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DEVELOPMENT OF NEW TECHNOLOGICAL SOLUTIONS FOR RECOVERY OF HEAVY NON-FERROUS METALS FROM TECHNOGENIC WASTE OF ELECTROPLATING PLANTS AND SLUDGE OF WATER TREATMENT SYSTEMS

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Проведено аналіз основних принципів і методів утилізації токсичних промислових відходів, що містять важкі кольорові метали. Наведено результати експериментів по обробці донних опадів хвостосховищ в сірчанокислому середовищі. Запропоновано схеми їх переробки, що дозволяє досягти максимальних показників вилучення основних цінних компонентів. Запропоновані технологічні рішення дозволять підвищити ефективність переробки зазначених видів техногенних відходів

Ключові слова: техногенні відходи, важкі кольорові метали, очищення стічних вод, відходи гальваноцехів

Проведен анализ основных принципов и методов утилизации токсичных промышленных отходов, содержащих тяжелые цветные металлы. Приведены результаты экспериментов по определению состава осадков городских сточных вод и гальванических кеков. Предложены схемы их переработки, позволяющие достичь максимальных показателей извлечения тяжелых цветных металлов. Предложенные технологические решения позволят повысить эффективность переработки указанных видов техногенных отходов

Ключевые слова: техногенные отходы, тяжелые цветные металлы, очистка сточных вод, отходы гальваноцехов

1. Introduction

During the operation of industrial and municipal facilities, a significant amount of multi-component waste is formed. The analysis of the situation in the regions of mineral extraction and processing shows that the intensification of production leads to a large-scale damage and pollution of the environment. At the same time, artificial sources of environmental pollution arise and function for a long time.

The negative impact of disintegrated mineral waste is not so obvious as that of toxic dust and gas emissions or discharges. The analysis of mineral waste storage processes showed that under the influence of natural and technogenic factors they undergo weathering and transformation into new crystallochemical phases. This contributes to their destruction and spreading with groundwater and atmospheric flows. The processes of geochemical transformation most actively occur on the day surface of tailing ponds when exposed to low-mineralized atmospheric precipitation and air components, UV irradiation. This is accompanied by intense wind erosion of soils and dispersion of toxic components. At the same time, there is a significant contamination of surface and ground water and lands for various purposes. The solution of this problem became especially important in the areas of intense technogenesis with a local concentration of mining enterprises [1, 2].

Thus, the processes of galvanizing, cadmium plating, nickel plating, chromium plating, copper plating, anodizing and phosphating take up to 95 % of the capacity of electroplating plants in Russia and the CIS countries.

The electrolytes used in production form toxic wastewater, which is a strong poison capable of destroying biota in natural waters or biological treatment facilities. The most common are inorganic acids and salts (in wastewater of metal etching processes), alkalis, surfactants (in degreasing), cyanide compounds, inorganic salts of heavy non-ferrous metals (in electroplating processes) [3, 4].

Wastewater of electroplating plants is most often classified based on the chemical composition and pH of the electrolytes, which serve as a source of wastewater. These are rinsing water and electrolytes containing cyanide compounds from operations of precious metal electroplating, water containing sulfate ions and water containing oil products from degreasing and etching operations. The type and concentration of pollutants in wastewater of electroplating rooms vary in a wide range, depending on the nature of production and the technological operations applied. It should be noted that the pollutants contained in them cannot be removed by filtration and other methods commonly used for municipal wastewater treatment [3, 4]. This is due to the fact that these pollutants are distributed unevenly in solid and liquid phases in variable concentrations.

In the electroplating industry, waste is formed due to the removal (0.2–0.7 l/m^2) of highly concentrated (about 100 g/l) solutions and disposal of spent solutions (because of difficulties of their regeneration).

Another kind of waste that is formed in large amounts and requires drastic solutions for disposal is municipal wastewater sludge (waste of housing and communal services).

Methods of storage and disposal of municipal wastewater sludge (MWS) do not meet modern requirements of environmental safety. In some cases, the organic phase of MWS may contain up to 2 % sulfur, which causes the formation and release of hydrogen sulfide into the atmosphere near silt detention ponds. An H_2S concentration of more than 1 mg/l in the atmosphere leads to a lethal outcome for warm-blooded organisms.

