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CLIMATE CHANGE & SUSTAINABLE DEVELOPMENT: NEW CHALLENGES OF THE CENTURY

MONOGRAPH

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Petro Mohyla Black Sea National University, Ukraine
Rzeszow University of Technology, Poland



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The book is written for scientists, lecturers, postgraduate students, engineers and students who specialize in the field of environmental researches.

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ECOLOGICAL AND ECONOMIC ASPECTS OF WASTEWATER TREATMENT OF GALVANIC PRODUCTION

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ABSTRACT

Ukraine has an urgent need for copper, which is used in various industries. Electroplating and PCB manufacturing are sources of environmental hazard. The purpose of the work is environmental and economic justification for the removal of copper from wastewater and its further use for metallization and for remelting as secondary raw materials.

The main factors of the negative impact of waste of boards and galvanics' production on the environment are revealed. In order to avoid the accumulation of sludge on the territory of the enterprises it is proposed to use the regeneration technology of waste digestion solutions, in which the recovered metal is used as secondary raw material for copper production, and the recovered solution is reused for etching of printed circuit boards.

The scientific novelty of the work lies in the fact that the proposed approach and the mechanism of obtaining additional raw materials from the sewage of PCB production has been discovered.

The practical significance is that the obtained results can be applied in the production of printed circuit boards to reduce the environmental impact of production wastes, as well as to obtain cheap raw materials from industrial wastewater. It is also important to reduce the environmental impact of production waste. The total sludge hazard index for the existing state of sludge storage in the territory of enterprises (0.045) and after the implementation of wastewater recovery (100) is determined. The economic indicators of the equipment created on the basis of this research are estimated. Implementation of new wastewater treatment technology with only one plant can bring more than 2.8 million UAH of economic effect.

Key words: copper, galvanic production, sewages, printing boards, regeneration

INTRODUCTION

There is an urgent need for copper in Ukraine, which is used in various industries. Meanwhile, there is insufficient exploration of copper ores in Ukraine. Prospective and predictive resources of copper ores are estimated: in the Volyn region, in Donbass and in the Dnieper-Donetsk basin within the Ukrainian Shield in the Mid-Dnieper and Volyn regions. Total resources of ores of

Volyn region with an average copper content of 1.0% are estimated at 28 million tons of metal. All the above points to the lack of copper ore deposits in Ukraine. The annual needs of Ukraine for this metal are about 120-140 thousand tons, twenty percent of which provide their own copper scrap, and the rest in the form of rough copper has to be imported from neighboring Russia and Poland [1].

Galvanic production is one of the most dangerous sources of environmental pollution, mainly surface and groundwater reservoirs, due to the formation of large volumes of wastewater, as well as a large amount of solid waste, especially from the reagent method of wastewater disposal. The compounds of metals transported by the sewage of galvanic production have quite a detrimental effect on the soil-plant-animal-human-ecosystem [2-8].

The use of galvanic processes in modern production creates a risk associated with emergencies, which can be considered as a risk of waste storage and the direct carrying out of technological processes. It is safe to identify technical, technological, organizational and other causes of adverse situations. Waste storage and technological processes are hazardous to the environment in which humans, wildlife and fauna are located. Therefore, this risk can be called environmental.

Modern enterprises, producing up to about $4 \cdot 10^3$ m² of boards, have accumulated around 1500-3000 tons of waste per year in their territory in the form of salts stored in tanks, plastic bags and subject to atmospheric precipitation. In the course of atmospheric precipitation, salts are washed away and transferred to soils, surface waters, polluting the environment.

The production of printed circuit boards in Ukraine is represented by the following enterprises: JSC NPO "ETAL", Kirovograd, which produces about 4-5 thousand m² of boards, with capacity for production of up to 50000 m² of boards, SE "Galvanotechnika", PJSC "Kyiv Radar Plant", PJSC Novator (Khmelnitsky) with output within 0.9 thousand m², PJSC Concern-Electron - 0.8 thousand m². This means that only one enterprise can dump wastewater or accumulate sludge up to 5-6 tons of copper per year, which clearly does not contribute to improving the environmental situation around the enterprises engaged in the production of boards. Until 1992, nearly 20 tonnes of copper were dumped annually in Kyiv. The Electronmash plant annually etches ≈ 15000 m² of boards (which leads to the allocation of 7500 kg of copper) [8].

