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EVALUATION OF THE EFFECT OF INDUSTRIAL ENTERPRISES ON THE ATMOSPHERE AND EFFICIENCY EVALUATION OF ENVIRONMENTAL PROTECTION ON THE EXAMPLE OF PRYDNIPROVSKA THERMAL POWER PLANT

Heat and energy consumption is currently one of the largest environmental polluters. First of all, this is expressed in an increase in air pollution, poor quality of drinking water, soil pollution and the accumulation of certain types of waste. In order to reduce the harmful impact on the environment, it is necessary to solve the issues of effective purification and standardization of emissions and calculation of maximum allowable emissions. Therefore, the object of research is the impact of an industrial enterprise on the environment. One of the sources of environmental pollution is heat production enterprises, to which the Prydniprovska thermal power plant (Dnipro, Ukraine) belongs.

The research is aimed at assessing the impact of the Prydniprovska thermal power plant (TPP) on the environment and develop proposals for the implementation of appropriate environmental measures. Like most industrial enterprises, Prydniprovska thermal power plant is a source of solid waste, polluted rains and gaseous emissions into the atmosphere. Since the enterprise is located within the city, the relevant environmental protection requirements for it have been increased. The economic activity of the enterprise is accompanied by the fulfillment of the requirements for the rational use of natural resources, environmental safety, planning measures for environmental protection and public health.

In the work, an assessment was made of the impact of Prydniprovska thermal power plant on the environment and a description of the area where the enterprise was located was given. The analysis of these data allows to give recommendations on the choice of the type of treatment facilities and the requirements for them.

As a result of the research, it can be concluded that the excess of the surface concentration for the main emitted substances was not recorded. In the future, the study of emissions from the Prydniprovska TPP can be carried out on other emitted harmful substances, as well as after the work on the modernization of treatment equipment.

Keywords: *emissions from industrial facilities, air pollution, purification systems, environmental pollution, environment.*

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1. Introduction

Heat and energy consumption is currently one of the largest environmental polluters. First of all, this is expressed in an increase in air pollution, poor quality of drinking water, soil pollution and the accumulation of certain types of waste. When pollutants enter the atmosphere, water basins, soils, they significantly worsen the ecological situation. All this leads to the need to address the issues of effective purification and standardization of emissions, as well as determining the values of maximum allowable emissions [1, 2]. The impact of the destructive effect of biosphere pollution on a person can be different. This is, for example, the toxic effect of chemicals, which can lead to injury to organs, allergies, etc. Some substances and radiations are mutagenic or carcinogenic, that is, the cause of cancer or genetic pathology [3–5]. One of the sources of pollution of the natural environment is enterprises of the energy complex, which includes the Prydniprovska thermal power plant (TPP).

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 using the example of Prydniprovska TPP.

2. Research methodology

Prydniprovska TPP is located in the city of Dnipro. The main purpose of this station is to generate electricity in the base mode and is included in the Unified Energy System [6, 7].

The main sources of environmental pollution from Prydniprovska TPP are:

1) boiler and turbine shop (BTS);
2) steam turbine shop (STS);
3) electrical shop;
4) chemical shop;
5) motor transport shop;
6) fuel oil shop;
7) pumping and filtering station.

Production processes at the Prydniprovska TPP affect the microclimate, which is due to the specifics of the energy production process, which is accompanied by significant emissions of the entire spectrum of flue gases into the atmosphere and the discharge of heated water into water bodies. The consequences of these processes are thermal and chemical pollution of the atmosphere and hydrosphere.

The subject of study produces energy to provide heat supply, in particular steam, hot water – to provide hot water supply and heating of residential and industrial facilities. Prydniprovska TPP can operate both on solid fuel and natural gas.

The main emissions from power generation are:

1) solid particles of ash;
2) sulfur oxides (SO_2, SO_3);
3) nitrogen oxides (NO_x);
4) heavy metals;
5) carbon monoxide (CO);
6) hydrocarbons (CH);
7) benzapyrene $C_{20}H_{12}$.

All these chemical compounds have a negative impact both on nature and on humans and can lead to the occurrence of «acid rain» as a manifestation of sulfur oxide SO_2 reacting with nitrogen oxides, the formation of sulfuric acid and many other negative consequences [8].

The negative impact of thermal power plants on the environment includes both air pollution by gas and aerosol emissions, and thermal energy emissions and groundwater pollution. Thermal power plants emit into the atmosphere about a third of the total volume of all harmful industrial emissions, which upsets the balance of the natural environment, as well as the living conditions of living organisms.