Negative trends in the field of environmental protection, taking place in the mining regions, develop also in megalopolises (housing and communal services facilities), transport complex, machine building, defense industries, etc. [1, 2].

Pollutants of both natural and technogenic origin, contained in semi-products and waste, are valuable and scarce products. It should be noted that the market value of the majority of rare-earth and trace elements is significantly higher than that of the main extracted products. Therefore, the development of technological options of processing of environmentally hazardous technogenic waste containing heavy non-ferrous metals, followed by their industrial implementation, taking into account economic feasibility is an urgent task.

2. Literature review and problem statement

The method of liquid-phase oxidation [5] is known, however, it does not provide the formation of new compounds and selection of rock-forming and valuable components.

In [6], the authors propose the method of heterogeneous catalysis, which involves thermocatalytic oxidation, thermocatalytic reduction, and heterophase catalytic oxidation. It should be noted that the authors do not consider the specifics of catalytic processes, their economic characteristics and the probable presence of catalytic poisons in technogenic raw materials of variable composition.

The pyrolysis processes considered by the authors [7] are applicable to products that are not prone to subsequent migration in the environment and require the implementation of industrial gas cleaning systems, which does not ensure the self-sufficiency of the main technology.

High-temperature processes (incineration, high-temperature oxidation of nonflammable waste and high-temperature reduction) and plasma methods [8, 9] are energy-intensive and can be implemented only with the use of complex and expensive equipment. Similar to pyrolysis processes, their industrial implementation will require the creation of multi-stage gas cleaning systems. Industrial gas cleaning systems used in the processing of technogenic raw materials should provide for neutralization of the carcinogens contained in discharges if organic compounds are present in the waste.

In the industrial practice of waste treatment, the processes of dehydration, drying, thickening, reactant treatment using products in composite materials and the construction industry are also used. The authors of [10–11] suggest the production of composite materials using binders as the final stage of the technology, which does not involve the recovery of valuable components and does not exclude the risk of secondary migration of environmentally hazardous compounds.

Biotechnologies using oxidants (anaerobic digestion, aerobic stabilization), proposed in [12], allow concentrating toxic compounds in the organic phase. However, they cannot ensure the recovery of heavy non-ferrous metals to manufacture commodity products in the form of high-purity compact metals.

The analysis of existing technologies of management of environmentally hazardous waste of mining and processing and metallurgical complexes shows that in practice, hazardous waste is collected and subsequently buried in underground mines. This approach to environmentally friendly nature management is considered promising, it is based on the idea of creating closed geotechnological cycles. The problem is what waste, how and in what form to place in local geoecocoenosis for inclusion in the projected migration of substances in the biosphere.

The Russian treatment practice of wastewater of electroplating plants provides for treatment at neutralization stations with a solution of soda or lime milk, which leads to deposition of heavy metals in the form of hydroxides or carbonates mixed with gypsum. Sludge (cake) has a moisture content of 86–90 %. Due to the lack of an acceptable technology of recovery of heavy metals, disposal is made by landfilling. This represents a great environmental hazard due to the possibility of secondary contamination of the environmental components as a result of leaching of heavy metal ions by acidic soil waters. In addition, with the possible subsequent processing of stored waste, it will be necessary to spend funds for its extraction and transportation to the processing site [4].

With the traditional approach to utilization of multi-component cakes, the transfer of metals to insoluble forms is possible with the subsequent creation of ceramic and asphalt compositions, similarly solving the problems of environmental safety [4]. However, valuable components are lost irrevocably. There are technological developments aimed at concentrating non-ferrous metals in a sulfide product. However, the lack of specific production facilities in the places of galvanic cake formation makes the implementation of this utilization method difficult.

Despite the variety of methods for neutralizing semi-products of electroplating production, the problem of complex processing of galvanic cakes with selective separation of components and manufacture of commodity products has not been solved to date [4, 9, 13].

With regard to the treatment of municipal wastewater sludge, primary and secondary sludge is distinguished depending on the method of treatment and the phase-disperse state. The first group includes the coarse impurities contained in the treated water and which can be isolated by mechanical treatment (sedimentation, filtration, flotation, centrifugal settling). The second group is impurities originally present in water in the form of colloids or in an ionic form and which can be converted to the solid phase by biological or physicochemical water treatment.

