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Optimization of Technological Process Parameters to Create an Environmentally Friendly Waste Processing Technology

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ABSTRACT

Sources of formation of environmental hazards in the Technosphere are industrial facilities and other objects of economic activity. The danger lies in the transformation of elements of the natural subsystem, and in the impact on humans. Man-made impact contributes to the emergence and accumulation of environmental hazards in the environment. The type of technological process, the frequency of its action and the intensity of man-made factors contribute to the appearance of manifestations of environmental danger, which puts before society the need to study the state of this danger and ways to eliminate it. Determining the real state of human environmental safety and the natural environment under the influence of factors of contamination of soil and hydrosphere waste from electroplating production with harmful and dangerous substances is a problem today. The economic complex of the electronic and radio engineering industry plays an essential role in the formation of the city's environmental hazard. These enterprises are the main sources of environmental hazards, the priority among which is the type of hazard caused by chemical factors affecting the environment. Liquid and solid waste in their storage areas on the territory of enterprises creates an environmental hazard, since harmful substances contained in them pollute soils, open reservoirs, and underground aquifers. Heavy metal ions found in sludge and taken to landfills can form water-soluble complex compounds and create an environmental hazard, which manifests itself in contamination of soils and underground aquifers. All of the above causes a problem that needs to be solved in order to significantly limit the formation of sludge during the production of printed circuit boards and the use of electroplating processes, which will make it possible to reduce environmental hazards. One of the serious, unresolved and constantly increasing problems is the problem of solid waste: its quantity is constantly growing, the composition is becoming more diverse, there are not enough territories for their placement, and the cost of their disposal is increasing. It should be noted that the problem of solid waste has long turned from a purely ecological one into a socio-ecological one: solid waste is not only a significant factor in pollution of the air Environment, Water Resources, soil and other natural components, but also the cause of a decrease in the quality of life, which is manifested in an increase in the incidence of diseases of the population, a decrease in income, deterioration of working and Recreation conditions. Solid waste management within the framework of socio-economic policy directly affects the development of the region. A special feature of Solid Waste Management is that this process is initiated simultaneously at different levels of management: from state to local (level of an economic entity).

Keywords: land, waste, sludge, reclamation, soils.

INTRODUCTION

Monitoring of the state of environmental danger of enterprises and the industrial zone of Taganrog allowed: (i) to establish the real state of environmental danger on the example of a technogenically loaded socio-economic zone; (ii) determine the most influential factors of Environmental Safety Management based on the results of experimental studies; (iii) develop specific technical and organizational solutions to reduce the impact of environmental hazards on people and the environment.

The object of research on environmental hazard manifestations is identified as Taganrog, which is characterized by an intense man-made load. In this industrial city, there is a presence of dangers of various origins, an insufficient level of environmental awareness of the population, which is manifested by individual consequences of environmental danger:

- deterioration of groundwater quality indicators;
- contamination of surface reservoirs with harmful substances;
- environmental pollution in residential and industrial areas;
- atmospheric pollution by stationary and non-stationary sources of pollution;
- seasonal deterioration of the quality of natural water indicators.

Studies show that the factors of environmental hazard formation in Taganrog are: (i) migration of harmful substances by underground horizons from waste disposal sites; (ii) industrial and domestic wastewater; (iii) insufficient level of environmental awareness of the population; (iv) development of blue-green algae (secrete algotoxins) in the sedentary part of the reservoir.

Sources of the technogenic class of environmental hazard include chemical and physical factors of influence produced by enterprises of the chemical and machine-building industries. Chemical waste leads to contamination of the environment with harmful substances that are contained in the waste. These factors can manifest themselves in soil pollution, natural and artificially created objects of the hydrosphere, and changes in the state of atmospheric air. Enterprises of the machine-building complex can be characterized by typical factors of environmental hazard formation. This approach defines the directions of environmental safety management, taking into account industry aspects. The highest degree of environmental danger is represented by the western direction. Powerful sources of environmental danger are concentrated here – mechanical engineering and metalworking enterprises, electronic and radio industries, which can be attributed to the machine-building complex, an aluminum remelting plant, and a plant for the production of household chemicals.

