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Honorary editor
I. G. Filippenko
Doctor of Technical Sciences, Professor
Ukrainian State University of Railway Transport (Ukraine)

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Shatilova dacha str., 4, Kharkiv, Ukraine, 61145

Contact information
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Визначено фізичний зміст й числові значення коефіцієнта компонування фільтра твердих частинок у випускній системі дизельної установки для математичної моделі його ефективності роботи. Це дозволяє врахувати вплив температури відпрацьованих газів дизеля на вході у корпус фільтра, а також прогнозувати робочі характеристики фільтрів з урахуванням місця їх розміщення у випускному тракті. Описано методику отримання експериментальних даних на моторному випробувальному стенді з автотракторним дизелем та робочим діючим зразком фільтра твердих частинок, на основі математичної обробки яких отримані залежності значень коефіцієнта від конструктивних і режимних робочих параметрів випускної системи дизеля

Ключові слова: техногенно-екологічна безпека, дизель, фільтр твердих частинок, ефективність очищення, наноматеріали

Определены физический смысл и числовые значения коэффициента компоновки фильтра твердых частиц в выпускной системе дизельной установки для математической модели его эффективности работы. Это позволяет учесть влияние температуры отработавших газов дизеля на входе в корпус фильтра, а также прогнозировать рабочие характеристики фильтров с учетом места их размещения в выпускном тракте. Описана методика получения экспериментальных данных на моторном испытательном стенде с автотракторным дизелем та рабочим действующим образом фильтра твердых частиц, на основе математической обработки которых получены зависимости значений коэффициента от конструктивных и режимных рабочих параметров выпускной системы дизеля

Ключевые слова: техногенно-экологическая безопасность, дизель, фильтр твердых частиц, эффективность очистки, нано материалы

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ASSESSMENT OF IMPROVEMENT OF ECOLOGICAL SAFETY OF POWER PLANTS BY ARRANGING THE SYSTEM OF POLLUTANT NEUTRALIZATION

S. Vambol
Doctor of Technical Sciences,
Professor, Head of Department*
E-mail: sergvambol@nuczu.edu.ua
V. Vambol
Doctor of Technical Sciences, Associate Professor
Department of Labour Protection and
Technogenic and Ecological Safety**
E-mail: violavambol@nuczu.edu.ua
O. Kondratenko
PhD, Associate Professor*
E-mail: kharkivjanyn@i.ua
Y. Suchikova
PhD, Associate Professor
Department of Vocational Education***
E-mail: yo_suchikova@bdpu.org
O. Hurenko
Doctor of Pedagogical Sciences,
Associate Professor, First Vice-Rector***
E-mail: oi_hurenko@bdpu.org
*Department of Applied Mechanics**
**National University of Civil Protection of Ukraine
Chernyshevska str., 94, Kharkiv, Ukraine, 61023
***Berdyansk State Pedagogical University
Schmidta str., 4, Berdyansk, Ukraine, 71100

1. Introduction

The level of ecological safety (ES) of an urban system is obviously determined by the numeric values of certain parameters. These parameters characterize the levels of ecological safety of the individual components of such a system. In this case, the level of ES is formed in line with a synergetic principle, that is, it is not a simple algebraic sum of components. Among such components, special attention should be paid to the sources of factors of environmental hazard that have intensive, multi-faceted influence even during their normal (not in emergency) operation. In urbosystems, such sources include power plants (PP), equipped with pistol internal combustion engines (PICE), in particular automotive vehicles (AMV) and specialized equipment (SE).

The problem on making PICE in PP environmentally safe is tackled in a large number of fundamental scientific studies [1–7], which testifies to its relevance. The latter is proved by the information in analytical reviews based on the results of annual congresses of the Society of Automotive Engineers (SAE) [8–10].

The most effective, as well as radical, out of the known ways of solving this problem is a partial or total rejection from the use of PICE as sources of mechanical power for AMV and SE. The first principle is implemented in hybrid cars, the second – in electric vehicles. In this case, a substantial obstacle to the widespread introduction of the above technologies is insufficient level of research into and development of the elementary base, first of all, accumulators of electrical power, in particular, batteries and supercondensers [11–13].

