data of TALCO, 2010

1.1.3. Characteristics of existing air pollution

[3] Data from the reports of the AS RT, 2010;

In light of socio-political and economical changes in the past decade in Tajikistan, the system of air monitoring has deteriorated, which makes it difficult to assess the transboundary air pollution. In the early 90-ies, there were 21 air quality observation stations in Tajikistan. Currently, the number of observation systems went down 5. The observation systems in Tursunzade and Sughd are closed down. Thus it is not possible to get reliable data on air emissions from sources of industrial pollution in Tajikistan and other neighboring states. Road and rail transport also significantly contributes to air pollution in Tajikistan.

The most significant emissions of fluorides are observed around the plant and are 1.5-4.5 tons of fluoride a day. Fluorine emission standards from an electrolysis plant for producing pure aluminum is no more than 0.5-4 kg of fluorine gas and 0.2-0.7 kg fluorine salts. Within the distance of 8-10 km, the emissions of gaseous fluorine are about 80% and of solid fluorine about 15%. Due to the winds, the fluorine emissions are spread to further distances and precipitate in the soil with rain.

1.1.4. Standards for fluorine content in the atmosphere

Currently in Tajikistan has a uniform standard for maximum allowable concentration (MAC) of harmful pollutants to the atmosphere. Average daily MAC for fluoride hydrogen is 0.005 mg/m^3, for solid fluorides 0.03 mg/m^3 and for sulfur dioxide 0.05 mg/m^3. The European Union has established the following indicators of MAC for pollutants in the atmosphere during the growing season: for very sensitive plants 0.0003 mg/m^3, for sensitive plants 0.0005 $mg/\ m^3$ and less susceptible plants 0.001 $mg/\ m^3$. Highly sensitive plants react to fluoride content of 50 mg/m^3, sensitive plants react to 50-200 $mg/\ m^{3,}$ and relatively stable plants to above 200 $mg/\ m^3$. Natural fluoride content in plants is usually less than 20 mg/kg.

Among all existing pollutants, fluorine is of major importance since it is the third most harmful pollutant after sulfur oxides. The following are the specific characteristics of fluorine:

- It has an extremely high chemical and biological activity;
- Pollution of the environment with fluorine causes direct and indirect adverse effects;
- Steady increase in emission of fluoride.

The increasing tendency of fluoride concentrations with their high chemical and biological activity requires consideration of its sources, the extent of pollution and their consequences. Fluoride is one of the strongest oxidants and removes the oxygen from majority of compounds. There are over 100 known fluorine minerals, among which the highest fluorine content is discovered in cryolite (54.3%), fluorite (48.7%), and less in fluorine apatite, biotite, muscovite etc. Calcium of fluorine phosphate and apatite contains up to 3.8% of fluorine (Astrelin *et al*. 2000). Apart from technical means for air cleaning, the plants are also of great as they act as biological filters and are natural indicators of environmental pollution. High concentration of air pollutants in the atmosphere causes damage to plants and even their death.

During production process, hydrogen fluoride does not occur separately from fluoride, thus it is difficult to distinguish the poisoning due to the action of hydrogen fluoride or fluoride ion. Irritation of the mucous membranes and respiratory system is associated with hydrogen fluoride, and damage of calcium metabolism and changes in the skeleton with the action of the fluoride ion. The dynamics of emissions of fluoride and other contaminants of TALCO is provided in Table 3.

Table 3: Dynamics of emissions of fluoride and other contaminants in TALCO in tones

Name of ingredients	2006	2007	2008	2009
Solids	**2416.79**	**2027.31**	**20.21**	**2038.5**
Sulfur dioxide	**700.67**	**692.55**	**690.5**	**693.8**
Carbon monoxide	**18441.5**	**18539.3**	**18701.0**	**18800**
Nitrogen oxide	**197.0**	**212.6**	**213.4**	**214.1**
Hydrogen fluoride	**120.66**	**119.39**	**119.0**	**120.2**
Tarry substances	**22.25**	**22.98**	**22.0**	**22.0**

Source: Statistical data of TALCO, 2010

The biological effect of fluoride promotes the optimal development, mineralization of bones and teeth. It stimulates reparative osteogenesis in fractures of bones, prevents the development of osteoporosis. The optimum fluorine content within the hygienic standards in the diet positively affects the generative function, hematopoiesis, immunological activity and increases the body's resistance to radiation and chemical carcinogens.

The optimal daily human need of fluorine is 3.2-4.2 or 0.5-0.7 mg/ kg of body weight. Excessive intake of fluoride in the human body is harmful because its high concentration reduces the activity of enzymes involved in metabolism[4].

1.1.5. The impact of magnetic fields on health

Within the moderate levels, the magnetic field has anti-inflammatory, analgesic, antispasmodic and neurotropic effects. However, continuous exposure to high levels of magnetic field may result in health problems. Hygienic evaluation of magnetic fields was tested in the first electroplating baths with the currents of 150 kA, as well as in the last buildings where the currents through the furnace were already in the order of 250 kA. It is worth mentioning that the gradient of strength of the magnetic field in the air is not constant: within a distance of 0.5 m it sharply decreases to 12 d /cm, then within 1 m it goes even lower to 5.8 d/cm, within 3 meters even lower to 2.6 d/cm and in 8 m it becomes 1.0d/cm. During the operation of boilers the level of magnetic field is at the level of maximum permissible and even higher. However, the workers spend little time in the zone with high magnetic field.

The following are the measures for reducing the effect of magnetic field:

1. Screening of magnetic fields of current-carrying wires and furnaces using materials with low residual magnetism;

2. Automation of processes which the worker is forced to perform in the high magnetic field:

3. Conducting medical monitoring of workers health in the factory buildings.

Production of each ton of aluminum results emissions of tens of kilograms of fluorides, dust, sulfur dioxide, carbon oxides, tar and etc.

The main reason for poor working conditions and excess emissions of harmful substances into the atmosphere from electrolysis production of TALCO is its design deficiency and poor operation. The plant was constructed in 1975 following the latest technology innovations, however, in the modern world; the current technology used by TALCO is outdated. Many operations in modern aluminum plants are automated, for example automatic feeding of bath with alumina, maintenance of electrolyzers with cranes with low-hanging cabin.

Treatment of electrolyzer is done by gantry machines PMAP and diesel CPM-5, during which the electrolyzers become depressurized and a large amount of fluorine compounds and dust are

[4] Data from the reports of the AS RT, 2010;

emitted inside the shop.

