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EVALUATION OF THE EFFECT OF INDUSTRIAL ENTERPRISES ON THE ENVIRONMENT AND EFFICIENCY EVALUATION OF ENVIRONMENTAL PROTECTION ON THE EXAMPLE OF «KHARKIV ELECTROMECHANICAL PLANT» SE (UKRAINE)

Розвиток науково-технічного прогресу поряд із загальним поліпшенням якості життя людей має найпотужніший техногенний вплив на навколишнє природне середовище. Для зниження шкідливого впливу на навколишнє середовище необхідно вирішувати питання ефективного очищення та нормування викидів, розрахунків гранично допустимих викидів. Тому об'єктом дослідження є вплив промислового підприємства на довкілля. Одним з джерел забруднення природного навколишнього середовища є підприємства машинобудівного комплексу. Тому на прикладі одного із них проведено оцінку впливу на навколишнє середовище – на прикладі Державного підприємства «Харківський електромеханічний завод» (Україна). А також розроблено пропозиції по впровадженню відповідних природоохоронних заходів.

Як і на більшості промислових підприємств, на Державному підприємстві «Харківський електромеханічний завод» утворюються тверді відходи, забруднені зливові стоки та газоподібні викиди в атмосферу. У зв'язку з тим, що підприємство знаходиться в межах міста, до нього пред'являються відповідні вимоги з охорони навколишнього середовища. Господарська діяльність підприємства супроводжується виконанням вимог екологічної безпеки, охорони здоров'я населення, планування заходів з охорони навколишнього середовища та раціонального використання природних ресурсів.

В роботі була проведена оцінка впливу Державного підприємства «Харківський електромеханічний завод» на навколишнє середовище та загальної характеристики району розміщення підприємства. Також були проаналізовані природно-кліматичні та метеорологічні умови території та приведена оцінка стану навколишнього середовища. В роботі виявлені джерела забруднення технологічного процесу виробництва підприємства. Показано, що з 131 джерела викиду 20 джерел оснащені газоочисними установками. Аналіз впливу виявлених джерел на довкілля показав, що необхідно застосовувати газоочисні установки для очищення викидів до атмосферного повітря, а також те, що викиди підприємства в цілому не перевищують допустимих нормативів.

Проведені дослідження стануть в нагоді для реалізації природоохоронних заходів на підприємствах різних галузей, які є джерелами викидів потенційно-небезпечних речовин.

Ключові слова: *викиди промислових об'єктів, техногенний вплив, системи очищення, забруднення довкілля, навколишнє середовище.*

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1. Introduction

The development of scientific and technological progress, along with a general improvement in the quality of life of people, has an environment of powerful technogenic impact. First of all, this is expressed in air pollution, unsatisfactory quality of drinking water, soil pollution and waste accumulation. The production of electrical products is accompanied by a significant release of pollutants into the environment. All these pollutants during operation, getting into the atmosphere, in water basins and in the soil significantly worsen the environmental situation. To reduce the harmful effects on the environment, it is necessary to solve the issue of effective cleaning and regulation of emissions, calculation of maximum permissible emissions [1, 2]. The nature of the destructive effect of biosphere pollution on humans can be different. This, for example, the toxic effect of chemicals that lead to poisoning of the body, organ trauma (skin, vision, hearing, etc.). A number of substances can cause allergies. Some substances and radiation are carcinogenic or mutagenic, that is, they can cause cancer or genetic pathology [3–5]. In [6], it is noted that enterprise emissions are an important component of both environmental well-being and economic stability. The authors of the study [7] believe that it is the increase in emissions, especially carbon, characteristic of developing countries. The study [8] analyzes the sources of the greenhouse effect enhancement, among which emissions from industrial enterprises occupy a significant place.

One of the sources of environmental pollution is the enterprises of the engineering complex. Therefore, on the example of one of them, an environmental impact assessment will be carried out – on the example of the State Enterprise «Kharkiv Electromechanical Plant» («KhEMP» SE, Ukraine). Thus, *the object of research* is the impact of an industrial enterprise on the environment. *The aim of research* is to assess the impact of an industrial enterprise on the environment and the effectiveness of environmental protection measures on the example of «KhEMP» SE.

