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# Directions of the environmental protection processes optimization at heat power engineering enterprises

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**Abstract.** The article observes the impact factors of heat power engineering enterprises on the environment and ways of anthropogenic impact reduction during the application of ecological security control technological methods. The authors suggest attending to the optimization of specific environmental protection processes during the elaboration of ecological security control technical methods in order to reduce the anthropogenic impact on the environment. At the industrial enterprises it is reasonable to implement the principle of the optimization of the environmental protection processes with the help of the high-intensity purification equipment. The optimization of the environmental protection process involves the choice of the physical-chemical factors such as: thermodynamic, kinetic, mass- and heat-exchanging, hydrodynamic, influence parameters on the heterogeneous, complex systems.

According to the results of the systems analysis of impact factors on the efficiency of environmental protection processes, it is suggested to optimize the cleaning equipment due to classified and structural parameters, which would allow design the systematic approaches to the selection of environmental protection equipment in future. The process intensity is considered as an environmental protection process optimization criterion.

**Keywords:** ecological security, heat and power engineering, environmental protection processes, optimization, intensity.

## 1 Introduction

Heat and power engineering enterprises, which are the sources of comprehensive environmental contamination, cause the ecological danger formation within industrially developed regions that is connected with the anthropogenic impact on the environment. Nowadays, Ukrainian heat and power engineering enterprises are considered to be main contaminators of the environment.

They cause above 30 % of harmful substances emission of the total volume of industrial enterprises emissions [1]. The growing demand for electric power and heat causes the growth of their output that leads to the comprehensive negative impact of heat and power engineering facilities on the environment and the increase of risk for the population living in the CHP influence area. Factors of heat and power engineering enterprises impact on the environment are air emissions, hydrosphere pollution, formation of the huge amount of by-products of various hazard categories significant part of which are slag wastes, various types of physical impacts, such as thermal and acoustic. Famous Ukrainian and foreign scientists including Barieva E. R., Kutovy V. O., Cherentsova A. A., Mylenka M. M., Gorova A. I., Krupska L. T., Zvereva V. P., Kulinenko O. R., Richter L. A. et al. studied the environmental status in the regions, where thermal power plants are located [1–9]. The impact of thermal power plants on the environment significantly differs due to types of fuel. Gas is the "cleanest" fuel for thermal power plants.

The "dirtiest" fuel is oil shales, peat, coal, and lignite. The largest number of dust items and sulfur oxides is formed in the process of burning. The new energetic policy in Ukraine is aimed at the decrease of oil gas consumption and at movement to the usage of multi-typed solid fuel. Due to this reason, power system enterprises extensively use the coal for energy production. This leads to the increase of ecological stress for the environment. Growing anthropological burden to the environmental elements provokes resistant changes in the structure and affects their functioning.

Environmental pollution is an essential factor of dangers for people's health. Getting into the environment, some ksenobiotics make a chronic action that causes organismic desadaptation, especially concerning vulnerable people. This situation is a base for development of the multi-sided approach to ecological safety control, that is based on the in-depth research connected with the conditions of a danger formation and with the domination of technical methods that are directed to regulate the danger state, besides to increase of environmental equipment intensively. Some territory is observed as compound social-natural-anthropogenic complex in the light of research of problems concerning resistant development. This complex is characterized with organic unity of all territorial components. Common mutual connections are being set either in the interior part of these components or between them. Their taking into account allows to investigate changes concerning parameters of human vital activity and environment depending on industrial regional infrastructure.

In 1996, EU released the directive "Concerning integrated pollution prevention and control". According to this directive, a decision about possibility to obtain the integrated permit for omissions, discharge of pollutants and waste disposal are made on the basis of ecological audit of an enterprise when the balance of pollutants is formed for the each kind of an enterprise with accounting of all omissions, discharges and waste. Also, in this case the comparison of ecological indicators is accomplished with the basic indicators "of the best accessible methods" . Energy efficiency of production is also estimated as well as the probability of emergencies, the elimination of their consequences, a plan of a territorial renovation in case of the production closure. According to the term, "the best available methods" are understood as the most effective ways for development. Also, they are methods of a production control that provide the opportunity to prevent omissions and negative factors for the environment, but when all this is impossible – just to decrease a negative effect.