1.1.6. Measures for reducing emissions in TALCO

In order to protect the air quality and the environment, there had been a number of measures taken aimed at reducing emissions which are harmful to human health and environmental system. In this regard, the main laws adopted in Tajikistan are: ¨Law of the Republic of Tajikistan on Nature Protection¨ and the ¨Law of the Republic of Tajikistan on air quality protection" which laid down the basic rights and obligations of enterprises, institutions and organizations responsible for supervising the conservation and management of natural resources. The responsibility for the development of improved methods for calculation of air emissions and emission standards is given to the Ministry of Nature Protection, Ministry of Industry and the Ministry of Internal Affairs of Tajikistan.

The environmental regulations and emission standards have not been modified or adjusted to the current standards in the last 10 years. Neither there been any incentive or program for technological modernization that would enable to maintain and possibly improve the air quality in the emerging since 1997 the industrial production growth in the country. The effectiveness of air filters in TALCO is presented in Table 4.

Table 4: Dynamics of TALCO's emissions for the last 5 years

Name of substance:	**2005**	**2006**	**2007**	**2008**	**2009**
Solid substances	94.4	94.3	94.6	94.6	94.5
Hydrogen fluoride	88.5	88.9	89. 4	89..3	89.8
Sulfur dioxide	88.3	88.4	88.4	88.3	88.2
Resinous substance	81.0	80.8	81.2	81.4	81.4
Total:	**88.0**	**88.1**	**88.4**	**88.4**	**88.5**

Source: Statistical data of TALCO, 2010

1.1.7. The effectiveness of trapping air pollutant in TALCO

TALCO has adopted a plan of measures for prevention of accidental emission of harmful pollutants into the atmosphere. The main measures of this plan are the following:

- Modernization of the gas-cleaning equipment by replacing the battery cyclones to dry cleaning technology imported from Norway;
- Introduction of automatic recorders for monitoring of the inlet of gas cleaning unit;
- Replacement of fens with smoke exhausters;
- Modernization of scrubber drip pans of the gas-cleaning equipment;
- To provide the electrolysis shops of aluminum with lids cover and end shields in sufficient quantities for all operating electrolyzers;
- To ensure that back-up gas purification equipment are ready for any accidents.

1.1.8. Legal basis for environmental regulation in TALCO

To comply with environmental regulations, TALCO follows the existing legal and normative acts of the Republic of Tajikistan:

1. The Law of RT "On Environmental Protection";
2. The Law of RT ¨ On Protection of Atmospheric Air ¨;
3. The Water Code of the RT
4. The Land code of the RT and etc.

In accordance with the article 11 of the Law of the RT on ¨ On Protection of Atmospheric Air ¨, all companies and enterprises, irregardless of their departmental affiliation, which have source of air pollution, must adopt the standards for maximum permissible emissions of pollutants into the atmosphere.

Articles 25 and 46 of the Law of the RT “On Nature Protection” define environmental requirements for industrial and energy facilities. Article 53 and Article 27 of the Law of the RT "On Nature Protection" and "On Protection of Atmospheric Air¨, prohibits production and use of ozone depleting chemicals and substances.

However, the lack of regulations for implementation of provisions laid down in these articles makes it difficult to apply them in practice and to comply with them. Priority should be given to adoption of regulations in order to clarify the procedures for public involvement, as well as defining the right to access environmental information. Therefore, the government needs to develop the necessary infrastructure and legal basis for monitoring of environmental standards.

CHAPTER II

CURRENT WAYS OF WASTE DISPOSAL FROM ALUMINIUM PRODUCTION

Wastes from the production of aluminum can be divided into three types:

- Liquid waste "slag field";

- Solid waste "slag field";

- Solid waste stock (SWS).

A well-known method of liquid waste recycling of aluminum production (Trubeckoy *et al.* 1998, Morozov *et al.* 1973) includes cooling of the sodium sulfate liquor after cooking of cryolite to -2 °C and exposing it for one hour. During this time, there is a loss of crystals of salts ($Na_2SO_4 \cdot 10H_2O$), which under vacuum, are separated from the solution. The disadvantages of this method are the loss fluorides and soda, as well as the complexity of its technological scheme of production.

Another method[5] of recycling of wastes from aluminum production includes dust extraction, neutralization of gas, processing of coal foam with sodium sulfate liquor. But it has the same disadvantages: large losses of fluorides and soda, as well as the complex technological scheme of production.

In their invention (Goyakov*et al* 1989.), the authors addressed these shortcomings with mixing the solution of the gas cleaning system with slag purification and flotation tails, then treating it with a calcium hydroxide solution of concentration of 1,0-1,6 g / l, then separating the solution from the sediment, while maintaining the ratio of the volumes of gas cleaning solutions and

[5] U.S. Patent #2231305, 1967: 16-94 pages.

calcium hydroxide within 1:1 to 1:2. The settled slag they recommended to granulate and use in the cement industry. The technological scheme of flue gas purification and regeneration of sodium sulfates used in Krasnoyarsk Aluminum Plant used as a basis for this method.

These researches (Snakin *et al.* 1998) present data on the method of recycling fluoride containing waste from aluminum production, which includes dust removal from exhaust gases from aluminum electrolyzers, preparation of soda solution, purification of gases with soda solution, the separation of slag from purification from the resulting solution, the flotation of coal foam with separation of flotation tails and other processes.

To increase the purity of purification solution from sulfates and increasing the extraction of fluoride in the solution the authors propose (Morozov *et al.* 1985) an option, which includes dust removal from gases, cleaning gases with an alkaline solution, the separation of slag of the purifier from the sodium sulfate liquor, treatment of coal foam with sodium sulfate of purifier, mixing of sodium sulfate solution of the purifier with the slag of the purifier and the solution containing calcium hydroxide concentration of 1,0-1,6 g / l, the separation of slag from the clarified solution, which differs from the work (Privalov *et al.* 1987) because it uses a solution containing calcium hydroxide and chloride concentration of 0,5-2,0 g / l in the volume ratio of 1,0-1,5, respectively, at the rate of the mixture of solutions with respect to the solution purification 0,1-0,25. With the ratio of solution of calcium hydroxide and its chloride of less than 1, extraction of sodium sulfate is very insignificant, and if the ratio is more than 1,5 then there is low degree of its purification from sulfates. In comparison with the known method using the proposed method allows increasing the degree of purification of sulfates by 1,5-2,0 times, and the recovery of fluorides by 1,2-1,5 times.

Also, there is a known method of extraction of soda-sulfate residues from the aluminate solution of alumina production[6] through evaporation of solutions in steamed powered evaporators up to the concentration of caustic alkali, equal to 250-320 r / l, followed by heating of the solution and its self evaporation. The disadvantage of this method is in the fact that, despite the heating and self evaporation of steamed solution, soda deposits formed in a direct flow steaming, still remain very small (no larger than 50 micrometers). This is the reason for the high content of alkali in the filtered soda, which is removed together with the slag from the Bayer cycle solution. To address these limitations, the authors of this research (Furman *et al.* 1966) undertook the steaming of solutions in the presence of 0,001-10,0 g / l of polyacrylamide and the heating is carried out simultaneously with dilution of solution with steam till reaching the caustic alkali concentration of 200-300 g / liter.