As a result of the scientific environmental and expert assessment, it was established that foundry and chemical industry enterprises affect the state of atmospheric air pollution. Electronic industry enterprises form the main factors of groundwater and soil pollution (Abdulrahman, 2017). Based on the conducted research, it can be concluded that the areas where industrial enterprises are located are factors in the formation of environmental hazards, among which the following are distinguished mechanical engineering and metalworking, chemical industry, construction industry, and transport industry (Baawain, 2015).

In Russia, up to 1 billion rubles are generated annually by industrial and household waste, and the volume of accumulation per 1 km of total area is more than 45 thousand tons, which puts Russia on one of the first places in the world at the level of man-made workload (Dada, 2015). The main share of waste is accounted for by the extractive industry. Among the enterprises of the processing industry, the largest volumes of waste are generated and accumulated in metallurgical, chemical and food industries (Khoshnaw, 2018). Excessive waste generation also leads to economic losses for enterprises. Waste is a lost resource for the enterprise, because it is the result of the process of processing primary raw materials.

The main sources of atmospheric air pollution are industry, thermal and power plants, and transport (Ma, 2018). Through the development of technological processes and equipment of existing enterprises, gases containing components of various toxicity, Organo-vapor compounds, fine droplets and solid particles enter the atmosphere. Greenhouse gases, which include water vapor, carbon dioxide, methane, ozone, nitrous oxide and chlorofluorocarbons, will have a significant negative impact. The leaders of CO_2 emissions into the atmosphere (almost 85% of the total volume) are enterprises of metallurgy, electricity production and distribution.

When burning 1 kg of coal, 2.3 kg of CO_2 is released, and when burning 1 m^3 of natural gas, 1.9 kg of CO_2 is released. In addition, harmful emissions affect the working conditions at the enterprise and the state of health of employees: they can lead to occupational diseases and reduce labor productivity. Therefore, each enterprise is responsible for the amount of harmful emissions into the air in the course of its activities. And states should constantly encourage enterprises to control and reduce harmful emissions into the atmosphere, in particular, by determining fees for regulatory and overtime payments.

METHODOLOGY

The economic complex of the electronic and radio engineering industry plays an essential role in the formation of the city's environmental hazard. These enterprises are the main sources of environmental hazards, the priority among which is the type of hazard caused by chemical factors affecting the environment. So on the territory of the Novator plant, about 3 thousand tons of waste from the production of circuit boards and electroplating production are stored. Enterprises in this industry use a wide range of technological processes, which negatively affects the state of atmospheric air, industrial effluents, and waste. Liquid and solid waste in their storage areas on the territory of enterprises creates an environmental hazard, since harmful substances contained in them pollute soils, open reservoirs, and underground aquifers.

Heavy metal ions found in sludge and taken to landfills can form water-soluble complex compounds and form an environmental hazard, which manifests itself in contamination of soils and underground aquifers (Abd El Monsef, 2014).

All of the above causes a problem that needs to be solved in order to significantly limit the formation of sludge during the production of printed circuit boards and the use of electroplating processes, which will make it possible to reduce environmental hazards.

The process of introducing corrective substances into the waste aqueous solution of etching printed circuit boards was studied using a printed circuit board etching unit with an aqueous copper-alkaline solution. The introduction of an aqueous solution of ammonia allows you to maintain the set pH value. The concentrations of the solution components that were used in this case are shown in Table 1, and diagrams of installations or processes for further testing are shown in Figure 1 and 2 (Abdulrahman, 2017).

Initial tests were carried out on a standard installation with dimensions: length – 1.575 m, width – 1.0 m, height – 0.885 m. the Test blanks were selected from double–sided blanks used in production with a length of 0.12–0.5 m, width – 0.1–0.4 M and thickness of 0.0001–0.003 m. The temperature of the solution was maintained in the range of 40–45°C. to regulate the pH value of the solution and its effect on the etching rate, water ammonia (25%) was used, or liquid synthetic, which was placed in the a separate room outside the workshop. In the course of research, an etching solution was used, the composition of which is presented in Table 1. The regenerator, which was used for further tests of solution reduction, was set to have a cached copper capacity of about 4 kg/h.