Over a long period of time, the studies have been focused on the processes that ensure a reduction in the critical amount of material through incineration (burning). The alternatives suggested the use of pyrolysis, followed by the burial of cinders. It should be noted that incineration processes are characterized by a high level of toxicants in the dust-gas phase directed to the atmosphere (Table 1) [14, 15].

Table 1

Concentration of toxicants in the dust-gas phase during waste incineration

Component	Concentration, mg/kg
Cd	150–170
Cu	850–1,000
Pb	4–6
Hg	25–35

Direct use of the collective concentrate of HNFeM, formed as a result of burning and having a variable composition, in the non-ferrous metallurgy is impossible and unacceptable due to stringent requirements for process parameters and composition of the final products. From environmental positions, the processes of high-temperature drying with preliminary dehydration and additional charging in road-building compositions in the presence of HNFeM are unacceptable due to the possibility of secondary pollution [14].

Real opportunities of using MWS as fertilizers, due to the availability of potassium, protein compounds, nitrogen, phosphorus, etc., are limited by the presence of heavy non-ferrous metals. Therefore, the problem should be solved by industrial methods using approaches specific to large-scale productions of the mining and metallurgical complex.

Based on the above, it can be concluded that the existing methods of toxic waste processing do not ensure the selection and efficient recovery of valuable components.

The main drawback of the existing technologies of processing waste of electroplating and metallurgical industries, as well as industrial wastewater sludge is that they do not involve the industrial recovery of valuable components.

It should be noted that the environmental hazard of these products is due to the presence of heavy metal compounds. Hence the expediency of developing fundamental and effective technological solutions for the recovery of heavy non-ferrous metals from these types of unconventional raw materials.

3. The aim and objectives of the study

The aim of the work is the experimental substantiation of the possibility of efficient recovery of heavy non-ferrous metals from technogenic waste of electroplating plants and spent sludge of water treatment systems.

To achieve this aim, the following objectives were set:

– to analyze the impact of technogenic waste formed in mining regions and megalopolises containing heavy non-ferrous metals on the environment;

– to investigate the composition of technogenic waste of electroplating plants and spent sludge of water treatment systems;

– to develop effective technological solutions for the treatment of municipal wastewater sludge and galvanic cakes with the ancillary recovery of valuable components.

4. Methodology of studies of processing of technogenic waste containing heavy non-ferrous metals

The industrial facilities where the samples were taken are located in Russia. Their chemical composition was studied. The content of heavy metals was determined by the semi-quantitative and quantitative spectral analysis, chemical analysis and ionometry.

The experimental study of technological options for recovery of valuable components from municipal wastewater sludge and galvanic cakes was carried out. The laboratory and large-scale laboratory studies were conducted. The studied materials were subjected to reactant treatment, changing reactant concentrations, temperature, duration, stirring intensity during dissolution or leaching. The reactant concentration varied from 0.1 to 50 %. The process temperature at which the laboratory studies were carried out ranged from 40 °C to 70 °C. The duration of leaching processes varied from 10 to 70 minutes.

Each of the studied temperature regimes was monitored and maintained using resistance thermometers and automatic control systems. Semi-products were analyzed and, based on the results of the analysis, the recovery factor of the individual components was calculated on the basis of their mass ratio before and after treatment.

5. Experimental studies of processing of technogenic waste containing heavy non-ferrous metals

The experimental studies included the determination of the composition of initial samples of municipal wastewater sludge and galvanic cakes with the subsequent investigation of processes and treatment regimes in the laboratory.

The data were obtained by full-scale testing of MWS followed by the study of the chemical composition of the averaged samples. The material was analyzed by the methods of quantitative spectral analysis, atomic absorption analysis with preliminary chemical preparation, and also X-ray diffraction analysis. To verify the validity of the data, control of the composition of at least three parallel samples of the starting material and semi-products was carried out with subsequent control over the convergence of the results.

Table 2

Composition of municipal wastewater sludge

Element	Content, %
C	33.3–90.2
H	3.8–8.9
S	0.19–0.69
N	1.3–7.95
O	6.9–30.8

Preliminary experiments were aimed at studying the physicochemical parameters of MWS and included determination of the density and specific surface area of the material. The average density of MWS was determined by the bottle method using toluene as a working fluid. The average density value of sludge for the considered products was 1.02–1.04 g/cm^3 for "fresh", 1.1–1.17 g/cm^3 for the deposited sludge.