2. Methods of research

«KhEMP» SE produces equipment for the energy, coal mining, metallurgical, chemical, engineering and shipbuilding industries. The company specializes in the production of electrical machines, low-voltage equipment and low-voltage complete devices, control station systems, components for machines and stations, thyristor converters, circuit protection monitoring equipment [9]. The main source of air pollution at the «KhEMP» SE is air handling units that remove contaminated air from the technological equipment of production sites, as well as from auxiliary units and services. Also the sources of pollution are:

1) machine shop, where the products are painted in the paint chamber, digestion with hydrochloric acid and tinning of copper parts;

2) hardware-station shop, where plating, soldering and welding, tinning of parts, as well as painting of parts are carried out, negatively affects the environment;

3) mechanical repair shop where the sharpening of the cutting tool, grinding of steel products and gas welding and gas cutting works, welding with electrodes are carried out, which are sources of pollution;

4) electric shop where electric welding in a welding cabin; impregnation of the winding of electric motors with subsequent annealing of insulation in an electric furnace, painting of electric motors are carried out, which negatively affects the environment;

5) tool shop, where metal cutting, thermal annealing of steel, heat treatment of steel in furnaces, grinding of steel products, welding are carried out, which negatively affects the environment;

6) production packaging shop, where the source of pollution is dust from woodworking machines;

7) model woodworking shop where wooden models for foundry are made and spray boards are used, which are a source of dust pollution;

8) motor vehicle shop where the source of air pollution is internal combustion engines, which are emitted into the atmosphere when heated: carbon oxide, saturated hydrocarbons, nitrogen dioxide, soot, sulfur dioxide, lead, benzo(a)pyrene.

According to the degree of danger, substances are divided into 4 classes. With pollutants emitted by the enterprise into the atmosphere, lead and benzo(a)pyrene are classified as hazard class I.

«KhEMP» SE refers to the IV category of danger. There are no accidental and volley emissions at the enterprise. Landfills and landfills for industrial solid waste are not available at the «KhEMP» SE.

The company does not have its own landfill. The removal of industrial waste should be carried out according to the permission of the city sanitary-epidemiological station.

According to the appendix 4 to the State Sanitary Rules for the Planning and Development of Settlements [10], the regulatory sanitary protection zone (SPZ) for industrial site of «KhEMP» SE is 100 m.

Since the object is a large enterprise, it accordingly emits various kinds of impurities in large volumes (Table 1). 131 sources of pollutant emissions into the atmosphere are allocated from all the shops of the enterprise. Of these, 130 are stationary sources, one source (No. 131) is nonstationary.

Data on the concentration of pollutants in the wastewater of «KhEMP» SE when discharged into the city sewer network are presented in Table 2.

Therefore, as can be seen, the excess of the permissible values given in [11, 12] does not occur.

At the «KhEMP» SE, retail waste is generated in the production process. Their characteristics are given in Table 3.

Table 1

List of pollutants released into the atmosphere

No.	Substance name	Hazard Class	Gross emission, t/year
1	2	3	4
1	nitrogen dioxide	2	0.442
2	nitric oxide	3	2.400
3	sulphurous hydride	3	0.0042
4	carbon monoxide	4	5.250
5	benzo(a)pyrene	4	0.000385
6	sparingly soluble fluorides	2	0.00092
7	silicon oxide	SRLI 0.02	0.00092
8	hydrogen fluoride	2	0.00476
9	phenol	2	0.0094
10	formaldehyde	2	0.0050
11	lead	1	0.01840
12	tin oxide	3	0.0289