In order to determine the best parameters and capabilities, we used scheme of physical desorption (carried out by passing air through an ammonia solution). The resulting ammonia-air mixture was used to correct the alkaline pickling solution. The installation diagram is shown in Figure 1.

Air from the working Chamber of the pickling machine through the filter, where drops of pickling solution are captured, enters the desorber and is saturated with ammonia. The ammonia-air mixture is sucked in by an ejector, the working fluid of which is an etching solution. In the ejector, ammonia is absorbed by the etching solution, and the air is returned to the working Chamber of the etching machine. To intensify the desorption process, the water-ammonia solution in the desorber is heated with an aqueous pickling solution. The desorption process stops when the ammonia water in the desorber reaches 5% by weight, after which the ammonia solution is replaced with a fresh one (Fig. 2).

Just as in a batch unit, air from the working Chamber of the etching machine enters the lower part of the nozzle desorber and is enriched with ammonia. The ammonia-air mixture is sucked in by an ejector, the working fluid of which is an etching solution. In the ejector, ammonia is absorbed by the etching solution, and air is returned to the working Chamber of the etching machine.

Fresh aqueous solution of ammonia through a heat exchanger, where it is heated with an etching solution to intensify the desorption process, is constantly fed to the upper part of the nozzle desorber and can be used in the ammonia washing module (Fig. 2). In these studies, the unit was a cube filled with an initial 25% ammonia solution before starting work. To heat the initial solution,

Table 1. Concentrations of components used for research

Component name	Indicators, kg/m^3
Ammonia complex of copper bicarbonate (for metal)	40–60
Ammonium chloride	50–100
Water-based ammonia (25%), or liquid synthetic	variable value
Orthophosphoric acid	20–30
pH of the solution	variable value

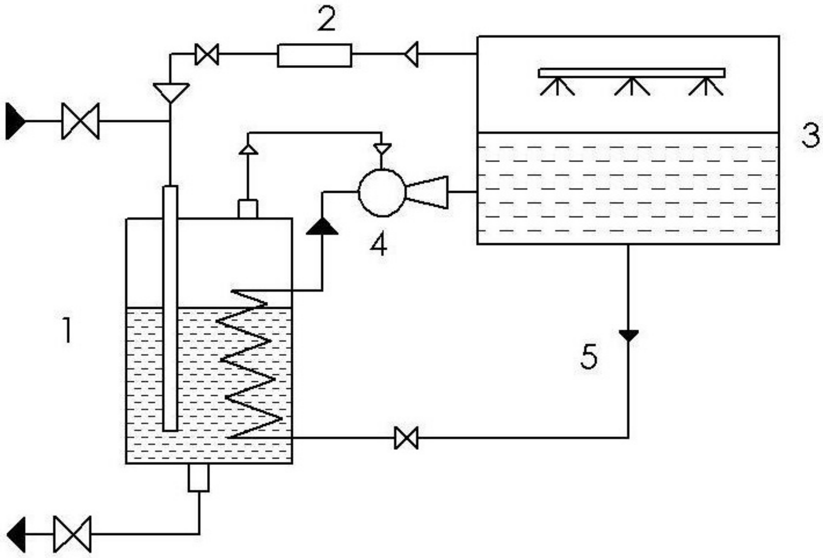

Figure 1. Diagram of the installation of periodic physical absorption for an aqueous copper-puddle outlet. 1 – physical desorber, 2 – filter, 3 – pickling machine, 4 – quarterly, 5 – pump.