The reactivity of highly disperse materials is determined, along with the chemical and phase composition, by the specific surface area. This value was determined by the gas chromatography method of thermal desorption of argon [16], which allowed determining the specific surface area of MWS, which was approximately 1.21 m^2/g.

Table 3

Composition of the inorganic part of municipal wastewater sludge

Component	Content, %
SiO_2	16.7–56.3
Al_2O_3	0.25–25.9
Fe_2O_3	3.9–19.4
CaO	7.8–36.9
MgO	1.7–12.6
K_2O	0.56–4.2
Na_2O	0.64–7.8
ZnO	0.05–0.28
CuO	0.07–0.92
NiO	0.2–3.7
Cr_2O_3	0.3–4.1
SO_4^{2-}	3.0

Based on the data obtained, the experimental study of the fundamental technology of concentration and selective recovery of HNFeM directly from sludge and processing semi-products was carried out. The experiments were performed by the method of modeling of separate stages with analytical control of semi-products. The process flow diagram is shown in Fig. 1.

The experimental study of the possibility of processing galvanic cakes suggested the determination of the kinetic and thermodynamic characteristics of the proposed process.

The thermodynamic analysis of the probability of the main reactions was carried out using standard methods considering the process probability depending on the thermodynamic parameters of the main components [17, 18].

The experimental determination of the kinetic characteristics was carried out by the method of E. M. Vigdorchik and A. B. Sheinin [19]. The activation energy was calculated by the formula:

$$E = \frac{2.3R \cdot \lg(\tau_2/\tau_1)}{1/T_2 - 1/T_1}, \quad (1)$$

where E is the activation energy, τ_1 and τ_2 are the durations of the first and second experiments, respectively, T_1 and T_2 are the temperatures of the leaching process in the first and second experiments.

The reaction order was determined from the results of two periodic experiments at the same temperature, but at different initial concentrations of the reactant C_1^0 and C_2^0. In these experiments, the dependences of the shares of the undissolved component on the dissolution duration were determined, that is, the dependences $C_1(\tau_1)$ and $C_2(\tau_2)$, where C_1 and C_2 are the current concentrations of the reactant in the first and second experiments. Based on the experimental data, the dependence of τ_2 on τ_1 was constructed.