ISSN 2664-9969

Continuation of Table 1

1	2	3	4
13	hydrocarbons C12-C19	4	0.0115
14	soot	3	0.8717
15	iron oxide	3	0.5581
16	manganese oxide	2	0.0262
17	aerosol oil	SRLI 0.05	0.2459
18	sulfuric acid	2	0.5025
19	toluene	3	18.2455
20	ethanol	4	18.1150
21	aerosol	SRLI 0.1	1.2991
22	solvent	SRLI 0.2	2.7680
23	white spirit	SRLI 1.0	8.4246
24	xylene	3	14.4333
25	kerosene	SRLI 1.2	0.8790
26	wood dust	SRLI 0.1	1.1235
27	PSK dust 20–70 %	3	2.2696
28	metal dust	SRLI 0.1	1.2969
29	PSK dust >70 %	3	0.3687
30	abrasive metal dust	SRLI 0.4	1.5385
31	fiberglass dust	SRLI 0.06	0.3531
32	fiberglass plastic dust	SRLI 0.06	2.8357
33	phenolic dust	SRLI 0.05	1.6414
34	asbestos-containing dust	1	0.0755
35	CEM dust	SRLI 0.04	0.0488
36	FR-2 dust	SRLI 0.1	2.7347
37	ethyltoluene	SRLI 0.7	0.3484
38	ozone	1	0.00276
39	aluminum oxide	2	0.01306
40	zinc oxide	3	0.1295
41	copper oxide	2	0.1305
42	vanadium pentoxide	1	0.000647
43	epichlorohydrin	2	0.1687
44	hydrochloric acid	2	0.2593
45	ammonia	4	0.00064
46	acetic acid	3	0.06096
47	chromium anhydride	1	0.90752
48	sodium hydroxide	SRLI 0.01	0.8802
49	phosphoric acid	SRLI 0.02	0.00030
50	nickel sulfate	1	0.00343
51	boric acid	3	0.00857
52	nitric acid	2	0.03092
53	vinyl chloride	SRLI 0.005	0.000001
54	sodium carbonate	SRLI 0.04	0.12576
55	trisodium phosphate	SRLI 0.1	0.25155
56	sodium chloride	SRLI 0.15	0.85760
57	copper sulfate	2	0.01742
58	potassium carbonate	4	0.01742
59	tin sulfate	3	0.00311

Note: information on the materials of the «KhEMP» SE [9]; SRLI – safe reference level of impact

Table 2

Concentration of wastewater pollutants

No.	Name of substance	Concentration of the substance in wastewater, mg/l	Permissible concentration of substances in wastewater, mg/l	The mass of the substance discharged, kg/year
1	pH	7.7	6.5–9.0	–
2	dry residue	702	–	58700.1
3	suspended substances	78	400	1050.6
4	chlorides	145.4	350	7142.8
5	sulfates	105.4	350	8520.7
6	oil products	1.95	5	142.05
7	iron	2.1	5	141.1
8	ammonia nitrogen	4.53	27	97.05
9	copper	0.74	2	54.55
10	nickel	0.03	0.1	–

Note: information on the materials of the «KhEMP» SE [9]

Table 3

Characteristics of waste generated at the enterprise

No.	Name of waste	Technological process of education care	Hazard class	Amount of waste, pcs/t/year	Disposal direction
1	Used mercury-containing fluorescent tubes	Lighting and operating instructions SNTP 11-4-79	1	1000	Rent for disposal by specialized companies
2	Spent lead-free battery plates	Motor transport	1	0.909	Rent for disposal by specialized companies
3	Slag of non-ferrous metals and alloys containing lead	Non-ferrous metal processing	1	11.410	Sent to scrap metal collection plants
4	Waste electrolyte acid battery	Motor transport	2	2.730	Neutralized
5	Oil waste, engine oils	Motor transport	2	1.000	Accumulation
6	Polishing waste	Production of electrical equipment	3	0.500	Landfill in the Derhachi (Ukraine)
7	Tanned rags (textiles)	Metal machining	3	0.500	Landfill in the Derhachi (Ukraine)
8	Aluminum waste	Production of electrical equipment. Metal machining	3	7.000	Sent to scrap metal collection plants
9	Copper waste	Production of electrical equipment. Metal machining	3	100.00	Sent to scrap metal collection plants
10	Tin waste	Production of electrical equipment. Metal machining	3	2.000	Sent to scrap metal collection plants
11	Ferrous metal waste containing iron and its compounds	Production of electrical equipment. Metal machining	3	5000.000	Sent to scrap metal collection plants
12	Sludge after reagent and electrocoagulation treatment	Production of electrical equipment. Metal machining	3	0.588	Landfill in the Derhachi (Ukraine)
13	Solvent compound: toluene, xylene, white spirit	Electroplating wastewater treatment	3	in fact	Reapplied for the preparation of primers
14	Used battery housings	Machine manufacturing	3	2.730	Landfill in the Derhachi (Ukraine)
15	Sludge, emulsion	Motor transport	3	3.333	Accumulation. natural drying
16	Waste materials (resin waste)	Production of electrical equipment. Metal machining	3	13.158	Landfill in the Derhachi (Ukraine)
17	FR-2, CEM waste	Production of impregnation machines	4	3.333	Landfill in the Derhachi (Ukraine)
18	Waste foundry mixtures without heavy metals	Making negative boards	4	10.000	They are used to repair roads, territories and avoid ice in winter
19	Abrasive metal dust	Foundry	4	1.630	The accumulation is exported to the landfill
20	Spent refractory brick	Gas cleaning	4	2.300	Landfill in the Derhachi (Ukraine)
21	Wood shavings and dust	Foundry	4	178.287 5.357	Transmitted to the public
22	Tires with steel cord	Woodworking. gas cleaning	4	1.000	Rent for disposal by specialized companies
23	Waste paper	vehicle maintenance	4	200.000	Rent for disposal by specialized companies
24	Garbage from the territory	Finished Product Packaging	4	20.000	Landfill in the Derhachi (Ukraine)