To avoid the accumulation of sludge on the territory of enterprises it is proposed to use the technology of regeneration of waste digestion solutions, in which the isolated metal is used as a secondary raw material for copper production, and the recovered solvent is reused for etching of printed circuit boards [9-12].

To open the ore in an open manner, it is necessary to carry out the excavation work with the movement of a large number of soils and other rocks. Thus, if 20-25 years ago the marginal coefficient of overburden was taken in the size of 2-4 m³ / t, now during the development of deposits with rock formations it reaches values of 5-10 m³ / t, and during the development of sloping fields with soft cover rocks - 20-25 m³ / t. Now open development of mineral deposits can be performed at depths up to 250 m. These are the large masses that need to be moved, encumbered, which indicates significant work and material costs [13-15].

Environmental protection activities in the field of subsoil use are regulated, among others, by the Mining Law of Ukraine, which defines the following basic requirements for mining operations: ensuring the safe conduct of mining operations and rational extraction, use of minerals and protection of subsoil [5].

The complexity and severity of the problem is due to the fact that Ukrainian consumers, who are in need of copper, are forced to buy a large part of it outside Ukraine and because of the lack of foreign currency to reduce the production of goods. At the same time, the existing capacities for the production of rolled copper and its alloys in Ukraine are not loaded because there is no

copper raw material, and a large part of copper-containing scrap and waste is exported for various reasons, even though the export of rolled copper and its alloys is much more efficient than export of copper scrap. For each tonne of exported rental, in addition to saving jobs, you can receive up to \$ 1.000 in foreign exchange earnings, that is 30-40\$ million per year [1, 8, 16]. But analysis of the patent and technical literature has shown that in the absence of raw materials for the smelting of non-ferrous metals, the issue of copper extraction from wastewater is given insufficient attention.

Formulating the goals of the article (setting the task). Non-ferrous metal production technology has its own peculiarities. This is due to the low concentration of non-ferrous metals in the ore compared to iron (only a few percent in non-ferrous ores) and the presence of several metals in the ore. In particular, ore with a base metal content of on average 2-3% is used to produce copper. Transporting them is not great. Therefore, copper smelting is carried out near the mining sites. Initially, copper ores are enriched and receive a copper concentrate with a metal content of 35%. Then the melting and purging in the converter to produce rough copper takes place, the last step is the removal of impurities (refining). With the use of special technology of copper ore can be obtained and some other non-ferrous metals [1, 8]. The specific energy consumption during the smelting reaches 230 - 350 kWh per 1 ton of copper. This requires a considerable amount of energy input. And the production of scrap metal is cheaper by 25 times, the cost of transportation of raw materials is reduced by 5-6 times. This reduces the period of metal production and reduces electricity consumption; there is a nature conservation effect [1, 8].

In Ukraine, the non-ferrous base of non-ferrous metallurgy is insufficient, and many enterprises operate on imported raw materials or process non-ferrous metal scrap. The location of these businesses also take into account consumer, transport and environmental factors. Non-ferrous metallurgy is a pollutant of the environment and the main source of heavy metals [8, 14-15, 17].

At the same time, the source of replenishment of non-ferrous metal scrap may be partly the production of boards and electroplating, where copper is used as a conductive material and is etched in the process of surface preparation for use.

The purpose of the work is environmental and economic justification for the removal of copper from wastewater and further use for industrial purposes.

METHODS AND EXPERIMENTAL PROCEDURES

Surveys have shown that companies engaged in the manufacture of printed circuit boards dumped a whole range of metals - copper, iron, nickel, chromium, etc. In particular, during the annual one-line operation of the etching line of printed circuit boards with a productivity of 14 m² / h, nearly 28000 m² of blanks will be produced, and the amount of extracted (etched) metal (copper) will be about 14 tons, which at prices of UAH 85 / kg will be 14000 kg · 85 UAH / kg = 1190000 UAH. This metal can be reused. The amount of metal that will be etched during the resumption of industrial production of boards can be (at one-shift work and the number of lines in the work of 350 pieces) 14000 kg · 350 = 4900000 kg = 4900 tons.