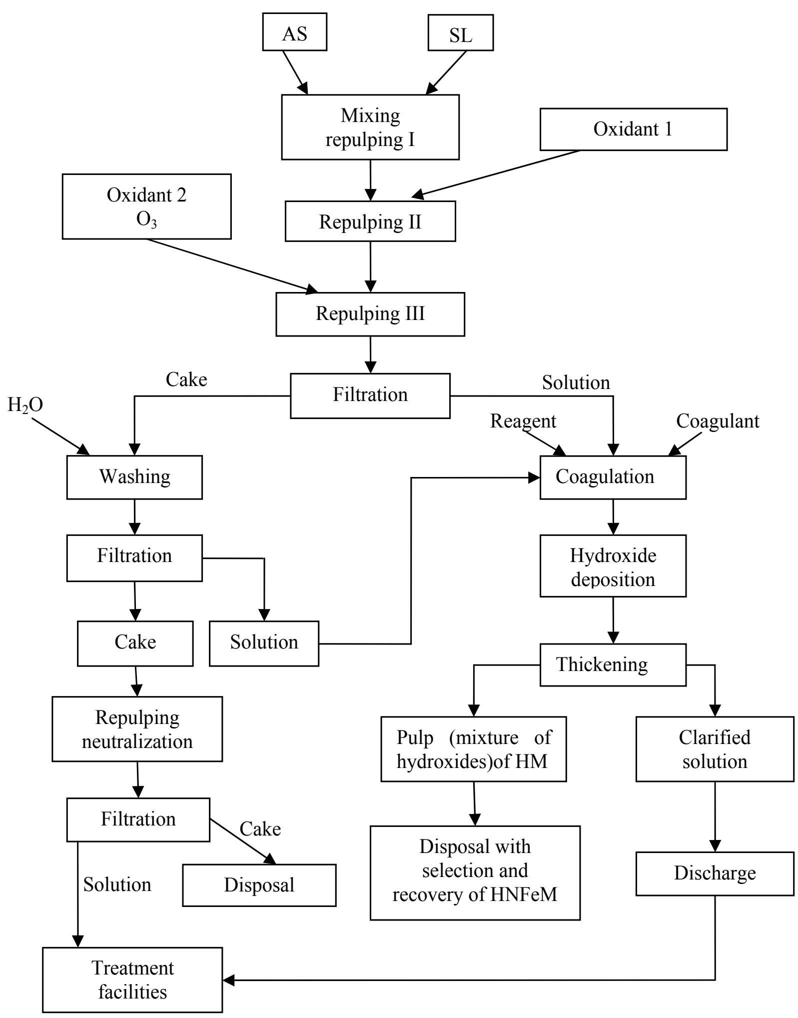

Fig. 1. Process flow diagram of disposal of municipal wastewater sludge to produce non-ferrous metal hydroxides

Then the calculated formula for the activation energy (α) takes the form:

$$\alpha = \frac{\lg(\tau_2/\tau_1)}{\lg(C_1/C_2)}, \quad (2)$$

where α is the reaction order, C_1 and C_2 are the reactant concentrations in the first and second experiments, respectively.

The time of complete dissolution is calculated by the formula:

$$\tau = \tau_o e^{\frac{E}{R}\left(\frac{1}{T_1}-\frac{1}{T_o}\right)}(C_o/C)^{\alpha}. \quad (3)$$

Thus, knowing the activation energy E, the reaction order α and the time of complete dissolution τ_o at some fixed values of T_o and C_o, the time of complete dissolution τ at any other values of T and C can be calculated by the formula (3).

The program of calculation is implemented in the "Mathcad" language, which enables to determine the activation energy, the reaction order and analytically determine the time of complete dissolution for a wide range of temperatures of the leaching process and concentration of sulfuric acid in the solution based on the data obtained from periodic experiments. The initial data were determined by the results of the experiments.

The thermodynamic probability of leaching processes was determined from the value of Gibbs free energy [14, 15] (Table 4).

Table 4

Gibbs free energy values for leaching processes at t=30, 50, 70, 90 °C

Sulfating reaction equation	$(\Delta G^0)_{328}$, kJ/mol	$(\Delta G^0)_{348}$, kJ/mol	$(\Delta G^0)_{368}$, kJ/mol	$(\Delta G^0)_{388}$, kJ/mol
$Zn(OH)_2+H_2SO_4=$ $=ZnSO_4+2H_2O$	–42.70	–42.73	–42.76	–42.80
$Cu(OH)_2+H_2SO_4=$ $=CuSO_4+2H_2O$	–23.82	–23.93	–24.04	–24.15
$Ni(OH)_2+H_2SO_4=$ $=NiSO_4+2H_2O$	–38.47	–38.56	–38.65	–38.75
$Cd(OH)_2+H_2SO_4=$ $=CdSO_4+2H_2O$	–7.58	–7.61	–7.63	–7.65
$Pb(OH)_2+H_2SO_4=$ $=PbSO_4+2H_2O$	–9.45	–9.47	–9.49	–9.51
$Mn(OH)_2+H_2SO_4=$ $=MnSO_4+2H_2O$	–6.772	–6.771	–6.769	–6.767
$2Fe(OH)_3+3H_2SO_4=$ $=Fe_2(SO_4)_3+6H_2O$	–58.04	–58.06	–58.07	–58.09
$2Al(OH)_3+3H_2SO_4=$ $=Al_2(SO_4)_3+6H_2O$	–11.92	–11.95	–11.97	–11.99
$2Cr(OH)_3+3H_2SO_4=$ $=Cr_2(SO_4)_3+6H_2O$	–12.31	–12.55	–12.79	–13.04

The thermodynamic analysis of the process indicates a high thermodynamic probability of leaching of HNFeM compounds with sulfuric acid solutions.