The most possible gas and aerosol polluting emissions of Prydniprovska TPP are shown in Table 1.

The impact of thermal power plants on the environment is largely associated with the consumption of a large amount of oxygen to support the combustion of fuel and carbon dioxide into the atmosphere. Taking into account the current fuel balance, oxygen consumption for fuel combustion is approximately 5 times greater than its consumption by the entire population of the Earth. It should also be noted that with an increase in air temperature, thermal power plants are most «responsible» for the increase in the greenhouse effect. In addition, the technological process at thermal power plants requires the use of fossil fuels, which leads to air pollution with oxides of nitrogen, carbon, sulfur, as well as significant emissions of other harmful substances (Fig. 1). Especially dangerous are nitrogen oxides, which have carcinogenic properties, sulfur dioxide, sulfur dioxide, because they can be transported over long distances and deposited, in particular, with precipitation on the earth's surface, while leading to pollution of the hydrosphere and lithosphere. In this case, weak solutions of sulfuric and nitric acid can occur in the atmosphere, which have the ability to fall out in the form of precipitation, sometimes after several days, at a considerable distance from the source of occurrence.

Table 1

Main types of gas and aerosol polluting emissions

Fuel	Aerosols		Gases					
	Ash	Soot	CO_2	H_2O	NO_2	SO_2	NO	CO
Natural gas	–	–	+	+	+	–	+	+
Fuel oil	+	+	+	+	+	+	+	+
Coal	++	+	+	+	+	+	+	+

Note: symbols characterizing the probability of emissions from the combustion of different types of fuel: «++» – very high; «+» – high; «–» – low or not [9]

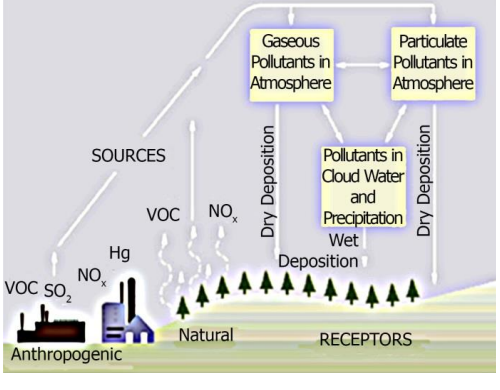

Fig. 1. Scheme of TPP interaction with the atmosphere

The list of pollutants emitted into the air by stationary sources and their gross emissions for each substance and for the whole TPP for 2021 is given in Table 2.

From the data in Table 2, it is possible to conclude that about 61 thousand tons of pollutants are emitted into the atmosphere of the Prydniprovska TPP. At the same time, about 90 % are emissions from boilers. Gross emissions of pollutants from other sources are insignificant and practically do not affect the total emissions into the atmosphere [11].

On the territory of the main industrial site of the Prydniprovska TPP, 140 sources of pollutant emissions into the atmospheric air were recorded. Stationary sources of pollutant formation are located in the electrical shop, fuel and transport shop, boiler and turbine shop, chemical shop, chemical laboratory, metal laboratory, heat supply shop, auxiliary production shop, underground utilities and hydraulic structures. The main sources of pollutant emissions into the atmosphere at Prydniprovska TPP are boilers (power units No. 7–11, 13). Boilers of power units operate in a maneuvering mode, with a low quality of the fuel burned [12].

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Table 2

List of all pollutants emitted into the atmosphere

Pollutant	MPC, mg/m^3	Emission into air, t/year
Metals and their compounds:	–	7.481
Arsen and their compounds	0.003	0.976
Vanadium and its compounds	0.002	0.006
Iron and its compounds	0.04	0.118
Copper and its compounds	0.002	0.678
Nickel and its compounds	0.001	0.785
Mercury and its compounds	0.0003	0.308
Lead and its compounds	0.001	1.077
Chromium and its compounds	0.015	1.013
Zinc and their compounds	0.05	2.503
Manganese and its compounds	0.01	0.008
Substances in the form of suspended solids (suspended solids)	0.5	6121.001
Soot	0.15	1.768
Nitrogen compounds:	–	9624.774
NO_2	0.2	9580.146
N_2O	–	44.627
Ammonia	0.4	0.001
SO_2	0.5	44185.922
CO	5.0	380.706
Methane	50	145.986
Fluorine and their compounds	0.2	0.034
Non-methane volatile organic compounds	–	523.407
Total		60989.13

Note: built on the basis of [10]