The disadvantage of this method is in multi stage steaming, which significantly complicates the process and increases the energy consumption for dilution and self evaporation. Furthermore, the process is relatively expensive because of the high cost of polyacrylamide. In order to simplify and reduce the cost of this process [Zlokazova *et al.* 1967] the steaming of solutions is done up to reaching the concentration of caustic alkali, equal to 270-280 g / l and the separation of slag. Organic additives are used in the process, which is a production waste - production residue 2-ethylhexanol in the amount of 5-100 mg / l, which is used its numbers in the 30-35% in the steaming process and additionally added in the amount of 65-70% before separating the slag. The residue contains 20-30% of normal alcohols and esters limit of 70-80% of higher alcohols.

The invention patent[7] describes a method of regeneration of soda from black ash slag - a byproduct of pulp production - by co-firing liquor and fuel oil in the soda regenerating boiler. Also there is a known method of obtaining carbonate of alkali or alkaline metal[8], which consists of mixing the calcium nitrate with pre-crushed calcium carbonate. In order to accelerate and simplify the process, the authors of the invention[9] offer a way to obtain carbonate of alkali or alkaline metal at a temperature of 400-600 °C, characterized in a way that the original product before carbonization contacts with natural gas at 740-900 °C for 2-3/seconds. As a result the yield of product is 95-99%.

In the method of producing carbonates of alkali metals[10] by thermal carbonization of sulfates of the metals, containing hydrogen, carbon monoxide, carbon dioxide and water vapor. In order to increase the yield of the desired product, gas with the total content of hydrogen and carbon monoxide 40-80 vol.% is used, with ratio of CO/H_2 greater than unity and the partial pressure of water vapor of 0,2-0,3 atm. The method results in 92-95% yield of the desired product.

The research[11] provides a method of obtaining soda or potash, in which the formation of fusible eutectics is prevented. The restoration of sulphate is carried out in a reactor, previously filled with carbonate and potassium sulfate, at a ratio of 85-95% carbonate and 5-10% of sulphate.

[6] Author Ceritificate 461900, USSR 01 F 7/14, 27.12.71.
[7] Author’s Certificate 1662933: USSR. Sposob regeneracii sodi [Method of soda regeneration] by G.Y., Aleshin, M.A., Gurkevich et al. 15/09/1991.
[8] UK Patent #1150538 cl.a. 1968;
[9] Author’s Certificate 611885: USSR. Sposob polucheniya karbonata shelochnogo ili shelochnozemelnogo metalla [Method of production of alkali carbonate or alkali earth metal] by Adamskiy, N.M., Bodova, T.P. et al. 25/06/1978.
[10] Author’s Certificate #396308: USSR. Sposob poluchenie karbonatov shelochnikh metallov [Method of carbonate production alkali metal carbonate] by Vladimirov, P.S., Nasirov, G.Z. 29/08/1973.
[11] Author’s certificate 334182: USSR . Sposob polucheniya kalcinirovannoy sodi ili potasha [Method of potash

The outcome of Na_2CO_3 up to 98%.

Vladimirov, P.S.[12] proposed a method for producing carbonates of alkali metals by thermal carbonization of sulphates of alkali metals in presence of a catalyst.

The research on Prepariation works for disposal of saline aluminum production (Privalov *et al*. 1987) presents the results of research on the utilization of saline solution of aluminum production. Also it offers an efficient technology to process them, which consists of their dehydration. It allows obtaining dry and easily transportable product. A promising way of dehydration is drying - granulation in a fluidized bed.

2.1.1. Waste disposal technologies used at TALCO

U.M. Mirsaidov (2002b) for the first time, on the example of TALCO developed a technology for integrated treatment of the waste from slag field from aluminum production, including sintering with coal and calcium carbonate, characterized in that before sintering the slag is treated with water at 25-80 °C till removal of sodium ions in flushing waters. The solution is steamed to dryness, and after the sintering, sodium carbonate and potassium are extracted by water .

The authors Gulyanickiy (1975) and Gus (1964) demonstrated that during evaporation of solutions containing fluorides, sulfates and carbonates of sodium, the crystallization of salts such as NaF, Na_2SO_4 and $Na_2CO_3 \cdot 2Na_2SO_4$. occurs. The authors recommend producing of sodium sulfate in the form of double salt from clarified solutions of purifier through steaming of the sum

production or soda ash] by Rubinchik, F.,I,, Vladimirov, P.S. 30/03/1972.

of sodium carbonates 130-140 g / l. In this case 65-75% of sodium sulfate precipitates in the solid phase.

Sodium bicarbonate which is contained in solution is very important in the process of regeneration of fluorine from the gases of aluminum production. Firstl, as it is a main component in the reaction, which is responsible for the formation of cryolite and sodium. Soda is then used for the absorption of hydrogen fluoride in the wet gas cleaning equipment. Secondly, sodium bicarbonate carbonizes caustic soda that is used with the aluminate solution for producing cryolite (Belyaev *et al*. 1962).

The presence of NaOH in the reactor increases the content of unbound NaF and $NaAlO_2$ in the sodium sulfate liquor, and their loss with slags in the form of cryolite using the sodium sulfate liquors in the gas treatment.

Thus, the lack of sodium bicarbonate in solution leads to a deterioration of technological parameters of melting of cryolite. Consequently, the preservation of bicarbonate in the solutions is an important technological challenge. In order to identify the causes of the decomposition of $NaHCO_3$, authors conducted laboratory experiments to change the salt composition of solutions, the period of the experiment, the area of contact of solution with the atmosphere and other factors. Experiments showed that the decomposition of bicarbonate in the entire solution occurs with approximately same velocity. According to the results of the research, it is possible to create conditions for technological operations of cryolite regeneration, in which the decomposition of

[12] Author's certificate #367052. Sposob polucheniya karbonatov shelochnikh metallov [Method of metal alkaline carbonate production] by Vladimirov, P.S. 23/01/1973.

bicarbonate in solution purification will be minimal. N.G Lokhova (1994) studied the conditions of extraction of fluoride and aluminum from the slag of electrolytic aluminum in alkaline solution.

The special research on the utilization of circulating gas cleaning solutions using electro-processes is done in the researches (Nee *et al.* 1988, Manankav and Sisalova 1995).

Technology for treatment of solutions includes:

- Electrochemical decomposition of sodium carbonate in double camera membrane cell;
- Selective separation of the sulfate-fluoride liquor with regeneration of sulfuric acid in the system with cation and anion exchanging membranes;
- Sedimentation of cryolite in the presence of bicarbonate ion.