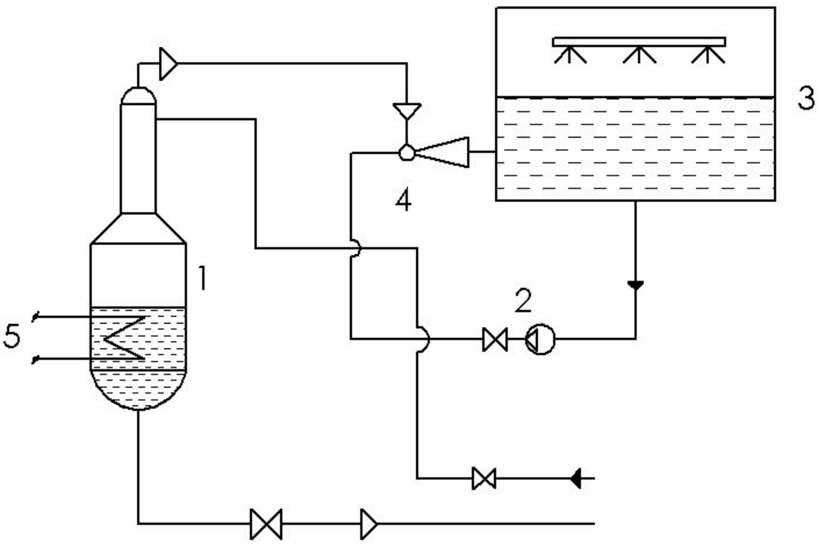

Figure 2. Diagram of the simple distillation installation: 1 – Alembic; 2 –pump; 3 – etching machine; 4 – jet pump (injector); 5 – electric heater.

an electric heater is installed in the cube. The Distilled ammonia from the cube enters the ejector, the working fluid of which is a copper-alkaline solution, and is absorbed by the etching solution – rectification. The upper part of the distillation column, operating at a pressure of 0.15 MPA, continuously receives the initial solution of ammonia (25% by weight). Heating of the solution in the column is carried out using an electric heater whose power depends on the thermometer reading. Cubic liquid under the action of overpressure enters the module of ammonia washing of printed circuit boards. The released Steam mixture enters the ejector, the working fluid of which is a copper-alkaline pickling solution.

In the ejector, the Steam mixture is absorbed by the pickling solution. To check the compliance of the bubbling ammonia desorber with a real object, an experimental test of the model was carried out on a mock-up installation. As a model of the bubbling desorber, a Drexel glass with a capacity of 0.5 liters was used, into which 0.45 liters of 25% ammonia solution were poured during the experiment. The air was pre-saturated with water vapor before being fed to Drexel with an ammonia solution until a humidity of 100% was reached. To do this, the air was passed through a similar Drexel filled with clean water. Both Drexels with water and ammonia were thermalized at a temperature of 40°C using a TB-3-M1 thermometer. The choice of temperature control was determined based on the temperature of the etching solution in the etching – regeneration unit.

The waste water solution

Waste water produced by printed circuit boards "PJSC plant temp", LLC "Novator", model solutions simulating the composition of spent solutions of electroplating production, spent Chrome-containing solutions obtained at plants of various industries were studied. Distillate with an electrical conductivity value of no more than 0.5 MSM/CM and chemical reagents of the H.H. and H.D.A. brands of domestic production were used to prepare model solutions.

During the operation of electroplating etching lines and printed circuit boards, waste water solutions appear, including copper-alkali etching solutions, which must be removed and neutralized. The main advantage of copper-alkaline etching solutions in comparison with other systems is that during operation in Jet-type etching installations, the oxidizer is self-healing with oxygen, that is, the concentration of divalent copper ions increases. To carry out the self-healing process, it is necessary that there is an excess of free ammonia in the solution. Therefore, the process of reduction of copper-alkaline solutions is reduced to removing excess divalent copper ions from the etching machine and maintaining the concentration of free ammonia at a certain level (Al-Saidi, 2019).

The most cost-effective and environmentally friendly method is to remove excess divalent copper ions by electrochemical means, that is, using an electrochemical reduction method. Electrochemical reduction in recycling with the etching process allows the use of an aqueous etching solution for almost unlimited time, which reduces the consumption of chemicals to the value of mechanical losses of the solution due to its assignment to printed circuit boards, dramatically reduces the amount of waste water and their contamination, stabilizes the etching rate, thereby improving the quality of printed circuit boards and increasing the productivity of equipment (Wang, 2017).

Adjusting pH and Eh values to restore solutions

Adjustment of pH and Eh values. To adjust the pH and Eh values, the following devices were used: laboratory ionomer I-130 m, industrial pH meter ph-101p, laboratory electrode EPP-103 (0–100 °C, up to 0.101 MPA, d = 8 mm., L = 130 mm), portable copper sulfate comparison electrodes of the ESMION-2p type, the ESR-10101 comparison electrode, the P-215 m industrial converter, the B5–43 DC source, the BSA-111B type selenium rectifier with a rectified voltage of up to 80 V and a current of up to 8 A. To intensify the reduction process of an aqueous copper chloride etching solution, an aqueous copper chloride etching solution was reduced by depositing Metallic Copper in a closed cathode chamber when the redox potential of the anolyte +1.1 was reached +1.2 V, and the chlorine gas released in the anode chamber was sent to the solution before being fed to the anode chamber (Vijayaraghavan, 2018).