The main pollutants of the atmospheric air are the combustion products of fossil fuels: oxides of sulfur, nitrogen, carbon, solid suspended particles (suspended matter):

1) sulfur oxide (IV) (sulfur dioxide, sulfur dioxide, sulfur dioxide, sulfur dioxide) – a compound of sulfur with oxygen of composition SO_2. Under normal conditions, they are a colorless gas with a characteristic pungent odor (with the smell of a match that is lit), they are toxic;

2) nitric oxide (I) – when heated, it decomposes into oxygen and nitrogen. At high concentrations, N_2O excites the nervous system («laughing gas»);

3) carbon monoxide (II) CO is formed during incomplete combustion of fuel. It is a colorless gas without an odor that is poorly soluble in water (2.3 cm^3 in 100 cm^3 at 20 °C). Carbon monoxide (II) is highly toxic. When inhaled, its molecules bind to hemoglobin in the blood and prevent the transfer of oxygen. Under normal conditions, it is not subject to reaction with water, acids and bases;

4) suspended hard particles consisting of many components. This is primarily dust, soot, ash, smoke, nitrates, sulfates and other solid components. They are formed as a result of the combustion of all types of fuel and production processes [13–15].

3. Research results and discussion

Prydniprovska TPP is a source of many substances that adversely affect the atmosphere. Therefore, the development of a gas purification scheme is based on an analysis of the initial data, since, depending on the characteristics of the technological process and the physicochemical properties of the dust and gas flow, a certain type of apparatus and the sequence of emission purification are selected.

So the power unit No. 10 of the Prydniprovska TPP has a two-fan scheme of the dust system, containing a mill fan (MF) and a gas recirculation smoke exhauster (GRS), with gas-air drying. The selection of gases for drying is carried out from the limits of the boiler duct at the water economizer, and for the transportation of dust – with a drying agent from the MF [16].

Such a scheme of dust preparation and dust supply to the burner is carried out on the analysis of the operation of the dust system of boilers TP-90 of the Prydniprovska TPP No. 7, 9 and 13.

One of the main sources of impact on the state of atmospheric air is sulfur dioxide. Scattering is calculated according to the procedure [17]. This technique makes it possible to calculate the dispersion of impurities emitted into the atmosphere both by single, point and linear sources, and by 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 released from a single point source with a round mouth is achieved under adverse meteorological conditions at a distance (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 ΔT=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.

Let's calculate f_e – parameter determining the coefficient 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 limiting concentration is below $MPC_{a.d.}$ (0.5 mg/m^3), it is not advisable to conduct sulfur dioxin dispersion.

Applying the method [16] to other main substances emitted by the Prydniprovska TPP, the following results are obtained, shown in Table 3.

Table 3

Results of calculation of maximum surface concentrations of pollutants

Substance	*MPC*, mg/m^3	Ground concentration, mg/m^3
NO_2	0.2	0.16
CO_2	5.0	2.976
Substances in the form of suspended solids (suspended solids)	0.5	0.473

Thus, it can be concluded that no excess of the surface concentration for the main emitted substances was recorded.

In the future, the study of emissions from the Prydniprovska TPP can be carried out on other emitted harmful substances, as well as after the work on the modernization of treatment equipment.

4. Conclusions

Analyzing the emissions of harmful substances into the atmospheric air from the industrial site of the Prydniprovska TPP, it is possible to draw the following conclusion: the concentrations of the ingredients emitted by the enterprise do not exceed the corresponding maximum permissible values. Emissions into the environment ensure a satisfactory state of the environment in the area where the facility is located and outside the sanitary protection zone.

As a result of the analysis of emissions from the Prydniprovska TPP, it was revealed that most of their share falls on sulfur oxide – 72.4 %, while emissions of nitrogen oxides account for 15.8 %, suspended solids – 10 %. In total, Prydniprovska TPP is a source of about 61,000 tons of pollutants.

The analysis of emissions treatment at TPP power units revealed that the main sources of pollutants emitted into the atmosphere are the boiler units of blocks No. 7–11, 13.

It is recommended to timely control emissions of pollutants into the atmosphere by direct measurements at the source, to check the efficiency of dust and gas cleaning plants. Given the non-agricultural nature of the use of lands of the sanitary protection zone of the plant, it is recommended to inspect of soils for contamination, according to an expert assessment with the existing production technology not earlier than in 15–20 years. In order to reduce the man-made impact of emissions on the environment, it is necessary to improve the technological process at Prydniprovska TPP.

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