An extensive series of studies were conducted by U.M Mirsaidov et al. (1992) served as a foundation for the technology for obtaining valuable products from waste aluminum. In particular, the research studied the impact of soluble part of the slag with limestone and carbon dioxide in order to obtain soda ash (Gatina *et al.* 1994; Mirsaidov *et al.* 1996; Safiev *et al.* 1996, Mirsaidov *et al.* 2001; Azizov *et al.* 2001). The study also describes conditions for obtaining Na_2CO_3 adding coal, tails flotation using exhaust gases from heat of TALCO (Mirsaidov *et al.* 2000).

Researches (Mirsaidov *et al.* 1999; Kurokhtin *et al.* 2000, Dadabaeva *et al.* 1997, *Jalolidinov et al.* 1997, Radzhabov *et al.* 1997) describe the principal technological schemes of waste treatment in TALCO. The main stages of the technological schemes are:

- Extraction of water-soluble part;

- Removal of carbon by flotation and burning of carbon and receiving the cryolite-alumina mixture;

- Drying of cryolite-alumina concentrate, study of kinetics, description of the mechanism of this process;

- Deferrization of carbon, fluorine-containing wastes and their products.

Studies (Mirsaidov *et al*. 1999; Gatina *et al.* 1996; Abdullaev *et al.* 1996) determined that during steaming and further cooling of gas cleaning solutions in TALCO, the process results in sedimentation containing sulfate, carbonate, sodium bicarbonate and sodium fluoride. Furthermore it has been proven that the sediment consists of a double salt $3Na_2SO_4NaF$.

Authors (Mirsaidov *et al*. 1999; Gatina *et al.* 1996; Abdullaev *et al.* 1996) defined a condition for conversion of Na_2SO_4 from the sediment to sodium carbonate using Leblanc method. It has been determined that the presence of sodium fluoride in the mixture reduces the temperature of conversion process.

H.S Safiev et al. (1997) carried out magnetic separation of coal-cryolite aluminum waste. Studies (Mirsaidov *et al.* 1997; Privalov *et al. 1987*) describe the basic technological scheme for recycling of aluminum waste:

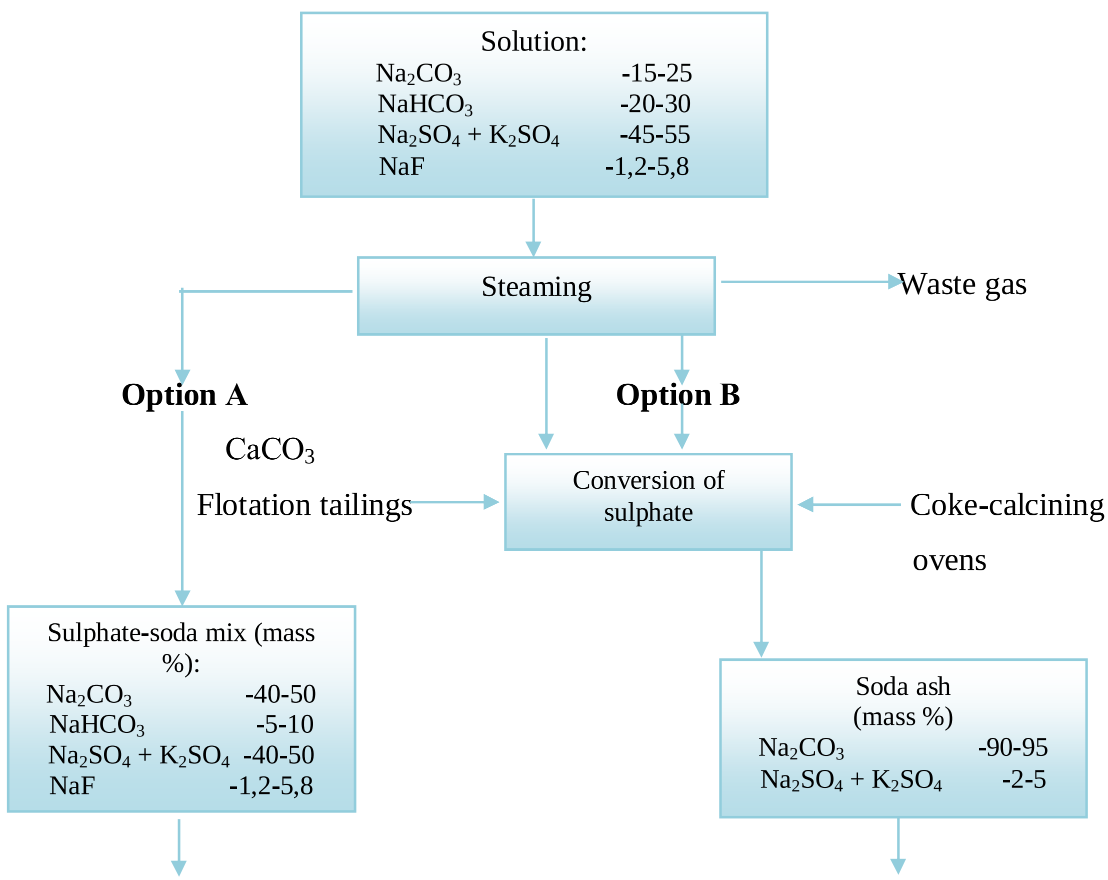
a) Scheme of liquid phase of slurry field treatment process

The liquid phase of slurry fields and identical to its composition water-soluble portion of the solid slag contains valuable salt - carbonates, and sulfates, which can be processed into carbonates. The study proposes a scheme for conversion of sulfates to carbonates, including soda ash, which is in high demand in the country and in particular in TALCO. This scheme has been brought to the stage of experimental development and its planned to be introduced in TALCO. (see image 1.2.1).

b) Scheme of primary slag treatment

Primary slag is one of the most difficult waste to recycle. It contains both a water-soluble and insoluble components. For the treatment of primary slag it is suggested to use technological schemes according to the exponential growth in their volume. Technological schemes of waste in terms of exponential growth in their volume.

Image.1.2.1. Basic schematic flow chart of obtaining the soda from the solution of slag field:



Production of liquid glass, glazes, alumina, etc. *For gas purification, degreasing and Etching of aluminum products etc.*

Analysis of industrial development, the scope and the extent of the use of raw materials, as well as the dynamics of production waste accumulation, consumption and their impact on the environment clearly demonstrated the need for new resource-saving and cost-based approach to organization of industrial production.