The necessary motivation for innovative processes is the adoption of state standards of environmental management [10, 11]. The orientation of industrial production to meet the requirements of these standards allows to optimize and stabilize the operation of the main technological equipment, promotes technical re-equipment of industrial enterprises and improvement of environmental equipment, which leads to compliance with the norms of influence on environment.

In works devoted to the development of technical methods of environmental safety management, insufficient attention has been paid to optimization of specific environmental protection processes in order to reduce the technogenic load on the environment.

The objective of this paper is to consider the ways of improving the environmental situation in places where heat energy objects are located in terms of optimizing environmental protection processes.

## 2 Methods

The main principles of ecological safety in the system "settlement – industrial enterprise" are based on the following principles: compliance of normative and legislative framework with international requirements; rational planning of settlements development; minimization of pollutants formation through the improvement of industrial production technologies and implementation of environmental measures, which include upgrading of environmental equipment; integrated approach to the issue of reducing the population morbidity risk of caused by pollution of the environment.

In the zone of thermal power plants, according to the intensity of the impact and the nature of the transfer of pollutants one can distinguish the zones of the immediate (core) and indirect effects (Fig. 1), which differ in intensity and limits of influence on environment and people.

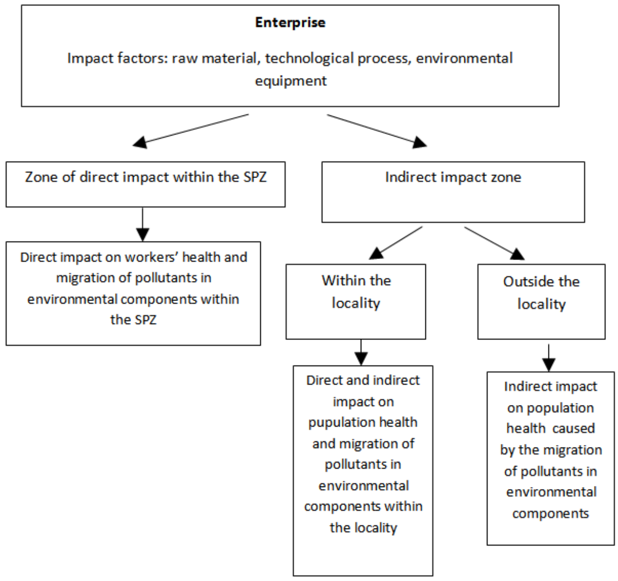


Figure 1 – Environmental impact of thermal power plants

One of the ways to increase the level of environmental safety is choosing technologies that are more effective compared with existing environmental ones and which provide normative levels of environmental impact. The task of increasing environmental safety can be reduced to the task of structural elemental optimization of environmental protection processes in general and a separate environmental protection process in particular.

The problem of optimization of the environmental protection process is defined in:

- establishing the criterion of optimality of the environmental protection process;
- determining the set of parameters $X = (X_1, X_2, ..., X_n)$ which have the influence on the efficiency of environmental protection according to the chosen criterion;
- developing the target function $F = f(X)$, solving optimization problem, that is finding the extremum of the target function, and as the result finding one of the possible processes, the parameters of which are the extremum of the target function.

As one of the ways to increase the level of environmental safety is to reduce the amount of pollutants entering the environment, optimization of the environmental protection process will be aimed at extracting the largest mass of pollutants for a certain period of time.

The process of integrated treatment of emissions and discharges of heat power engineering objects should be considered as a purposeful transformation of the physical and chemical system, namely a multi-component continuous medium distributed in the volume of the apparatus, at each point of which the transfer of matter, energy and momentum occurs.

Each of the phases can be considered as a transport stream, which introduces one or more reagents into the working area of the apparatus.

In the flow of a multi-component mixture, different components move at different speeds, which allow the composition of the mixture to change both in space and time.

The effectiveness of environmental processes will be a result of the simultaneous occurrence of physical and chemical processes, the interconnection of which causes the distribution of concentration fields and momentums in the reaction zone of the apparatus.