Note: information on the materials of the «KhEMP» SE [9]

ISSN 2664-9969

Thus, it is possible to draw the following conclusion that the following types of waste are generated at the enterprise:

– foundry slags;
– petroleum products;
– various kinds of solvents;
– sludge neutralization of spent solutions;
– waste solutions of various kinds of galvanic production;
– waste primers, enamels, putties;
– dishes contaminated with chemicals;
– wastewater of hydraulic locks of the painting chambers;
– waste metal machining;
– fluorescent lamps;
– wood shavings;
– garbage from the territory.

3. Research results and discussion

To reduce dust emissions at the «KhEMP» SE there are 20 gas treatment plants, including:

1) dust precipitation chambers;
2) cyclones;
3) filters and hydraulic filters.

Table 4 presents the characteristics of gas treatment plants (GTP).

Table 4

Characteristics of gas treatment plants

No.	GTP name	Pollutant		Entrance, m^2/m^3	Treatment efficiency	Exit, m^2/m^3
		Code	Name			
1	Dust chamber	10414	Metal dust	21.31	69.5	6.50
2	TsN-15 cyclone (Russian Federation)	2915	Fiberglass dust	17.42	55.8	7.70
3	Dust chamber	10431	Abrasive metal dust	4.15	51.8	2.00
4	VNINOT No. 7 cyclone (Russian Federation)	10414	Metal dust	12.36	72.0	3.46
5	TsN-15 cyclone (Russian Federation)	10431	Abrasive metal dust	53.13	76.0	12.75
6	VNINOT No. 7 cyclone (Russian Federation) (2 pcs.)	10414	Metal dust	61.54	87.0	8.00
7	BC cyclone (Russian Federation)	10678	Phenolic dust	18.56	68.9	5.77
8	BC cyclone (Russian Federation)	10036 2916	FR-2 dust Fiberglass dust	49.14 49.14	67.6 67.6	15.92 15.92
9	BC cyclone (Russian Federation)	10678	Phenolic dust	42.70	71.9	12.00
10	BC cyclone (Russian Federation)	10678	Phenolic dust	1.57	68.1	0.44
11	BC cyclone (Russian Federation)	10036 2916	FR-2 dust Fiberglass dust	63.29 63.29	68.4 68.4	20.00 20.00
12	TsN-15 cyclone (Russian Federation)	10368	Asbestos dust	48.86	86	6.84
13	TsN-15 cyclone (Russian Federation)	10431	Abrasive metal dust	163.54	77.4	36.96
14	Hydraulic filters	2752 11510	White spirit Aerosol	63.70 19.74	18.1 53.6	45.80 9.16
15	Hydraulic filters	2752 2750 616 11510	White spirit Solvent Xylene Aerosol	75.21 66.95 65.30 26.82	17.7 17.7 17.7 56.0	61.90 55.10 53.74 11.80
16	TsN-15 cyclone (Russian Federation)	10036 2716	FR-2 dust Fiberglass dust	199.79 199.79	81.2 81.2	37.56 37.56
17	Hydraulic filters	2752 2750 616 11510	White spirit Solvent Xylene Aerosol	44.86 3.26 7.58 9.43	21.4 21.4 21.4 56.5	35.26 2.56 5.96 4.10
18	Fiber filters	203	White spirit Solvent Xylene Aerosol	0.0191	57.0	0.0082
19	Dust chamber	10293	Wood dust	75.0	92	6.00
20	Gidroderevprom cyclone (Russian Federation)	10293	Wood dust	137.93	94.2	8.00

Note: information on the materials of the «KhEMP» SE [9]

As a result, it is possible to conclude that the gas treatment plants work well, with high treatment efficiency. All dust and gas cleaning equipment is in good condition, in fact, the efficiency of the equipment corresponds to the data recorded in the GTP passport.