An analysis of articles [11–13] allows us to conclude that, in the short term, it is necessary to concentrate on studies into less radical ways of provision of the level of environmental safety of an urbosystem through harmonization of indicators of environmental safety of PICE with legislatively established standards, described for auto-tractor PICE, which equip AMV and SE of various purposes, in the UNECE Regulations No. 49 and 96 [14, 15]. According to data in [16], among such ways, the most effective is the neutralization of pollutants in the flow of exhaust gases (EG) of PICE, and among the means – diesel particulate matter filters (DPF). Modern ways and means of providing ES of motor vehicles based on elementary base from nanostructured semiconductors are an extremely promising direction for subsequent research, which, however, may be conducted sometime in the future.

Study [17] and the aforementioned emphasize the relevance of scientific-research work, aimed at creating fundamentally new and improvement of the known structures of DPF. Moreover, the peculiarities of their operation require further research.

2. Literature review and problem statement

As of 01.01.2016, norms of toxicity of AMV and SE with diesel PICE of standards of UNECE Regulations Nos. 49 and 96 of EURO V level have been put into effect on the territory of Ukraine. The norms of the same standards of EURO V level (as of 01.01.2016) are currently in force on the territory of the Russian Federation, and standards of EURO VI level (as of 01.09.2014 and 01.09.2015 for various types of AMV and SE) – on the territory of the European Union [14, 15, 17–19].

Authors of study [16] developed a system of management of ecological safety (SMES) of the process of operation of PP with PICE. Such PP, first of all, include the transportation AMV and SE that are on ready alert of the units of the State Emergency Service of Ukraine (SES), Armed Forces of Ukraine, the Ukrainian National Guard, the National Police of Ukraine, the State Border Guard Service of Ukraine, Security Service of Ukraine on other law enforcement agencies [20], as well as the mountain-rescue units [21]. Such SMES is structurally similar to:

– SMES of processes of dust and gas supression, which uses multi-phase disperse structures [22];

– SMES of processes of recycling of solid domestic wastes [23];

– SMES of the lifecycle of nano-structured semiconductor materials [11–13].

Developed SMES is constructed on the basis of the principles of multilevel decomposition, hierarchical structures, methodological approach and decimal division and includes several stages, each of which is divided into several levels.

The first stage of this SMES, termed “Source data for creating SMES”, includes two levels:

– Level 1, entitled “Identification of sources of factors of environmental hazard” and an analysis of the normative-legal framework”;

– Level 2, entitled “Classification of factors of environmental hazard with regard to their genesis and significance”.

Achieving these SMES levels resulted in updated classification of factors of environmental hazards, the source of which is PP with PICE, and the separation of particulate matters (PM) as one of the most dangerous legislatively normalized pollutants in EG of diesel engines. PM consist of uncombusted hydrocarbons of motor fuel and oil C_nH_m, adsorbed on surfaces of soot nuclei – porous amorphous carbon. By definition from [14, 15], PM are all substances, which settled on a special Teflon filter while passing through it of a specially prepared sample from EG, diluted with pure air, rather than water. In this case, it was found that up to 95 % of reduced toxicity of nitric oxide fall on nitrogen oxides NO_X and PM, in which, depending on the operation mode of the diesel engine, PM make up 20–45 % [16, 17].

The second phase of such SMES, entitled “Improved and new technologies for provision of ES, used by SMES”, consists of two levels:

– Level 3, entitled “Development of new and improvement of the known preparatory processes”;

– Level 4, entitled “Development of new and improvement of existing equipment for the implementation of technological processes”.

Results of implementation of levels of this stage are:

– new classifications of the ways and means of reducing the mass release of PM with EG flow from diesel engimes (primarily, DPF);

– implementation of the process of their regeneration;

– positioning of the design of DPF, developed by the authors, in these classifications.

Mathematical model of efficiency of the developed DPF was described in the previous part of research [17].