2.1.2. "Wast-free technology"

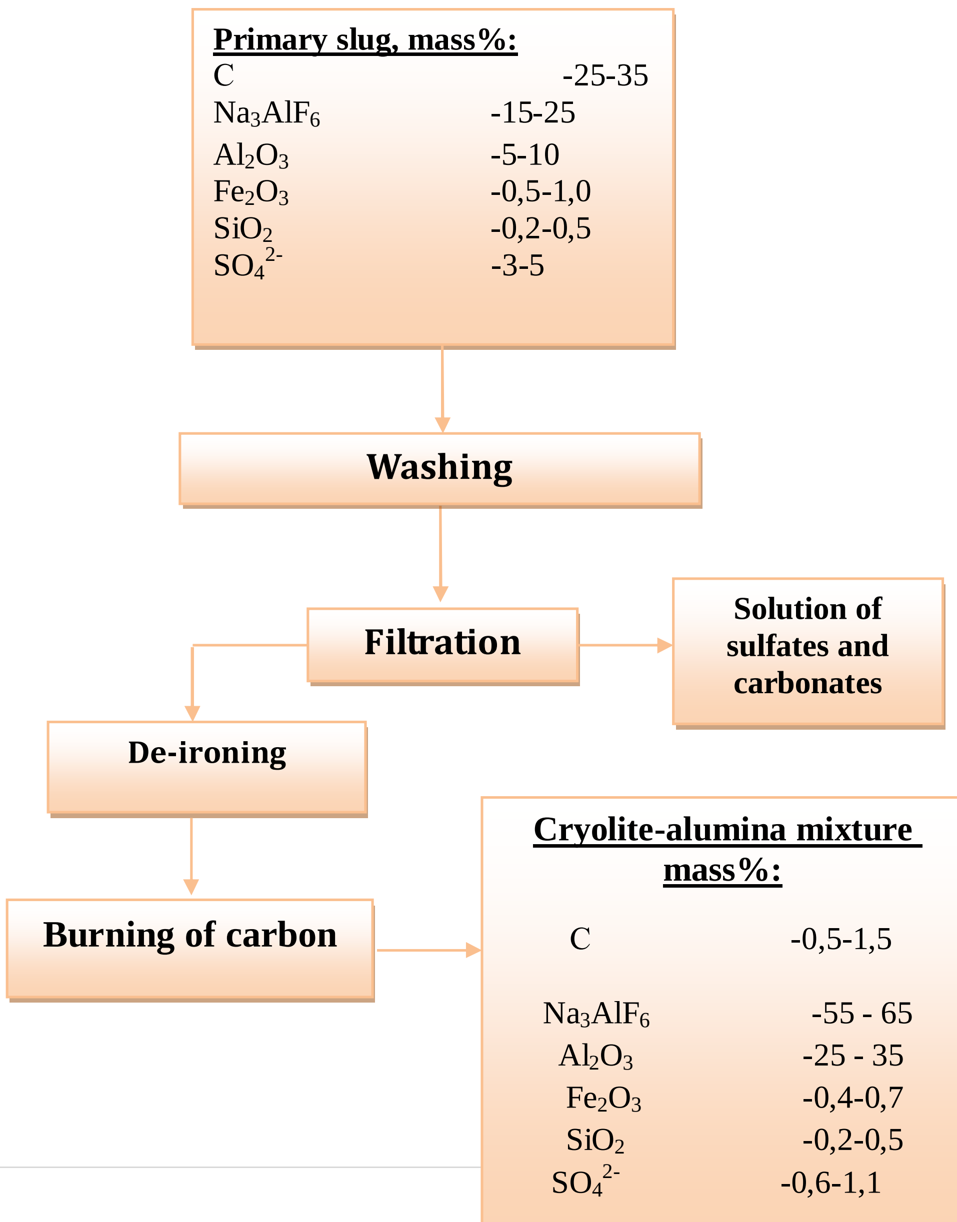
In a broad sense, the concept of "waste-free technology" refers not only to processes, but also to planning, research and a set of organizational and managerial activities. It also covers the consumption area, where after having served its purpose, the particular product should go back into production process for reuse or turned into an environmentally safe product that can be disposed off.

Recently, the term "waste-free technology" has been widely used around the world. The term "waste-free technology" implies practical application of methods and means to ensure that human needs are met with rational use of natural resources, reduced industrial waste and care for the environment.

Waste-free technology is based on several principles. First of all, the need for use of raw materials in the cycle, this includes the consumption sector. Waste-free production should be practically closed system, organized by analogy with natural ecological systems. In natural systems, waste products of some organisms are used by other organisms, and have generally been a self-regulating biogeochemical cycle of substances. The basis of the same kind of waste-free production would be organized and controlled by man cycle of raw materials, products and wastes.

In addition, the important factor of waste-free technology is a mandatory inclusion of all components in the production and consumption, including washing of slag from soluble salts and further removal of carbon, its flotation processing or baking.

Image 1.2.2. Scheme of trement in the Solid Waste Disposal Site (SWDS):



SWDS of TALCO currently contains more than 1200 thousand tons of waste, and there is an urgent need for their re-utilization. There is a technological scheme for recycling of SWDS which has passed industrial tests and has been introduced in the TALCO (image.1.2.3). On the basis of laboratory studies, the flotation technology for screening of SWDS. For this purpose, in the existing scheme of the electrolytic froth flotation, screening flotation was gradually introduced. The carbon content of the primary source ranged from 20 to 36%. The output cryolite-alumina concentrate ranged from 30 to 80%.

CHAPTER III

RECYCLING OPTIONS OF SOLID WASTE FROM ALUMINUM PRODUCTION

Production of primary aluminum produces large quantities of solid wastes: wastes from coal and thermal insulation lining of electrolyzers, anode ashes, coal foam and slag. For example, in the U.S., amount of waste generated annually is about 172 thousand tons (Galkov *et al.* 1978b), and in Western Europe more than 130-150 thousand tons (Galkin *et al.* 1975). According to a study (Istomin *et al.* 1999), the amount of highly fluorinated wastes (dust and gas cleaning slag from aluminum electrolysis) is about 30-35 kg / t Al.

All these types of waste contain large amounts of valuable components (fluorine, carbon, aluminum). Thus, the fluorine content in the faulty lining may take up to 20%. Coal foam recovered from baths, contains 60-70% of the electrolyte. Loss of fluorine from carbon foam is on average 35% of the total solution of electrolysis process. Disposal of solid waste to the dump requires much space, transportation costs, resulting in loss of valuable and scarce raw while polluting the environment (Galkin *et al.* 1978; Vekler *et al.* 1977; Skryabceva *et al.* 1986; Lazarev *et al.* 1985).

Therefore the processing of solid wastes for recovery and reuse of valuable substances is given a huge importance, since they reduce the production cost, improves the technical and economic performance of the electrolysis process and improves the state of environment. (Dubchak *et al.* 1982; Istomin *et al.*1999;Galkov *et al.* 1978b).