In general, the main sources of pollution affect the environment as follows:

Atmosphere. «KhEMP» SE is a source of many substances that negatively affect the atmosphere. The main source of exposure to atmospheric air is carbon monoxide. The dispersion calculation is carried out according to the procedure [13]. This technique allows calculating the dispersion of impurities emitted into the atmosphere by single, point and linear, as well as a group of sources, taking into account the influence of the terrain.

The maximum value of the surface concentration of a harmful substance (C_m) when a gas-air mixture is emitted from a single point source with a round mouth is achieved under adverse weather conditions at a distance of (X_m) and is calculated by the formula:

$$C_m = \frac{A \cdot M \cdot F \cdot m' \cdot \eta}{H^{7/3}}, \quad (1)$$

where A – coefficient depending on the temperature stratification of the atmosphere; M – mass of the harmful substance emitted into the atmosphere per unit of time, g/s; F – coefficient taking into account the sedimentation rate of harmful substances in the air; m' – coefficient taking into account the conditions of exit of the gas-air mixture from the mouth of the emission source; H – height of emission source above ground level, m; η – coefficient taking into account the influence of the terrain.

Because $\Delta T = T_T - T_B, \Delta T = 0$ °C, the release source is cold.

To obtain the value of the coefficient m', let's determine the following intermediate coefficients:

$$\omega'_m = 1.3 \cdot \frac{\omega_G \cdot D}{H}, \quad (2)$$

where ω_G – rate of release of the gas-air mixture from the pipe, m/s; D – diameter of the chimney pipe, m.

$$f_e = 800\left(\omega'_m\right)^3, \ \omega'_m = 1.107,$$

$$f_e = 1086.46, \ m' = 0.9.$$

Since $\omega'_m \geq 0.5$ and $f_e \geq 100$, then let's use the formula (1) and obtain the values:

$$C_m = 0.0045 \ \ \text{mg/m}^3.$$

Since the maximum concentration limit is lower than $\text{MPC}_{\text{a.d.}}$ (3 mg/m^3), it is impractical to calculate carbon oxide dispersion.

Hydrosphere. The company uses water from the city water supply. The total actual discharge of normalized substances in the sewage network is 1668.598 m^3/day (418820 m^3/year). Of these, 191.198 m^3/day – household and 1179.47 m^3/day – production. The enterprise consumes 1770.75 m^3/day of water.

According to the permission for wastewater discharges approved by the Kharkivkommunochystvod utility company, the volume of wastewater at the enterprise is 46819 m^3/month.

The wastewater of the research object is discharged into the city sewer system through one outlet into the city sewer d=200 mm, which passes along Moskovsky Prospect of Kharkiv metro station and belongs to the Dykanevska biological treatment complex sewage basin (Q=500,000 m^3/day).

Due to the fact that the company discharges waste water into the city sewer, there are no sources of impurities in water bodies.

In wastewater there is always a complex set of various pollutants. Wastewater of an enterprise containing substances that are practically not disposed of in urban wastewater treatment plants should be treated at local treatment facilities of industrial enterprises. The degree of such concentration, which, taking into account the diversion of industrial effluents in the sewerage network and the receiving reservoir, will ensure the water quality in it that meets the regulatory, that is, established by environmental authorities.

Groundwater. Potential sources of increased additional infiltration may be water-bearing communications, production with a «wet» process, treatment facilities for local wastewater treatment.

The model of additional infiltration nutrition is $3.6 \cdot 10^{-3}$ m/day. Sources of groundwater pollution at the industrial site are not found.

Since the regime network for monitoring groundwater pollution has not been implemented on the territory of the industrial site, it is not possible to conduct a predicted calculation of pollution.