The most common method of extraction of metal ores (including copper) is open-cast mining, through which more than 2/3 of all minerals are extracted from the bowels. This is a relatively inexpensive way of developing powerful and high-performance equipment. However, when conducting open works for many decades, huge tracts of farmland and forestland are removed from economic circulation. To access the deposit from the surface it is necessary to remove, move and put in the waste heaps of rock, the volume of which is several times bigger than the volume of extracted minerals [1, 8].

The second most important method of field development is underground, which accounts for about 20% of iron production, up to 45% of copper production, up to 70% of zinc, up to 75% of

tin and lead, 100% of tungsten. Ore mining costs during underground mining are noticeably higher than open pit. However, it is conducted in fields that are not economically feasible or technically impossible to develop in an open manner. Due to the primary depletion of readily available metal ore reserves, the depth of development is gradually increasing, increasing the cost of underground mining. The trend of increasing depth of development is being observed all over the world. In Canada, ores containing gold, copper, nickel are mined at depths of 1800–2600 m, in the USA, copper and gold, at depths of 1700–3000 m, in India, gold is extracted from a depth of 3500 m. The world's deepest deposit is being developed in the Republic of South Africa, with work at more than 4,000m depth. Underground development in some cases allows to completely save the earth's surface, which provides a significant advantage over opencast mining [1, 8].

At the same time, some of the required copper raw materials can be obtained not from the bowels, but by sewage treatment for the production of boards and electroplating.

Studies have shown that the existing options for the organization of galvanic wastewater treatment systems do not provide the required quality of treatment not only for the main components of heavy metals, but also for salt and organic impurities, and such insufficiently treated effluents are discharged into the city sewer network or nearby rivers and water bodies. which complicates the operation of the sewerage system, pollutes rivers and reservoirs.

For the proposed scheme of regeneration of the spent pickling solution in the pickling module used only solid electrodes. For such purposes, use platinum and graphite, which in this work were taken as a basis. The possibility of replacing expensive platinum with a titanium electrode has been investigated. The corrosion behavior of titanium in the etching solution was previously investigated. The weight of the sample of titanium wire with a length of 100 mm and a diameter of 0.7 mm (0.2104 g) after 115 hours in the etching solution did not change when weighed on analytical balances. This allowed the use of a titanium electrode in the pickling solution as a working one.

The authors proposed and investigated the scheme of wastewater regeneration from etching, washing, with the release of copper-metal in sheet form for possible remelting at the metallurgical enterprise.

The sludge hazard index for copper compounds is calculated by the formula:

$$K_i = \frac{MPC_i}{(S + C_w)_i}, \quad (1)$$

where

K_i – hazard index;

i – is the serial number of the substance,

MPC_i – maximum permissible concentration in the soil of a dangerous chemical substance contained in waste, mg / kg of soil;

S – is the coefficient of solubility of a chemical in water;

C_w – the content of the chemical in the total mass of waste, mg / kg;

The total hazard index, determines everything by the formula:

$$K = \frac{1}{n^2} \sum_{i=1}^n K_i, \quad (2)$$

where, n – is the amount of hazardous chemicals contained in the sludge production boards and electroplating.

Determination of waste hazard class: based on the actual content in the waste, water solubility, active reaction, the lowest toxicity index have sodium compounds, hydroxide in particular.

The toxicity index of an individual chemical waste ingredient is determined by:

$$K_c = \frac{\lg(LD_{50})i}{(S + 0,1F + C_w)i} \quad (3)$$

where, LD_{50} – the average lethal dose of a chemical ingredient when ingested, S – a coefficient that reflects the solubility of a chemical ingredient in water, F – the coefficient of volatility of the chemical ingredient, C_w – the amount of this ingredient in the total weight of the waste, or part of t/t; i – serial number of a specific ingredient.

To assess the carcinogenic risk of heavy metal, we calculate the average daily dose of LADD, moderated with considering the average life expectancy (70 years) according to the formula [25]:

$$LADD = \frac{C \cdot CR \cdot ED \cdot EF}{BW \cdot AT \cdot 365} \quad (4)$$

where: $LADD$ – average daily dose, mg/(kg×date);

C – the concentration of the substance in the contaminated environment, mg/kg;

CR – the rate of quantitative flow of the active medium, kg/day;

ED – duration of action, years; EF – frequency of action, days/year; BW – human body weight, kg;

AT – exposure averaging period (for carcinogens $AT = 70$ years; 365 – number of days in the year.