The purpose of DPF is the neutralization of PM in EG by removing them from the flow, accumulation in the filtration element (FE) and converting them into safe substances directly in FE or outside PP. When creating the above classifications, we applied the methods of literary-patent search, analysis and synthesis of information, and the principle of decimal division.

The third stage of SNES is named “Organization and execution of processes that provide a specified level of ES” and has two levels:

– Level 5, entitled “Organization and management of SMES”;

– Level 6, entitled “Production processes that provide a specified level of ES”.

Results of their implementation include researched, described and rationalized processes in FE of DPF and in the exhaust tract of PICE.

That means that this series of studies takes a defined place in the construction of operation process of PP with the piston ICE in SMES.

An analysis of up-to-date information from current scientific research suggests that temperature of EG in different sections of the exhaust tract of diesel PICE in general, and in particular in the units of the system of pollutant neutralization, exerts significant influence on the progress and results of operation processes in them. Thus, paper [24] describes the features of operation of DPF with ceramic FE of the cellular structure with longitudinal channels with gas-permiable walls with catalytic coating that are plugged in staggered order at decreased temperature of EG. Article [25] studies the effect of temperature of EG on efficiency of a selective absorber of nitrogen oxides; while article [26] explores its influence on efficiency of application of EG recirculation. Research [27] is devoted to the influence of EG temperature on operation processes in a catalytic oxidizing agent of uncombusted hydrocarbons with netlike-steel FE as parts of DPF. Paper [28] describes results of multi-zone mathematical modeling of relationships between temperature of EG, operation efficiency and hydraulic resistance of DPF. Articles [29, 31] analyse selection of temperature of EG in the process of regeneration of DPF, article [30] explores the influence of temperature of the combustible generator gas at the inlet to PICE on efficiency of its cleaning. Paper [32] examines the effect of temperature of EG on the process of standard passive regeneration of the first kind by the thermocatalytic method of DPF, and research [38] focuses on the specifics of operation of sensors of the system of electronic control over this process. The influence of the temperature of EG on the course of processes of chemical transformation of polycyclic aromatic hydrocarbons in EG for three types of diesel fuels of biological origin are given in paper [34], on other processes – in papers [39, 42].

The examined DPF has FE of non-conventional design that contains modules filled with granular natural zeolite in netlike holders and does not contain catalytic coatings. The relationship of the processes of oxidation of PM and reduction of nitrogen oxides in DPF with the use of zeolites with catalysts was studied in papers [33, 41], and in case of their different spatial structuring, it was explored in articles [37, 40]. The temperature of EG has a significant impact on the course of operation processes in DPF with non-conventional design, which is constructed by the triboelectric principle of self-powered operation, which is explored in paper [36].

In this case, the problem is the lack of description of the influence of processes, taking place in the EG flow in the exhaust tract of PICE, on the performance characteristics of the studied DPF. These processes include the following consecutive chain, determined by causal relations [16, 43]:

– cooling of EG flow due to heat exchange with unmoved details of the exhaust tract and radiation, expansion and slowdown of the viscous flow through linear and local losses of head;

– condensation of uncombusted hydrocarbons of motor fuel and lubricants on PM due to cooling of the EG flow;

– increase if dimensions of PM themselves at the expense of their coagulation due to the presence of adhesive properties of layers of hydrocarbons, adsorbed on soot cores.

The latter, obviously, should improve the efficiency of the process of cleaning of the EG flow from PM with the help of devices, built on inertial and filter methods. However, direct research into processes of condensation and coagulation in the flow of EG of diesel PICE still pose certain difficulties of technologically-methodological nature.

In the present study, we plan to perform assessment and mathematical description of the influence of length of the exhaust tract of the diesel engine between the exhaust collector and DPF on temperature of the EG flow. The influence of the length of the tract on the DPF efficiency may be regarded as a useful practical result of the studied effect. Assessment and a mathematical description will be carried out based on an analysis of experimentally obtained data.

It should also be noted that nanomaterials will gradually begin to occupy the niche of materials for DPF and unburned hydrocarbons, catalytic for oxidizers, in particular in the form of membranes from silicium carbide, as shown in paper [34].