Given the typical composition of galvanic cakes (Table 5), the principles of their processing involve the use of traditional hydrometallurgical operations: leaching, concentration of valuable components and selective electrolytic refining of non-ferrous metals. The required equipment is well known in Russia, Germany, Canada and other countries where the chemical and metallurgical industry is developed. For leaching processes, mixing reactors are used, for electrolytic refining – electrolysis baths, for filtration – filter presses, drum filters, vacuum filters.

Table 5

Typical composition of galvanic cakes

Content of elements, %											
Fe	Zn	Cd	Cr	Al	Ni	Cu	Pb	Mn	SiO_2	SO_3^-	P_2O_5
19.2	1.7	0.004	11.8	5.0	1.2	1.0	0.9	0.2	6.5	0.4	7.3

For leaching of similar materials, it is possible to use sulfuric acid as the basic reactant. The choice of the reactant is due to its relatively low cost, 200–210 USD/ton, as well as the possibility of further isolation of individual components from the leaching solution by traditional hydrometallurgical methods using existing methods. It is expedient to conduct the dissolution process at the highest possible temperatures of 40–70 °C.

This aim can be achieved by using the heat of the exothermic reaction of dissolving the galvanic cake in reaction with concentrated sulfuric acid; the process temperature is about 40–45 °C. The time of complete dissolution is 60 minutes.

The technology of processing of galvanic cakes includes the following basic operations:

– sulfuric acid leaching;
– filtration;
– carburizing processes;
– electrolysis;
– drying.

Filtration should be carried out using macroporous filters (for example, the time of filtration through a glass cloth on a vacuum filter is 35–45 minutes, while the time of filtration through a paper filter is several hours). Taking into account volumes of the processed waste, it should be considered advisable to use press filters traditional for hydrometallurgy and electroplating.

The implementation of such a technology of processing of galvanic cakes and similar waste will allow the disposal of the bulk of this type of waste. At the same time, the prospect of obtaining the following commodity products is obvious: cathode metals (Cu, Ni, Zn), gypsum ($CaSO_4 \times 2H_2O$), Fe_2O_3 and Cr_2O_3 oxides.

The components recovery factor was calculated on the basis of the initial, intermediate and final analyses of the content of valuable components as the ratio of the mass of the obtained product to the mass in initial raw materials as a percentage. The experimental studies showed a fundamental possibility of conducting the process in the temperature range of 40–70 °C, while the recovery factor of the main components in the solution amounted to about 99 % (Table 6).

The determining effect on the degree of recovery of components in the solution is exerted by temperature and duration of the main stages. The experiments were carried out by modeling industrial operations with control of process parameters at real temperatures, liquid to solid ratios, reactant concentrations with the prospect of the industrial implementation of the proposed technological options.

As a result of the experiments carried out at temperatures of 40 °C, 55 °C and 70 °C, the data were obtained and graphic dependences were plotted (Fig. 2). Calculation of the activation energy was carried out according to the formula (1).

Table 6

Results of calculation of recovery factor of the main components of galvanic cake in leaching

Metal (pure element)	Content of the valuable component in the initial cake, weight %.	Residual content of the valuable component in the cake after leaching, weight %	Content of the valuable component in the solution (by the results of the chemical analysis), g/l	Recovery, %
Fe	19.2	2.72	64.3	98.7
Zn	1.7	0.015	2.1	99.9
Cr	11.8	0.58	10.2	99.5
Ni	1.2	0.06	6.1	99.5
Cu	1.0	0.05	3.4	99.5

The results of the studies make it possible to speak with confidence not only about the kinetic limitation of the process of galvanic cake leaching (E_{Cu}=15.7 kJ/mol), but also clearly demonstrate the possibility of conducting the process at low temperatures, which, in turn, leads to lower energy consumption.

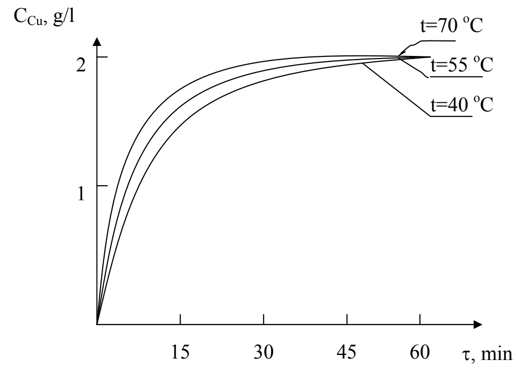

Fig. 2. Dependence of copper concentration on process time at t=40 °C, t=55 °C, t=70 °C

The experimental methods described are tested at industrial facilities of metallurgy. The process flow diagram of processing of galvanic cakes is shown in Fig. 3.