The value of the risk of non-carcinogenic effects for certain substances is determined on the basis of calculations of the hazard factor according to the formula:

$$HQ = AD/RfD, \quad (5)$$

where: HQ – danger factor; AD – average dose, mg/kg; RfD – reference (safe) dose, mg/kg.

The hazard index under the conditions of simultaneous action of several substances is calculated by the formula:

$$HI = \sum_i^n HQ_i, \quad (6)$$

where: HQ_i – hazard factors for the individual components of the mixture of substances.

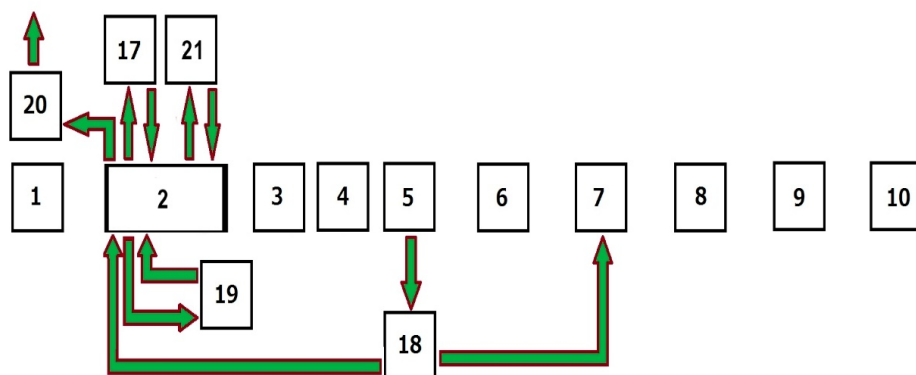
THE RESEARCH RESULTS AND DISCUSSIONS

Currently, the most common reagent technologies for removing metals from water do not provide the necessary efficiency of water purification for its re-use, leading to the formation and accumulation of toxic sludges that continue to accumulate in the territories of both existing enterprises of the former USSR and newly formed. The question of the utilization of regenerative solutions formed during the use of ion-exchange technologies, which make it possible to create closed systems of water use in galvanic industries, remains unsolved [14-15, 17-18]. The drawing shows the scheme of the line of digestion with wastewater for regeneration [8].

In the existing scheme, after the operation of etching and saturation of the solution with copper compounds in the etching module, the etching rate decreases and the etching solution must be replaced with a fresh one capable of etching at a sufficient rate. The spent solution is sent to the factory treatment facilities for pre-treatment, in which the residue can be discharged into the municipal sewer system after reaching the content of the components of the indicators set by the municipal water utility. The authors proffer a scheme for wastewater regeneration from etching operations, washing with the release of copper in sheet form for possible remelting at a metallurgical enterprise.

To implement the proposed scheme, a series of studies and tests were conducted, among which the following steps can be noted.

The analysis of existing problems of galvanic production, control systems, accumulation of waste in the territories of the enterprises is executed. Ways to reduce the harmful environmental impact on the environment and human life have been identified.



Drawing. Diagram of a line of etching of printed circuit boards with a lead for regeneration: 1 – module load; 2 – etching module; 3 – lighting module; 4 – overview module; 5 – the third module of cascading washing; 6 – is a second module of cascade washing; 7 – the first module of cascading washing; 8 – module of hot drying; 9 – module of cold drying; 10 – module unloading; 17 – regenerator etching solution; 18 – regenerator of wash water; 19 – filtration unit; 20 – treatment plants of the enterprise; 21 – installation of coating (if necessary).

Based on the analytical decision of Carslou-Eger, the impact of soil contamination in the storage area of galvanic waste and printed circuit boards was established, and it is shown that in one year the top layer of soil (0,5 m thickness) will pass into the category of slightly saline, and in 10 years the salt profile will reach depth of 1,5 m, which will lead to the destruction of living soil organisms for many years and after the elimination of sludge storage facilities.

The composition of the components of the pickling solution is optimized by the methods of factorial experiment, which according to its characteristics allows to provide balanced indicators of the process speed and simultaneous recovery of the spent solution without emissions into the environment.