3. The aim and tasks of the study

The aim of present study is to identify the impact of DPF lay-out along the exhaust tract of the diesel engine on the efficiency of EG cleaning from PM.

To achieve the specified aim, the following tasks were set:

– to describe prerequisites for the formation and the structure of the mathematical model of operation efficiency of a solid particle filter of diesel plants, as well as the methods of obtaining experimental source data for its creation;

– to improve the mathematical model of operation efficiency of the solid particle filter of diesel plants by taking into account the special features of its lay-out in the exhaust system of a diesel engine;

– to determine physical essense and definition of lay-out coefficient of such mathematical model;

– to evaluate effectiveness of taking of structural measures to improve the environmental safety of the operation process of power plants with the system of pollutant neutralization through the lay-out of its units.

4. Determining a lay-out coefficient of particulate matter filter in exhaust system of a diesel plant for the mathematical model of its efficiency

4. 1. Prerequisites for the formation of mathematical model of operational efficiency of a particulate matter filter of the diesel plants

The authors developed DPF with FE of a new modular alternative design [16, 17]. Results of physical and mathematical modeling of the process of motion of the EG flow in DPF were obtained. Under real conditions of operation, engine testing of the present layout of such DPF on the bench, equipped with autotractor diesel engine 2Ch10.5/12, were carried out. Based on these results, a mathematical model of hydraulic resistance (HR) of such DPF was constructed and data to build a mathematical model of its efficiency, which is similar to it by structure, were obtained. Peculiarities and differences of these models are described in study [17].

Design features of the current mockup sample of DPF, engine testing bench, motor-free experimental plant, autotractor diesel engine 2Ch10.5/12, manufactured at Vladimir tractor factory (Russian Federation), composition and characteristics of measuring equipment of the bench, programs and methods of conducting such a study and test cycles are described in [14, 15, 17, 44].

4. 2. Mathematical model of operatinal efficiency of a particulate matter filter of the diesel plants

The developed mathematical model establishes relationships between performance characteristics of DPF and the mode, regulatory, and design parameters of the diesel engine and operational factors, described with the mathematical language. Such a model in subsequent studies will form the basis for scientific-research works on construction of the standard series of DPF of the known and new, traditional and non-traditional designs, which, in turn, is the first stage of their implementation in the full-scale production and operation with the purpose of provision of ES of environment of urban systems.

The mentioned mathematical model, described in [17] and based on the same principles as the mathematical model of hydraulic resistance of DPF from [45], takes the following form:

$$K_{CE} = K_{CE}\left(G_{PM}\right)\left(g_{m\_EG}\right)\cdot k_L\left(t_{DPF\,int\,max}\right)\cdot k_\tau\left(\tau_M;N_{ei};WF_i\right) = K_{CE}\left(G_{PM}\right)\left(n_{cs}\right)\cdot k_L\left(L_{exh}\right)\cdot k_\tau\left(\tau_M;N_{ei};WF_i\right), \quad (1)$$

$$K_{CE}\left(G_{PM}\right)\left(g_{m\_EG}\right)=-0{,}332\cdot g_{m\_EG}^{2}+$$
$$+14{,}198\cdot g_{m\_EG}^{2}-112{,}557;R^{2}=0{,}96756, \qquad (2)$$

$$g_{m\_EG}=$$
$$=\left(1{,}558\cdot 10^{-2}\cdot n_{cs}+0{,}956\right)\cdot 20/z_{m}\cdot 55/S_{int}\ \text{kg/(s·m}^2\text{)}, \qquad (3)$$