6. Discussion of results of analysis of methods of processing of technogenic raw materials containing valuable components

Galvanic cakes and municipal wastewater sludge are characterized by the industrial content of non-ferrous and precious metals, the cost of which makes it possible to justify the payback and profitability of industrial implementation.

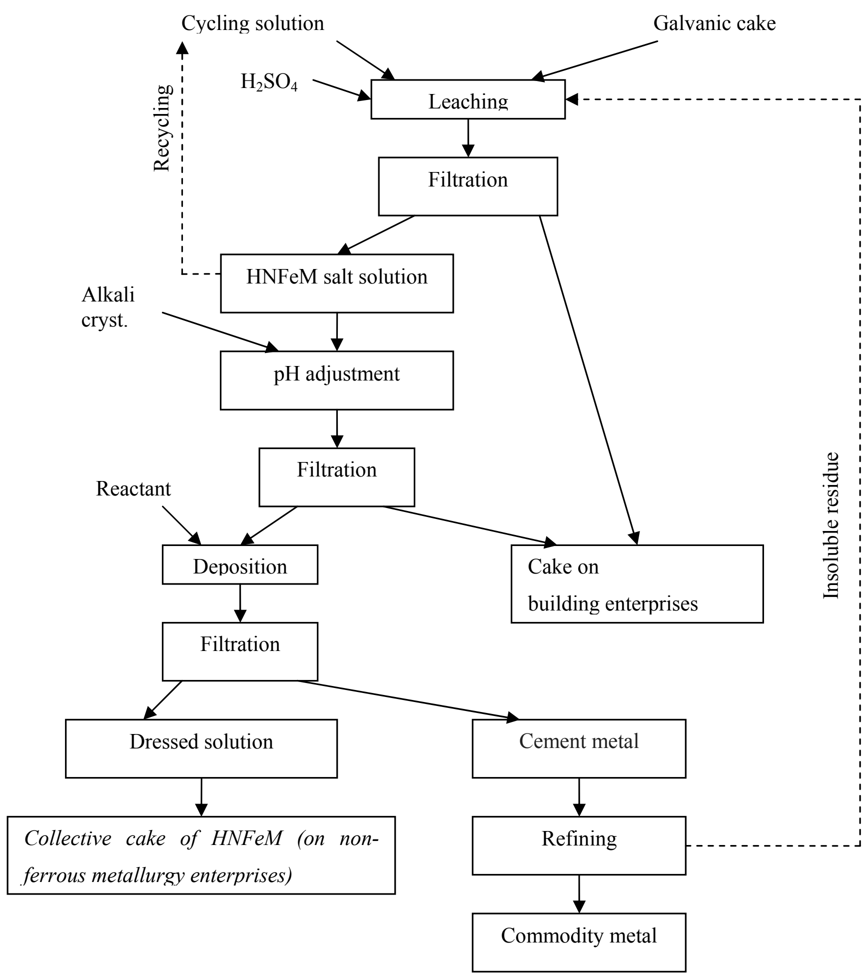

Fig. 3. Process flow diagram of processing of galvanic cakes

Given the similarity of the chemical and phase compositions of multi-component waste containing HNFeM, it is expedient to dispose them using a single technology. This will ensure partial or complete recovery of expensive elements – Cu, Ni, Zn, Cr, Cd along with a selection of individual components. The technology will allow processing of products with a wide range of components. This will require adjusting the parameters in each individual case.

The calculated kinetic and thermodynamic characteristics (activation energy, time of complete dissolution, Gibbs free energy value) of the proposed technological options allowed substantiating the structure of experimental technological modeling.

Experimentally valid processing options, the flow diagrams of which are presented in Fig. 1, 2, can be reproduced on an industrial scale with efficient throughout recovery of commodity metals (about 99 %).

The introduction of the technologies does not require the creation of fundamentally new devices and equipment, since traditional methods of hydrometallurgy are applicable for the recovery of valuable components.