The efficiency of the treatment equipment is determined by the formula:

$$\eta = \frac{M_B}{M_n} \cdot 100\,\% = \frac{K \cdot F \cdot \Delta}{M_n} \cdot 100\,\%, \tag{1}$$

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where $M_B$ – mass of pollutant extracted per unit time kg/s; $M_n$ – initial mass of pollutant in emissions or discharges, kg/s.

The mass of the extracted pollutant is determined from the material balance of the process or by the equation:

$$M = K \cdot F \cdot \Delta \cdot t, \tag{2}$$

where $M$ – mass of the collected material, kg; $F$ – phase contact area, m$^2$; $K$ – coefficient of process speed; $\Delta$ – the driving force of the process; $t$ – time, s.

Mass of the material can be considered as formalized productivity of the apparatus according to a certain type of material. Attributed to a parameter that characterizes the size of the working area of the apparatus, this value allows considering a more important characteristic that integrally reflects the functional and technological level of the process or the apparatus - intensity.

The intensity of any apparatus refers to the ratio of one of its target characteristics to the volume or area of the cross-section of the apparatus.

The intensity of the work is proportional to the speed of the process; therefore, they seek to create such a design of the apparatus, which would ensure the maximum speed of the process, and, accordingly, the maximum intensity.

Being one of the essential conditions of the industrial equipment tech level improvement, intensity gives us the possibility to increase the amount of products manufactured in the same period of time, to reduce the amount and the dimensions of the equipment units.

At the industrial enterprises it is reasonable to implement the principle of the optimization of the environmental protection processes with the help of the high-intensity purification equipment. In such case one should view the optimization process as the solution of the optimization problem, taking the intensity as the optimization variable of the purification equipment referred to [12].

The intensity of the equipment unit is calculated using the formula:

$$i = \frac{M}{V \cdot t} = K \cdot F \cdot \frac{\Delta}{V}; \qquad i = \frac{M}{S \cdot t} = K \cdot F \cdot \frac{\Delta}{S}, \tag{3}$$

where $V$ – capacity of the equipment unit, m$^3$; $S$ – cross-sectional area of the equipment unit, m$^2$.

The environmental protection process $P$, which has the maximum intensity, would be the most preferable one:

$$P = \max\{i(X)\}. \tag{4}$$

where $X$ – factors which influence the intensity of the process.

The optimization of the environmental protection process involves the choice of the physical-chemical factors such as: thermodynamic, kinetic, mass- and heat-exchanging, hydrodynamic, influence parameters on the heterogeneous, complex systems. The thermodynamic factors, combining features of both phase and chemical equilibrium, determine the technological parameters and the direction of the implementation of the process, its speed and selectability. The kinetic factors, in their turn, involve kinetic constant and the energy of the reaction activation within the system. The group of mass-exchanging factors is represented by the interphase transfer coefficient of all the initial, intermediate and final substances. The heat-exchanging factors include heat-transfer coefficient and the characteristic of the external heat-exchange of the system with the surrounding. The hydrodynamic factors are defined as the characteristic of the interface formation, linear momentum, the turbulization of gas and liquid phase flow. However, the sphere of their indirect influence increases significantly due to the integrated speed of mass- and heat transfer and chemical reactions.

The particular group is represented by the constructive factors the connection with physical-chemical phenomena of which and their influence on the heterogeneous complex systems is manifested in the instrumentation of the operating space of the equipment unit. These factors correspond to the structurally represented techniques, which influence the interphase transfer processes via the hydrodynamic factors and the formation of the developed contact phase surface. The predominant sphere of the manifestation of the constructive factors is the formation of the energy expenses related to the arrangement of phase movement in the equipment unit. Thus, they have a significant influence on the optimization indexes within the gas purification process.

Using the principles of system approach and structural optimization, factors that influence on the process of optimization of gas-cleaning processes, based on equation (2), can be represented by the following interconnected and at the same time functionally completed subsystems:

1 – subsystem of factors that lead to an increase in the surface area of phases contact;

2 – subsystem of factors that lead to an increase in average driving force;

3 – subsystem of factors that lead to an increase in the coefficient of process speed;

4 – subsystem of factors that affect the volume of the device.