The possibility of using ecologically safe technology of copper extracted from wastewater for metallization of printed circuit board substrates is theoretically substantiated and experimentally proved, which made it possible to offer specific technical solutions for environmental safety management, to stabilize and improve the environment.

To purify flushing wastewater with low concentrations of harmful substances at a final concentration of metal in the flushing water in the range of 0,002-0,005 g/l a fluidized bed installation of non-conductive parts is used, which prevents the formation of highly toxic substances and contributes to environmental safety.

The possibility of using electrochemical methods to determine the thickness of tin coatings on a copper basis is examined, which allows to automate the process of manufacturing boards and ensures its integration into the overall system of environmental safety.

The possibilities of using I2XI8HT stainless steel electrodes during the removal of heavy

metals have been experimentally tested, which makes it possible to offer specific technical solutions for environmental safety management.

Namely, the creation of a new scheme is determined by a number of studies aimed at reducing environmental damage from the operation of pickling lines and storage of sludge in the enterprise.

The developed scheme allows to carry out regeneration of solutions in the course of etching and constant maintenance of concentration of elements, that means, providing constant speed of etching of boards. At the same time the scheme of such line allows to use the extracted copper in metallization processes without sewage discharges, allowing no pollution of environment.

Assembling of installations is simple: they are established near the etching module and are connected to it by two pipelines. If necessary, the line of etching and installation of reproduction of water solutions can be placed in various rooms and even floors. In this case, the last ones are additionally equipped with a storage tank with a pumping station.

The introduction of electrochemical reduction of water solutions allows:

- to avoid volley discharges of concentrated waste water solutions to treatment facilities;
- to reduce water consumption in flushing operations after etching of printed circuit boards and electroplating due to its reusability;
- to return to production of precious metals, thereby increasing the efficiency of basic technological processes;
- reduce the cost of chemicals to neutralize spent water solutions;
- water is 0,8 m³ per hour and used only for cooling.

Assembling of installations does not demand a long stop and readjustment of production, and the modular principle of construction allows to increase productivity on metal removal, concerning the sizes needed for the customer.

As shown by the results of research, copper removed from wastewater meets the requirements that allows it to be used for further melting or for metallization of substrates in the corresponding technological processes [8].

Considering the fact that the creation of equipment that is environmentally safe and energy-efficient, it is possible to evaluate the economic indicators created on the basis of this research equipment. It is necessary to take into account the specific prices for the basic materials used in the technological process and the parameters of the plants, which make it possible to reuse aqueous solutions without discharging the treatment plants of both enterprises and cities. When determining the economic feasibility it should be based on the criterion of harm to the environment [19-24].

During the calculations, we take into account the fact that the existing line connects the sewage recovery (regeneration) installation without making structural changes to the PCB etching line and does not require any changes in the manufacturing process of the circuit board. The necessary data for the calculations are presented below:

- the price of water and sewerage in Kyiv as of 2019 – 21.756 UAH / m³;
- the price of electricity in Kiev as of 2019 - 2.47 UAH / kWh;
- the cost of installing wastewater recovery (regeneration) for the PCB digestion line - UAH 450000;
- the cost of copper scrap is 140 UAH / kg.

The cost-effectiveness of new equipment implementation will be performed for the annual workpiece production and work program. In this case, we take into account that the annual fund of working time will be 247 days, which in one-shift work will give $247 \cdot 8 = 1976$ hours.

During this time 1976 will be produced $\cdot 12 \text{ m}^2 / \text{h} = 23712 \text{ m}^2$ of blanks. The amount of extracted metal (copper) will be $23712 \text{ m}^2 \cdot 0.5 = 11856 \text{ kg}$.

The results of the cost-effectiveness calculations are summarized in Table 1.

Cost estimate for the billing period (year):

The basic variant: $Z_{Tv} = 1200000 + 206351 + 63000 + 2100000 = 3569351$ UAH.

New version: $Z_{Tb} = 1200000 + 450000 + 55000 + 34391 + 7500 + 35141 - 1659840 + 600000 = 722\ 192$ UAH.