where $K_{CE}(G_{PM})(g_{m\_EG})$ and $K_{CE}(G_{PM})(n_{cs})$ are, respectively, coefficient of efficiency of cleaning of EG flow (as a phenomenon) from PM in the function of EG flow (as physical magnitude) and rotation frequency of crankshaft of the diesel engine, %; g_{m_EG} are the second mass consumption of EG through a unit of area of the inlet hole of FE module of DPF (EG flow), kg/(s·m^2); G_{PM} is the mass exhaust of PM with EG flow, kg/h; k_L, k_τ are, respectively, lay-out coefficient and temporal coefficient of the model; t_{DPFint_max} is the maximum temperature of EG at the outlet into the case of DPF by external velocity characteristic (EVC), which is observed under the mode of maximum torque, °C; L_{exh} is the length of the exhaust tract of the diesel engine to the place where DPF is installed, m; τ_M is the operation time of the diesel engine under the mode of maximum torque, h; N_{ei} is the effective capacity of the diesel engine in the i-th operation mode, kW; WF_i is the weight factor of the i-th operation mode of diesel engine in the operation model; index i corresponds to the current operation mode of the diesel engine in operation model; z_m is the number of modules in FE, unit; S_{int} is the area of the inlet hole of module of FE, m^2; n_{cs} is the rotation frequency of crankshaft, s^{-1}.

Magnitudes G_{PM} in kg/h and $K_{CE}(G_{PM})$ in % are determined by formulas (4) and (5).

$$G_{PM}=\left(2{,}3\cdot 10^{-3}\cdot N_{D}+5\cdot 10^{-5}\cdot N_{D}^{2}+\right.$$
$$+0{,}145\cdot\frac{C_{CH}\cdot 4{,}78\cdot 10^{-7}\cdot\left(G_{air}+G_{fuel}\right)}{0{,}7734\cdot G_{air}+0{,}7239\cdot G_{fuel}}+$$
$$\left.+0{,}33\cdot\left(\frac{C_{CH}\cdot 4{,}78\cdot 10^{-7}\cdot\left(G_{air}+G_{fuel}\right)}{0{,}7734\cdot G_{air}+0{,}7239\cdot G_{fuel}}\right)^{2}\right)\times$$
$$\times\frac{\left(0{,}7734\cdot G_{air}+0{,}7239\cdot G_{fuel}\right)}{1000}, \qquad (4)$$

$$K_{CE}\left(G_{PM}\right)=\left(G_{PMICE}-G_{PMDPF}\right)\cdot 100/G_{PMICE}, \qquad (5)$$

where indexes of ICE and DPF refer to the cases of lack and existence of DPF in the exhaust tract of a diesel motor.

4. 3. Physical essence and definition of a lay-out coefficient of a particulate matter filter in the exhaust system of diesel plants

The coefficient that is being developed and researched establishes the relationships between the temperature of EG flow at the inlet to the housing of DPF and efficiency of cleaning EG flow from PM with the filter. It is determined by the place, where it is installed along the exhaust tract of the diesel engine (the course of processes of extenstion of EG flow and EG heat exchange with the medium in the exhaust tract) and growing in size of PM through condensation of C_nH_m on PM and coagulation of PM in EG flow. Herein lies the unsolved problem of the research and its scientific novelty.

Materials of research [11, 44] contain sufficient experimentally obtained information to describe the relationship between indicators of operation efficiency of the studied DPF, with the most important design parameters of the diesel engine, AMV and SE and the performance factors.

5. Results of examining a lay-out coefficient of particulate matter filter in the exhaust system of diesel plant

Approaches to the solution of the set problems of the research and its results are given in studies [17, 45]. The aforementioned engine tests were carried out at several stages, the results of the first of which formed the basis of the mathematical model itself. In the course of implementation of the first stage, we experimentally compared characteristics of performance of two types of experimental samples of FE during the operation of the auto tractor diesel engine 2Ch10.5/12 in the modes of external velocity characteristic (EVC), at which they were mounted in the housing of DPF directly behind the exhaust collector of the diesel engine (L_{exh}=0 m).

Advantages of the chosen approach to comparative studies with the use of EVC, peculiatiries of characteristics themselves and the way of their construction are presented in [17]. The value of the coefficient of luminous flux damping N_D in % was obtained as a result of direct single measurement by the smoke density indicator INFRAKAR-D. The value of volumetric concentration of C_nH_m in EG C_{CH} in mln^{-1} was obtained by the five-compoment gas analyzer AUTOTEST-02.03. The magnitude of G_{PM} in kg/h was calculated using known conversion formula (4) from [46].