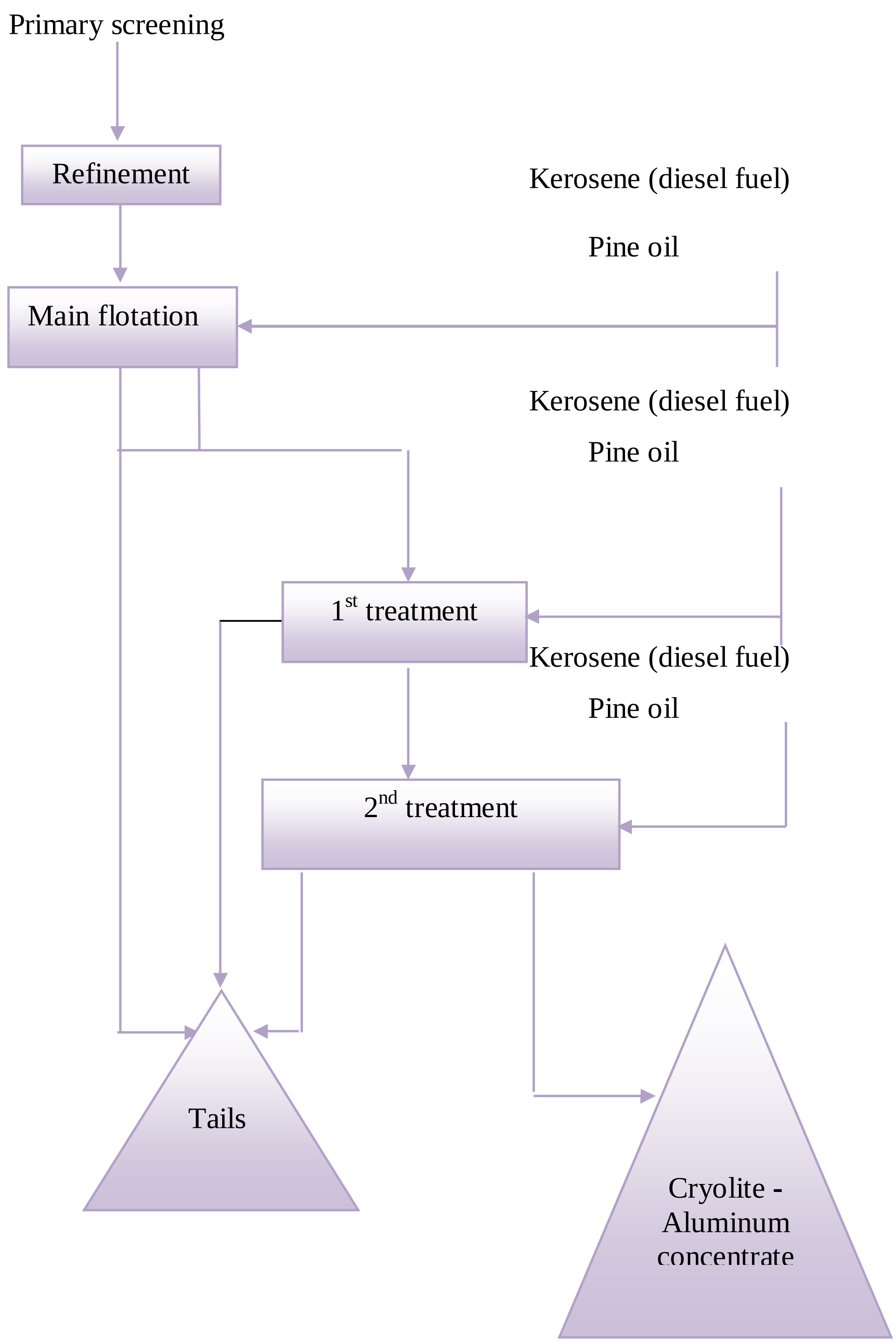
Recycling of solid waste from aluminum production is carried out in three areas: regeneration of fluorine, carbon regeneration and comprehensive extraction of valuable components (Korobcin *et al.* 1990; Gus *et al.* 1985).

The main methods of processing solid fluorinated waste from aluminum production can be divided into the following groups: alkaline, acidic, two-stage leaching, roasting, flotation, sintering and vacuum-thermal pyrohydrolysis (Galkov *et al.* 1978; Lavrenov *et al.* 1985; Dubchak *et al.* 1978a).

3.1.1. Alkaline regeneration methods

Alkaline regeneration methods of fluoride from the dismantled lining of pots, dust and slag purification have been widely used in many industrial countries including CIS, USA, Canada, Germany, Austria, etc. These methods are based on dissolving of fluoride salts in caustic alkali with the formation of fluoroaluminate solutions that are neutralized by any acidic agent ($NaHCO_3$, HF, CO_2) for obtaining cryolite (Dubchak *et al.* 1978b; Baevskiy *et al.*1977).

Image.1.2.3. Flotation method of processing carbon-fluorine-containing waste.



Acid leaching methods are based on the elevated temperature of aluminum and cryolite from coal lining solution of aluminum salt or diluted acid (hydrochloric or sulfuric), followed by salting out of cryolite from the obtained alkali metal salt solutions by adding fluoride acid. These methods are cumbersome and economically not feasible.

Two-stage methods of regeneration include first water or alkaline leaching, and then the acid, followed by mixing the solutions. Compared to the alkaline method, this option allows significantly improving the extraction of aluminum.

For regeneration of fluorine from dismantled fettling of electrolyzer is widely used hydrochemical method based on the leaching of refractory alkaline solutions followed by sedimentation of cryolite from the resulting solution of sodium aluminate and sodium fluoride by passing the CO_2 through the solution (Rotinyan *et al.* 1946). This method allows removing about 80% fluoride and 30% aluminum from the fettling. Cost price of cryolite, obtained in this way, is twice lower than the cost price of cryolite.

Application of hydrochemical methods can recover only cryolite and partially aluminum, and carbon together with insoluble impurities are stored in the heap. The carbon residue is being used as a mixing element in the foundry and cement industries, as well as a pulverized fuel. In France, it is proposed to reuse the solid waste product received after leaching as insulation under the cathode blocks, adding 10-15% - linking additive for the side walls of the electrolyzer.

The study (Grechko *et al.* 1992) shows the production of cryolite under hydrochemical process:

$$12HF + Al_2O_3 + 3Na_2CO_3 = 2Na_3AlF_6 + 6H_2O + 3CO_2.$$

Carbon dioxide is generated throughout the whole reaction, which allows separation of carbon by flotation using dust and slag instead of alumina. It was determined that there is a possibility of obtaining cryolite from highly fluorinated waste from aluminum production through flotation of carbon, initiated by release of CO_2 at formation of cryolite. Obtained after heat treatment at 500-600°C cryolite, is similar to the primary cryolite.