The spent aqueous copper chloride solution was sent to the anode Chamber of the diaphragm electrolyzer, where monovalent copper was oxidized to divalent due to the hydrolysis products released at the anode, and the solution was treated in the anode chamber until the redox potential of +1.1 was reached +1.2 V, which ensures complete oxidation of monovalent copper ions. The redox potential of the anolyte was regulated by changing the amount of current that was passed through the solution or by changing the amount of solution that was fed into the anode chamber (Ma, 2018).

Copper ions that accumulate in the cathode chamber are released at the cathode in the form of metal. Since the cathode Chamber of the electrolyzer is closed, the maximum possible concentrations of copper ions accumulate in it, which makes it possible to conduct the process of copper oxidation with a high current output and intensify the process of solution reduction. To maintain a high intensification of the process, experiments were performed at a catholyte redox potential from +0.28 to +0.32 V and a current density of 7–8 a/DM^2 (Khoshnaw, 2018).

The reconstituted water pickling solution was returned to the pickling Bath, where it was mixed with the working solution. The redox potential of the working solution was maintained from +0.50 to +0.55 V, and the

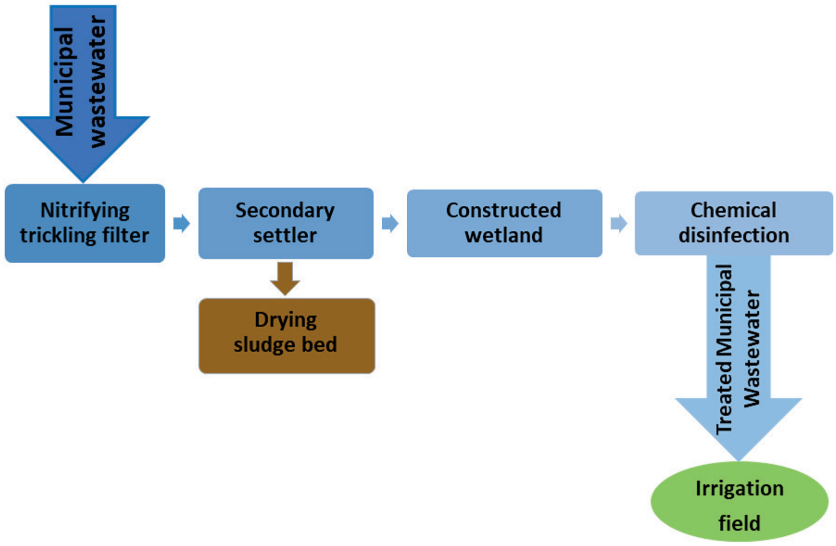

Figure 3. The municipal wastewater treatment process

concentration of monovalent copper is not more than 20–30 mg/L, which should provide a high rate of digestion (Ebrahim, 2015).

Continuous reduction of the aqueous working solution in parallel with the processing process allows you to ensure the consistency of the process at one processing speed and, as a result, high quality of printed circuit boards. The practical use of the electrochemical method for reducing aqueous pickling solutions is associated with economic issues. Isolated copper it needs the appropriate quality for its use as secondary raw materials.

In modern production, there is a method for reducing the spent etching solution produced by DP by electrochemical treatment in a non-diaphragm electrolyzer, where copper ions are deposited at the cathode, after which the deposited copper is dissolved and fed into the solution. The disadvantage of this method is its complexity. There is also a known method for electrochemical reduction of an aqueous chloride etching solution by passing it through the cathode Chamber of a diaphragm electrolyzer, where excess copper at the cathode is removed, and then through the anode chamber, where polyvalent metal ions (copper and iron) are oxidized to the highest degree of oxidation. In this process, the redox potential in the anode chamber reaches values from +0.40 to +0.55 V (Odhiambo, 2017).