Table 1. Results of cost-effectiveness calculations

The name of the article costs	Basicversion	A new variant is proposed
Cost of materials (basic and auxiliary for connection to the line), UAH	–	55000
Water consumption for process support, m ³ /h	4.8	0.8
Price for water and sewerage, UAH / m ³	21.756	21.756
Water cost program per year (1976 year), UAH / m ³	21.756·4,8 1976=206351	21.756·0.8·1976=34391
Number of sludge formed, t	2.1·12 =25.2	0.25·12 =3
The cost of removal of sludge (2500UAH / t), UAH	25.2·2500= 63000	3·2500=7500
Increasing the amount of electricity used to provide wastewater recovery, kWh	–	14227.2
Price for electricity, UAH / kWh	2.47	2.47
Increase in the cost of electricity to support the process, UAH	–	14227.2·2.47= 35141
The amount of extracted metal (copper), kg	–	11856
The cost of the selected metal (copper), UAH	–	11856·140= 1659840
Solutioncosts, UAH	2100000	600000
Total, UAH	3569351	722192

The economic effect will be $E = With_{TB} - W_{in} = 3569351 - 722192 = 2\ 847\ 159$ UAH.

The results of the calculation of the total sludge hazard index for the removal of copper compounds at one of the enterprises of Ukraine are presented in Table 2.

Table 2. The results of the calculation of the total sludge hazard index

A group of substances	MPC _i , mg / kg	(S + C _b) _i , mg / kg	K _i	K
Copper compounds	3	73.98	0.0405	0.7575
		21.15	0.141	

After removal of copper compounds from wastewater (not converted to sludge), the total hazard index becomes practically non-hazardous (Table 3).

Table 3. Results of the calculation of the total sludge hazard index for the production of boards and electroplating after the introduction of copper removal activities

A group of substances	MPC _i , mg / kg	(S + C _b) _i , mg / kg	K _i	K
Copper compounds	3	0.01	300.0	100
		0.03	100.0	

The calculation data (Table 2) shows that after removal of copper compounds from wastewater (not converted to sludge), the overall hazard index has improved. In addition, the raw material for smelting copper is received.

The calculation's results of the total sludge hazard index of the board's production and electroplating for one of the existing enterprises showed an increase (the value of the total sludge hazard index instead of the existing values of 0.7575 was respectively 100).

As the amount of sludge and copper in them sharply decreases, and this leads to an improvement of indicators of the hazard index, that is, to increase of ecological safety.

When setting a task to predict the environmental risk from a source that contains toxic substances, the main object of care and responsibility is the person. Therefore, all types of risks, including environmental, social and individual, must be focused on the saving of human life and health. Therefore, the most correct principle should be the application of an integrated risk indicator, as all areas of human activity are inseparably linked and have a corresponding interaction.

As a rule, for quantitative analysis and measurements the basic indicators-risks to human life and life – quality and longevity are used.

Quantitative assessment of the scope and severity of adverse effects that may occur as a result of the actual or intended exposure to the substance should be the entry of pollutants into the human body.

To determine the quantitative inflow of pollutants into the human body, which may be in the area of negative impact of galvanic production sludge, it is necessary to assess these hazards, which can be performed in the following stages:

- characteristic of the environment with the analysis of the main physical standards of the study area;
- determination of ways of influence of pollution sources and their distribution;
- determination and evaluation of the level, frequency and duration of action of each pollutant identified in the second stage.

Consider the situation with the preservation of sludge in the enterprise and the possible consequences of such a decision for the environment and human health. For example, we'll take a separate Ukrainian enterprise that has been accumulating waste for several years (table 4).

Waste is galvanic sludge with a precipitator: alkali, soda. Appearance and consistency: dry porous lumps of yellow-green color, odorless. General information about waste: waste is generated by repeated treatment of pipe blanks in baths with alkaline solution. After solidification has a firm consistency. Qualitative composition of waste and the content of hazardous substances in them: sodium hydroxide - 38-65 wt. %; sodium nitrate - 24-35 wt. %; sodium chloride - 5-6 wt. %; insoluble impurities (cinder, glass mass) - up to 100%; the active reaction of the water extract from the waste pH is 11.68.