3.1.2. Solid waste treatment options used in Russian Federation

The following basic options for treatment of fluorine-containing wastes and their rationale use are practiced in the aluminum plants of Russian Federation:

1. Production of cryolite through leaching of fluoride from waste with NaOH solution. This technology was positively tested in industrial conditions in cryolite shop of Achinsk alumina plant.
2. Production of cryolite-alumina concentrates through flotation of foam at the Irkutsk Aluminum Plant, which allowed obtaining a product containing less than 4% carbon.
3. Use of dust and gas cleaning slag as a starter batch of electrolyzers at the Irkutsk Aluminum Plant gave a negative result because of the large gas release caused by combustion of carbon and resin compounds.
4. Briquetting of waste for use in the steel industry. Briquettes manufactured using technologies of JSC Siberian Department of Aluminum Magnum Institute, were used at the West Siberian Metallurgical Plant with a positive results.
5. High-temperature granulation of waste in rotary kilns has been tested, and pellets were used at Kuznetsk Metallurgical Combinat as diluents of slag.

In study (Vekler 1977) JSC Siberian Branch of Aluminum Magnum Institute (AMI) proposed technical solutions for obtaining fluoride salts from highly fluorinated waste with the use of sulfuric acid decomposition. The essence of this technical solution is as follows: Sodium aluminum fluoride, contained in the waste, is decomposed in sulfuric acid to obtain the hydrogen fluoride and sodium aluminum sulfur. Hydrogen fluoride is sent to the production of fluoride on any of the known technologies, and sodium aluminium sulfur is neutralized by milk of lime to form gypsum, which is displayed in the field of slag, and solutions of sodium aluminate, which can be used in the manufacture of cryolite and alumina.

In the laboratory of fluoride salts of Irkutsk branch of AMI were conducted experiments to determine the optimal technological parameters of processes, which can reduce the content of sodium and fluorine in the tails, mainly in the form of cryolite, which allowed for their removal to apply hydrochemical alkaline method, developed for the processing of the dismantled carbon lining of aluminum electrolyzers.

The method consists in the decomposition of fluorides with caustic alkali by the following reaction:

$$2Na_3AlF_6 + 4Na_20 \Leftrightarrow 12NaF + 2NaAlO_2$$

$$MgF_2 + Na_2O + H_2O \Leftrightarrow 2NaF + Mg(OH)_2$$

The results of these studies (Bruzhenec *et al.* 1990) showed that reducing of sodium content in the slag to 0,4-0,5% is sufficient to hold two-stage, preferably countercurrent leaching with a two-stage countercurrent washing.

Leaching conditions: temperature - 80^0C; residence time of material in the reactor at each stage -

0,5 h; consumption of alkali by Na_2O - 150-200 kg / t.

Conditions of cleaning: the two-stage countercurrent: L ÷ S = 3 ÷ 5:1; temperature - 80^0C; flushing time - 10 min.

About 85-90% of fluoride is extracted from the flotation tailings, which can be used for regeneration of cryolite.

Complete chemical analysis of slag obtained after treatment showed that they also reduced the content of a number of impurities that negatively affect the process of aluminum electrolysis.

With an average consumption of anode mass 590 kg and removal of coal froth up to 60 kg per ton of Al, it is possible to achieve complete recovery of flotation tailings of coal foam. The proposed waste technologies allow full use of all the carbon in the production of anode mass and obtain up to 80-130 kg of cryolite recovered from each ton of processed tailings, as well as completely eliminate dumping on slag fields.

3.2.2. Floation and roasting of solid waste

According to authors of study by Abisheva (1992), Mirsaidov (1995) and Suleymanov (2007) flotation is considered to be one of the main stages of the technological scheme of slag utilization in aluminum production. Its goal is separation of coal from other water insoluble components of slag. The study (Mirsaidov *et al.* 1995) shows the results of industrial tests for improving the flotation process of electrolytic foam based on the existing equipment in the shop for production of fluoride acid and its salts in TALCO.

However, the flotation methods are characterized by cumbersome technological scheme, labor-intensive screening and is a sources of pollution of the shop.

The method of obtaining cryolite-alumina concentrate through burning of carbon from the carbon-fluorine-containing waste is more economical and easier. For this purpose, the authors (Mirsaidov *et al.* 2002a) developed a technological scheme for production of cryolite-alumina concentrate by burning.

Production of aluminum also produces s a large volume of carbon containing waste. These are, first and foremost, include coal froth flotation tails containing up to 75-85% of carbon. Recently, much attention has been paid to study the possibilities of re-using this carbon and improving the state of environment[13].

Flotation and roasting is also used for the processing of carbon-and fluorine-containing solid wastes, which is simple, and consists of burning of coal particles from the waste. The method consists of burning carbon at a temperature of 600-700°C with constant exposure to air (Bagryancev *et al*. 1986; Belyaev *et al*. 1985). The resulting from this process cryolite is used as a raw material in electrolysis (Sushkov *et al*. 1965). Burning has been repeatedly tested for the processing of coal foam lining of the coal electrolyzers, dust and gaseous wastes and electrostatic precipitators. (Galkov *et al*. 1978a; Grechko *et al*. 1992). Different ways of burning has been tested: in piles, in cyclones of rotary kiln fluidized bed. During the burning process, they were difficulties determined associated with flying of the dust and loss of fluorine from the exhaust gases in the amount of 8-13% of the original content. Additionally, all impurities (silicon and

[13] Patent 1836462 USSR: cl. 22B 58/00. Sposob pererabotki otkhodov elektrolia [Method of processing waste electrolysis] by Z.S. Abisheva, A.S. Kasimova, S.K. Zhanozarov et al.

iron oxides) turn into ash that makes difficult or impossible to use the obtained product. Therefore, the method has found only limited application for burning of coal froth in Czech Republic and India. The resulting ash has the following composition,%: 25,1 - Na; 13,43 - Al; 0,85 - Fe; 6,40 - SiO2; 28,4 - F; 10,76 - $SO4^{2-}$; 5, 89 - C. Using the two-stage process, it is possible to obtain cryolite with a carbon content of less than 5%.

Another option of roasting of lining in a fluidized bed was developed by "Electrochemics" in Norway. Peculiarity of the technology in this case is the use of air-hydrogen mixture (Dubchak *et al*. 1978).

Another very promising method, which still has not yet been incorporated in the industrial scale, is burning of lining in a fluidized bed, ensuring complete combustion of carbon and 85-100% extraction of cryolite (Davidov *et al*. 1987).

The main challenge of this process is the difficulty of regulating the temperature, which must be maintained above the ignition temperature of carbon (approximately 600 °C) and below the melting point of cryolite (approximately 800 °C).