The advantage of the proposed options of processing of galvanic cakes and wastewater sludge is the presence of commercial equipment, the use of traditional hydrometallurgical processes, availability and low cost of reactants, short payback periods and anthropogenic load reduction.

The proposed technological solutions can be implemented in mining regions of extraction and processing of non-ferrous metal ores, megalopolises and industrial agglomerations, the payback is determined by the high market value of the final products.

It should be noted that the work is completed and ready for the next stage – the creation of an investment project, and the results can be implemented on an industrial scale. The main difficulty in implementing the development is the lack of investment and the reluctance of traditional producers to process technogenic raw materials.

7. Conclusions

As a result of the studies of the composition of waste of electroplating plants and sludge of water treatment systems, as well as experiments on working out technological regimes for processing these raw materials, appropriate process flow diagrams were developed. The process flow diagrams of processing of galvanic cakes and disposal of municipal wastewater sludge, as well as data of the main technological parameters, indicate the feasibility of the hydrometallurgical processing of this type of raw materials.

The implementation of the presented technologies will allow the disposal of non-recyclable waste with the ancillary recovery of the entire range of valuable components. Thus, the processing of technogenic raw materials, which are not currently being processed and, accumulating at landfills and storage sites, represent a real environmental threat is ensured.

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HYDROTHERMAL MODE OF THE FLOW-THROUGH RESERVOIR-COOLER WITH RESPECT TO ITS MORPHOMETRIC CHANGES

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Наведені дані про морфометричні зміни за період експлуатації протічної водойми-охолодника теплової електростанції. Подано гідротермічний аналіз температурного режиму даної водойми з двома випусками в неї нагрітої циркуляційної води. Розглянута кінетика потоків в акваторії біля водоскиду в нижній б'єф з врахуванням допустимих температур води. Дана оцінка впливу замулення водойми на стан охолодника циркуляційної води

Ключові слова: протічна водойма-охолодник, замулення водойми, температура води в пригреблевій акваторії

Приведены данные о морфометрических изменениях за период эксплуатации проточного водоема-охладителя тепловой электростанции. Дан гидротермический анализ температурного режима данного водоема с двумя выпусками в нее нагретой циркуляционной воды. Рассмотрена кинетика потоков в акватории у водосброса в нижний бьеф с учетом допустимых температур воды. Дана оценка влияния заиления водоема на состояние охлаждающей циркуляционной воды

Ключевые слова: проточный водоем-охладитель, заиление водоема, температура воды в приплотинной акватории

1. Introduction

Discharge of circulating water of a thermal power plant (TPP) for cooling occurs far from water intake of a system of technical water supply (TWS) in water reservoirs-coolers (RC) of shallow and medium depths. As a result, an active area increases and temperature of cooled water decreases. This refers to the filled RC and the flow-through RC fed by small rivers A reservoir-cooler is a regulator of a surface flow. It provides reversible water supply. In deep RC (with a depth exceeding 6.0 m), especially with deep water intakes, we can find the latter near a place of disposal (discharge) of circulating water into RS. In the circulating water supply system of the Dobrotvir thermal power plant, the discharge of heated circulating water to RC occurs both to the tail part of it and to the head of *the reservoir-cooler* near the water discharge facility. The basic factor, which characterizes a water temperature during a discharge of circulating water is a natural temperature mode of the reservoir-cooler. Taking into account that disposal of warm water of TPP occurs to the head part of a running water reservoir-cooler also, a temperature mode in a water catchment area has a water preservation importance. An average water temperature in a reservoir and water temperature in a river, which flows into the lower water, depends on it.

The relevance of present study is in determining the effect of silting of a flow-through reservoir during an operation period on its characteristics as a cooler of circulating water of TPP, that is, an active area and a temperature mode. After all, a change in the volume and active area of RC affects the temperature of cooled circulating water, and thus the vacuum in a condenser of TPP turbines and the power of an energy generating unit.

2. Literature review and problem statement

As a rule, the purpose of calculation of reservoirs-coolers (RC) of technical water supply systems for TPPs and NPPs is determining the average temperature of cooled water in a water area and the required area of RC. We can forecast a hydrothermal mode of a reverse water supply system at the design stage, as well as in the course of special thermal research, based on the equation of a thermal balance [1].