Soil. Assessment of the aerogenic load on the soil is carried out for those indicators for which the value of background concentrations.

1. For the calculation, it is necessary to determine the concentration of sulfur and nitrogen:

$$\frac{C_{\text{NO}_2}}{C_{\text{N}}} = \frac{M_{\text{NO}_2}}{M_{\text{N}}}, \quad (3)$$

$$C_{\text{N}} = \frac{14 \cdot 0.03}{14 + 16 \cdot 2} = 0.009 \ \text{mg/m}^3;$$

$$\frac{C_{\text{H}_2\text{SO}_4}}{C_{\text{S}}} = \frac{M_{\text{H}_2\text{SO}_4}}{M_{\text{S}}}, \quad (4)$$

$$C_{\text{N}} = \frac{32 \cdot 0.001}{98} = 0.0003 \ \text{mg/m}^3.$$

2. Assessment of the load on the territory, which is created due to emissions of sources of air pollution, is determined by the formula:

$$P = C_s \cdot V_t \cdot K, \quad (5)$$

where C_s – concentration of the substance in the surface layer of the atmosphere, mg/m^3; V_t – fall rate, V_t=0.125 cm/s; K – coefficient of proportionality between units, K=864.

$$P_{\text{N}} = 0.009 \cdot 0.125 \cdot 864 = 0.972 \ \text{kg/m}^3 \cdot \text{day};$$

$$P_{\text{S}} = 0.0003 \cdot 0.125 \cdot 864 = 0.032 \ \text{kg/m}^3 \cdot \text{day}.$$

ISSN 2664-9969

3. The critical load on the soil is taken in accordance with international environmental standards:

$P_N = 2$ t/km^2·year;

$P_S = 1$ t/km^2·year.

4. The assessment is made by comparing the relative load of nitrogen and sulfur by calculating the total load:

$$K_i = \frac{Pi}{P_{kpi}}, \quad (6)$$

$$K_N = \frac{0.972 \cdot 365}{2000} = 0.177;$$

$$K_S = \frac{0.032 \cdot 365}{1000} = 0.012;$$

$$\sum K_i = 0.177 + 0.012 = 0.189 < 1.$$

Thus, the load on the soil does not exceed the permissible.

An approximate estimate of the specific load on the territory, which is created by the emissions of the enterprise with a radius of action of $R = 0.84$ km, is determined by the formula:

$$P_i = \frac{Q_i \cdot a \cdot K}{\pi \cdot R^2}, \quad (7)$$

where Q_i – annual emission of the i-th component, t/year; R – radius of the enterprise influence, km; α – coefficient characterizing the deposition of emissions in the zone of influence of the enterprise, $\alpha = 0.4$; K – transition coefficient – 2.76.

The specific load on the territory that is created by dust emissions:

$$P_{dust} = \frac{1.17 \cdot 0.4 \cdot 2.76}{3.14 \cdot 0.84^2} = \frac{1.292}{2.21} = 0.58 \text{ kg/km}^2\text{·day}$$

Thus, the enterprise does not have a harmful effect on the soil.

4. Conclusions

Analyzing the emissions of harmful substances into the atmospheric air from the industrial site of the «KhEMP» SE, the following conclusion can be drawn: the concentrations of the ingredients emitted by the enterprise do not exceed the corresponding maximum permissible values. Emissions to the environment are local in nature and ensure a satisfactory state of the environment in the area where the facility is located and outside the sanitary protection zone.

It is recommended to timely monitor emissions of pollutants into the atmosphere by direct measurements at the source, to verify the efficiency of dust and gas treatment plants. An analysis of the initial data and the results obtained showed that at the moment the composition of contaminants in the wastewater of the enterprise does not exceed regulatory requirements. It can also be concluded that the electromechanical plant does not damage the soil. Given the non-agricultural nature of the use of land in the plant's sanitary protection zone, re-examination of soil for pollution, according to expert assessment with the existing production technology, is recommended not earlier than after 15–20 years. In order to reduce the technogenic impact of emissions on the environment, it is necessary to improve the production technology of the «KhEMP» SE.

The conducted studies will be useful for the implementation of environmental measures at enterprises of various industries that are sources of emissions of potentially hazardous substances.

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