In accordance with the technological scheme developed by the UK firm Dutton West Recovery Limited (Ushakov *et al*. 1978), cryolite-carbon mixture is grated to a particle size of about 2 mm and with the help of the conveyor is loaded into the fluidized bed furnace with a grid made of ceramic materials. For the formation of fluidized bed combustion and maintaining of burning process, gas is continuously fed under area of the grid. The optimum temperature of the process is about 700°C. The temperature of the mixture in a fluidized bed is regulated by circulating cooling agent (air, water, etc.) in the tubes.

Pyrohydrolysis performed in the presence of water vapor with the formation of sodium aluminate and hydrogen fluoride. Hydrogen fluoride is captured, processed with aluminum hydroxide to obtain aluminum fluoride, which then returned to the electrolysis process.

The study (Sushkov and Troickiy 1965) proposed burning of lining with fluorspar and silica, followed by leaching the sinter and carbonization of the resulting solution for the allocation of cryolite.

As a result of increased attention for protection of the environment and depletion of world reserves of fluoride, there is a bigger need for reducing the waste from recycling of lining with regeneration of fluoride, aluminum oxide and sodium oxide. Companies such as “Keiser Aluminium”, “Lurgi”, “Vereiningte Aluminium Werke” in Germany have developed and tested in a semi-scale method of pyrolysis processing of lining waste. In this method, heat from combustion of carbon lining is used for hydrolysis (Davidov *et al.* 1987). Hydrolysis performed in the presence of water vapor with the formation of sodium aluminate and hydrogen fluoride. The last is captured and processed with aluminum hydroxide to obtain aluminum fluoride, which then returned to the electrolysis.

The studies (Ushakov *et al.* 1978; Safiev and Mirzoev 1990) researched the possibility of using fluorine-containing waste from aluminum production from cake obtained in alumina production.

With this purpose, they added to the nepheline-soda-lime, pre-shredded waste cathode blocks of aluminum electrolyzer, containing, mass of %: 15,6 - F; 18,3 - Al; 10,6 - Na; 2,1 - S; 1 8 - Fe; 1,3 - Ca; 0,9 - Mg; 0,2 resinous and 49,2 losses from calcining. Crystal-optical analysis of caking showed that the addition of these wastes in the furnace reduces the temperature of dissociation of CaCO3 and increases the speed of this process, activates and intensifies the process of caking. The most optimal is considered to be a supplement of wastes, in which the fluorine content is within 0,17-0,35% in relation to the weight of dry mixture.

The authors of studies (Ushakov *et al*. 1978; Safiev and Mirzoev 1990) demonstrated the possibility of using fluorine-and carbon-containing waste from TALCO in processing of nepheline syenite of Turpinskiy field. It has been shown that the addition of these wastes improves the quality of nepheline syenite and sinter.

The review of information (Chernisheva *et al*.1983), provides physical and chemical properties of slag wastes of KrAZ is and suggestions on their use in the manufacture of building materials: artificial porous aggregates of silicate products, glass, cement, stone casting, silica, acid-proof cement, mortar, concrete mixtures etc.

The work (Karnaukhov *et al*. 1990) studies the influence of fluorine-containing secondary raw materials - cryolite from the exhaust of coal lining, regeneration and flotation of cryolite on the physical and chemical characteristics (specific conductivity, thickness, viscosity) of electrolyte for production of aluminum. When adding to the industrial electrolyte of these components in quantities of up to 40%, no significant changes in these variables were observed. Consequently, the use of fresh and secondary fluoride in amounts commonly used in the aluminum factory, practically did not affect the process of electrolysis.

The results of industrial tests on adding of technical sodium fluoride to cryolite, obtained from the dismantled carbon lining of aluminum electrolyzers are provided in (Mokreckiy and Klimenko 1984). The cryolite obtained in such way is filtered better; the fluorine content in it increased on average by 4% and the quality has improved noticeably.

RECOMMENDATIONS FOR FUTURE RECYCLING ACTIVITIES

To improve the situation with environmental problems of waste recycling at the TALCO, first of all it is necessary to create a multi-phase program with a detailed description of the primary steps and the schedule of the further work in that direction. In order to address the problem of industrial pollution, there is a need to use the system for control and monitoring and to strengthen the economic incentives and harmonize the underlying legislation.

The market mechanisms should be effectively combined with non-market regulations. The mechanisms such as licensing system and taxes should be introduced to protect the air quality, placing the responsibility for emissions on the industries producing them. It is important to implement the principle of "debt to nature", funds earmarked for the environmental and social issues. These activities will contribute to the development of sustainable consumption and production.

There is also a need to develop consistent evaluation criteria for measuring progress in the field of air protection, in order to fill the gaps in the statistical and scientific data.

Furthermore, new and more efficient technologies should be introduced that would reduce the pressure on natural resources and would reduce the energy intensity of industries.

In addition, an appropriate legal framework should be created to focus on the development of regulations and laws which would enforce the existing laws. The old Soviet laws, which are still in place, must be actualized.

Moreover, there is a need to develop national and regional policies and identify the strategic directions to ensure an integrated approach to transboundary air pollution. These measures have to be supported with reliable systems for air quality monitoring, which would provide systematic and complete information.

CONCLUSION

The research has demonstrated that the improvement of waste recycling options is an important step in reducing environmental impacts of aluminium production.

In the example of TALCO, it has been demonstrated that the industrial waste produced in aluminium production is the subject of a huge importance not only from an economic point of view but rather more urgent due to the environmental impacts it causes.

Issues raised in the current research have determined that due to complex content of the waste from aluminium production as well as due to complex treatment process, various literature provide different views on the waste treatment processes. Most of the works published in post-soviet union region and do not consider the environmental aspect of waste recycling method of aluminium production.

Review of the current ways of waste recycling of aluminium production shows that three methods are the most common treatment options available to date: regeneration of fluoride, regeneration of carbon and complex extraction of other valuable materials. The principal ways of treating solid fluoride containing aluminum waste can be divided into the following categories: alkaline and acidic method, two-phase leaching method, sintering and flotation method and vacuum-thermal pyrohydrolysis. Furthermore, the research has identified that the dry alkaline process and substitution of soda with sodium sulphate during the sintering process is the most commonly used and successful method for obtaining cryolite-alumina concentrate (materials used for production of aluminium) from industrial waste of TALCO and from locally availably mineral resources. The latter method is considered to be the most effective and cost-effective among those TALCO can afford implementing.

During 2003-2006, a new technological innovation was introduced for the treatment of waste from aluminum production on the basis of patented method for obtaining cryolite-alumina concentrate from solid waste produced in TALCO. This innovation was done by Tajik scientists Mirsaidov, U., Safiev, H. and others (Euroasian patent#00336), which according to the Institute for Metallurgy would result in annual savings of USD 600,000.

Thus, it can be concluded that waste of aluminium production has an essential economic value and opportunity to re-enter the production process at TALCO if the above-discussed methods are being used effectively and efficiently. And in turn, the environmental impacts of aluminium industry can be lowered to minimum.

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