The disadvantage of the process is the low reduction rate of the etching solution, which is explained by the fact that the deposition of metallic copper at the cathode in chloride solutions passes through the stage of formation of monovalent copper ions. These ions are carried together with the aqueous solution to the anode chamber, where the concentration of monovalent copper ions increases and as a result they are not completely oxidized (Dada, 2015).

To intensify the process of reduction of an aqueous copper chloride pickling solution, we proposed to restore an aqueous one copper chloride etching solution by precipitation of metallic copper in a closed cathode chamber when the redox potential of the anolyte +1.1 is reached +1.2 V, and the chlorine gas released in the anode chamber should be directed to the solution before being fed to the anode chamber (Wang, 2015).

Practically, the method was implemented like this. The spent aqueous copper chloride solution was sent to the anode Chamber of a diaphragm electrolyzer, where monovalent copper is oxidized to divalent, and the solution was treated in the anode chamber until the redox potential of +1.1 was reached +1.2 V, which ensures complete oxidation of monovalent copper ions. Regulation of the redox potential of the anolyte was carried out by changing the amount of current that is passed through the solution, or by changing the amount of solution that is fed into the anode chamber (Yousuf, 2018).

Chlorine gas isolated from the liquid phase in the anode chamber was sent to the initial solution. The gas supply was carried out using an ejector: by mixing chlorine gas with a solution before feeding it to the anode chamber, which allows you to pre – oxidize the main part of monovalent copper and thereby reduce the load on the anode chamber. In addition, pre-oxidation increases the rate of migration of copper ions into the cathode chamber, since divalent copper has a higher mobility than monovalent copper (Zekri, 2014).

Copper ions that accumulate in the cathode chamber are released at the cathode in the form of metal. Since the cathode Chamber of the electrolyzer is closed, the maximum possible concentrations of copper ions accumulate in it, which makes it possible to conduct the process of copper oxidation with a high current output and intensify the process of solution reduction. Maintaining a high intensification of the process is provided at the redox potential of the catholyte from +0.28 to + 0.32 V and a current density of 7–8 a/DM^2 (Brown, 2018).

The reconstituted aqueous pickling solution was returned to the pickling Bath, where it was mixed with the working solution. As a result of mixing, the redox potential of the working solution was maintained from +0.50 to +0.55 V, and the concentration monovalent copper no more than 20–30 mg/L, which ensures a high rate of digestion.

The amount of aqueous solution that was selected for reduction was determined based on the need to obtain a working solution in an etching bath with the specified parameters of the redox potential and the concentration of monovalent copper. The entire volume of the solution was treated first in the cathode and then in the anode Chamber of the diaphragm electrolyzer, and according to our proposed method, 10 liters of solution were treated in the anode Chamber of the electrolyzer, which was mixed with 20 liters of the initial solution after reduction.

CONCLUSIONS

The possibility of correcting copper-alkaline water pickling solutions by desorption of ammonia from its aqueous solutions has been established, which will reduce the amount of sludge and increase the environmental safety of enterprises. It is proposed to use the Correction Device together with the electrochemical reduction unit, which makes it possible to create equipment that can operate automatically and develop a low-waste technological process for using aqueous solutions and reduce the impact on the environment.

A method for reducing aqueous chloride solutions is proposed, which can significantly reduce energy consumption due to two main factors. The first is to bring the redox potential of the anolyte to the values of +(1.1/1.2) V. the second factor that reduces electricity costs is the higher concentration of copper in the cathode chamber compared to the known method. This increases the current output of metallic copper at the cathode by an average of 16% and reduces the energy consumption for oxidation of 1 liter of chloride solution by 2.5 times. The method of electrochemical correction of PH and Eh values makes it possible to conduct the process of reducing an aqueous solution under moderate electrolysis modes (current density on the electrodes, volume current density, current strength), which significantly reduces the heating of the electrodes, electrolyte and allows you to abandon the cooling system.

The expediency of using electrochemical methods to determine the thickness of copper-based Tin coatings is shown. The most promising of the studied methods is the chronopotentiometric method, which allows you to conduct the process of restoring aqueous solutions and solve the issues of automation of production processes and improve the environmental safety of processes.

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