The first subsystem includes two types of factors: hydrodynamic methods and constructive methods. As components, they are interconnected and affect both each other and the subsystem.

$$X_1 = f(\mathrm{Re}, \Gamma), \quad (5)$$

where Re is the Reynolds criterion; Γ – characteristic of the constructive parameters of the apparatus.

The subsystem of factors that lead to an increase in the average driving force of the process is represented by three groups: hydrodynamic methods and physical and chemical properties of the phases, technological parameters of the process:

$$X_2 = f(\mathrm{Re}, \Phi, \Pi), \quad (6)$$

where Φ is a component that takes into account physical properties of the phases; Π is the technological parameters of the process.

The subsystem of factors that lead to an increase in the mass transfer coefficient is represented by groups: hydrodynamic methods; physical and chemical properties of phases; technological parameters of the process:

$$X_3 = f(\mathrm{Re}, \Phi, \Pi), \quad (7)$$

The fourth subsystem of factors $X_4$ – factors of influence on the volume of the apparatus.

Reducing the volume of the device happens due to increasing the speed of gas (reducing the area of the cross-sectional area of the device at a steady flow) and the effectiveness of the process (reducing the height of the device):

$$X_4 = f(\mathrm{Re}, \Phi, \Pi, L), \quad (8)$$

Hence,

$$i = f(X_1, X_2, X_3, X_4) = f(\mathrm{Re}, \Gamma, \Phi, \Pi, L). \quad (9)$$

Since the hydrodynamic mode of operation of the apparatus affects all components of the process intensification, we will consider the optimization task by operating parameters of the gas cleaning equipment. According to Berdt, Brunstein, Schegolev et al., the hydrodynamic mode of operation of the equipment and its structural design [12, 13] determine the mechanism of the influence of physical factors on mass-exchange and chemical processes in the working volume of the apparatus.

Hydrodynamic methods include the operation of equipment in highly turbulent mode at high gas velocities that promotes the grinding of the liquid, the creation of high foam layers, thin films of the liquid and leads to an increase in the contact surface of the phases and its continuous renewal.

Constructive methods will include the usage of mechanisms and contact devices. They contribute to the process of phases' turbulence and increase the contact surface of phases. It requires combining the technological methods of controlled influence on the structure of flows, creating the necessary conditions for the intensive flow of physical and chemical processes in the working volume of the device in the design of mechanism.

Hydrodynamic and constructive methods as components of the subsystem are interconnected and affect both each other and the subsystem.

The kinetic coefficient *K* of the process is determined by the reaction rate and diffusion in the liquid and gas phases. In the processes of mass transfer, the diffusion limits the speed of the process and determines the value of the coefficient *K* for heterogeneous processes, not related to chemical transformations. The value of *K* depends on the options of the gas-liquid system's state, which are sufficiently exposed to managed influence. They are temperature, pressure, the relative velocity of phases, physical properties of substances. Most of these options are functionally connected with the motive force of processes.

The degree of influence of these factors essentially depends on the hydrodynamic mode of the apparatus operation. The higher the intensity of the environment's flow, the less effect proceeds the molecular diffusion on the process compared with the convective, which causes the acceleration of mass transfer processes and the intensification of the gas purification process in general. Therefore, the intensification phase mixing should be considered as potentially promising method of increasing the rate coefficient of the process.

The fourth subsystem of factors $X_4$ are the factors of influence on the volume of the apparatus. Reducing the device's volume takes place due to increasing the gas speed (decreasing of cross-sectional area of the apparatus at a constant flow rate) and the effectiveness of the process (reducing the height of the device).

## 3 Conclusions

The problem of improving the environmental security level through the intensification of environmental processes is related to the proper selection and development of high-performance equipment that will improve cleaning efficiency and reduce energy costs of the process. We consider the possibility of optimizing the conditions of conducting environmental protection processes by intensity, as an integral characteristic of the efficiency of the processes carried out for each pollutant. Our conclusions are based on the analysis of the functional dependence of the effectiveness of environmental processes on kinetic characteristics, the mechanism of the interphase surface's formation, development of driving forces and structural features of the apparatus design.

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