Given the toxicity index of waste, calculated through the LD50 for laboratory animals, one of the most dangerous components - sodium hydroxide ($1.3 < Kc < 3.3$), galvanic sludge with a precipitator (alkali, soda) are highly hazardous waste (toxicity class II). Taking into account the sharply alkaline reaction of water extract from waste, their utilization should be carried out in compliance with safety rules while working with aggressive substances. The hazard class of waste can be reduced after neutralization.

According to the results of the study of the composition of galvanic sludge, the mass content of priority pollutants at the levels is defined: chromium – 1.25 kg/t, nickel – 0.01 kg/t.

We obtain:

$$Kc = \lg(150)/(1.0+0.0+0.56) = 1.39. \quad (7)$$

Using the necessary initial data for the calculation, some of which are specified in the annexes [25], we obtain the following value of the average daily dose of nickel:

$$LADD = \frac{C \cdot CR \cdot ED \cdot EF}{BW \cdot AT \cdot 365} = \frac{10 \cdot 0.2 \cdot 5 \cdot 365}{70 \cdot 70 \cdot 365} = 2 \cdot 10^{-3} \text{ mg}/(\text{kg} \cdot 24 \text{ h}). \quad (8)$$

Table 4. Concentration and toxicity class of the substance

Form	Concentration, mg/kg (X), substance toxicity class						
	Pb(1)	Cd(1)	Zn(1)	Mn	Cu(2)	Cr(2)	Ni(2)
Gross	26.88	1.87	3.68	626.73	86.25	12497	8.79
Mobile for $t=25^{\circ}\text{C}$	<0.5	<0.25	1.64	<0.5	73.24	200.4	<1.0
Hydrosoluble for $3a \ t=25^{\circ}\text{C}$	<0.5	<0.25	2.08	<0.5	0.53	201.8	<1.0
Solubility in the experiment,	insoluble	insoluble	56,5	insoluble	insoluble	16.0	insoluble
Average amount in waste, (kg/t)	0.027	0.002	0.004	0.63	0.086	1.25	0.01
MPC in the soil, (mg/kg) – gross form	32.0	1.5	–	1500.0	–	80.0	–
MPC in the soil, (mg/kg)	–	–	23.0	–	3.0	6.0	4.0

The carcinogenic risk of nickel as an additional probability of cancer in an individual during the life of CR is determined by the formula:

$$CR=LADD \cdot SF=2 \cdot 10^{-3} \cdot 0.84=1,68 \cdot 10^{-3}. \quad (9)$$

where, SF – tilt factor, $(\text{mg}/(\text{kg} \times \text{date}))^{-1}$.

Determine the hazard index according to the formula for priority pollutants of galvanic plant waste, in particular, for cadmium, nickel, lead, chromium:

$$HI = \sum_1^4 HQ_i = \frac{0.002}{0.0005} + \frac{0.01}{0.02} + \frac{0.027}{0.0035} + \frac{0.005}{0.005} = 82.5. \quad (10)$$

As the hazard index $HI > 1$, this level of risk is unacceptable, and pollutants, which are contained in galvanic sludge and entered the environment as a result of an emergency situation will adversely affect human health.

The novelty of the work is that the mechanism of obtaining additional raw materials from wastewater from the production of printed circuit boards is detected. The significance lies in the fact that the obtained results can be applied in the production of printed circuit boards to reduce the impact of industrial waste on the environment, as well as to obtain cheap raw materials from industrial wastewater.

The novelty of the work lies in the fact that the mechanism of additional raw materials from the wastewater of PCB production is obtained. Significance is shown in that the obtained results can be applied in the production of printed circuit boards to reduce the environmental impact of production wastes, as well as to obtain cheap raw materials from industrial wastewater.

CONCLUSIONS

Therefore, the economic effect of the introduction of new wastewater treatment technology and the reduction of the amount of sludge over the billing period (1 year) will be UAH 2847159. That is, the introduction of a new wastewater treatment technology with only one installation can bring more than 2.8 million UAH of economic effect, improve the environment and will make it possible to implement an ecologically safe process of electroplating copper sewage. The increase in electricity costs for the process of wastewater regeneration (recovery) is offset by a sharp increase in the level of environmental safety (the total sludge hazard index instead of the existing values of 0.7575 became 100 respectively) of the environment around the production plants and in general in the region of industry.

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