The second stage of the engine experimental research was carried out for the purpose of detection and estimation of the influence of temperature of dispersed medium of aerosol "EG of the diesel engine – PM" t_{EG} on efficiency of cleaning from disperse phase by means of the researched DPF.

There was made an assumption that when the value of t_{EG} decreases, the value of $K_{CE}(G_{PM})$ is to increase under other equal conditions. Such an effect might be expected due to the above reasons, which may be described in more detail as follows.

Firstly, the place of mounting of the current DPF mock-up immediately after outlet flange of the exhaust collector of the diesel engine is characterized by value L_{exh}=0 m and t_{EG}=605 °C, as well as maximum velocity of EG flow through FE. In this case, the processes that determine dimensions of PM (condensation of C_nH_m on soot core, coagulation of PM themselves), which are in the logarithmic dependence on t_{EG} [47], under these conditions are far from being completed. In the exhaust collector of the diesel engine, according to presented in [16, 43, 46, 47], they have dimensions of about 5 nm (at t_{EG}=600 °C), in the cross-section of the exhaust tract at the inlet to the EG silencer – around 0.1 μm (at t_{EG}=350...400 °C), and in the cross-section at the outlet of the exhaust system of AMV, they exceed 3...5 microns (t_{EG}=200 °C and less). That is, in function of $t_{EG,}$ there is a decrease in dimensions of PM and a change in their composition (calculation, chemical, dimensional, by weight, by area of adsorbing surface), structure and geometric shapes (complex branching).

In FE of the studied mock-up operating sample of DPF, the number of modules z_m=20 units, while by preliminary estimations for the diesel engine 2Ch10.5/12, with operation volume of 2.0 dm^3, the rational value z_m should be 30...50 units. This provides a greater degree of extension of EG flow at the inlet to FE and a corresponding decrease in the velocity of motion of EG in FE.

At these dimensions of the experimental sample, soot capacity, that is, the dynamics of filling of PM over time, is also limited. Then the change in time of living cross-sections of randomly placed random-shape channels between the granules of fill from natural zeolite in netlike holders is also limited.

The state of fill (fractions, temperature, way of briquetting and compacting), obviously, also has to make some impact on K_{CE} [45]. Detection and assessment of such effects require additional research.

In the experiment, the change in value t_{EG} was achieved by extending the exhaust tract between the flanges of the exhaust collector and the case of the experimental sample with pieces of flexible heat-resistant pipeline by magnitude L_{exh}=1.5, 5.0 and 8.0 m. In this case, the EG flow was cooled naturally due to the processes of heat exchange with the environment and extension. For each new position of the researched experimental sample, EVC was recorded, which was later compared with such characteristic for L_{exh}=0 m, obtained in the first stage of experimental research.

It should be noted that in the course of experimental verification, these assumptions were proved. $K_{CE}(G_{PM})$ increased from 40.1 % at L_{exh}=0 m to 86.8 % at L_{exh}=8,0 m under the mode of maximum torque of the diesel engine. Under this mode, there is a global maximum of mass emission of PM and $K_{CE}(G_{PM})$. However, the limit to the value of L_{exh}=5,0 m is rational, because, in practice, larger values are difficult to achieve even for heavy-duty AMV and SE, in this case, $K_{CE}(G_{PM})$=77.4 % [44, 45].

Along with this, we also observed a decrease in EG of experimental sample and a difference in temperature of EG on the sample, the physical nature of these processes is interpreted in [45].

In the same study, the relationships between magnitudes were found:

a) temperature of EG in the place of mounting of the operating mock-up of DPF in the absence of t_{EG}, at temperature at the inlet to the housing of DPF t_{DPFint} and temperature of EG at the outlet from the housing of DPF t_{DPFint};

b) hydraulic resistance of DPF t_{DPFint}, a part of the exhaust tract of the diesel engine, which is located behind the housing of DPF ΔP_{exh}, housing of DPF without FE of ΔP_{DPFh} in qualitative terms are conserved for all values of L_{exh}.

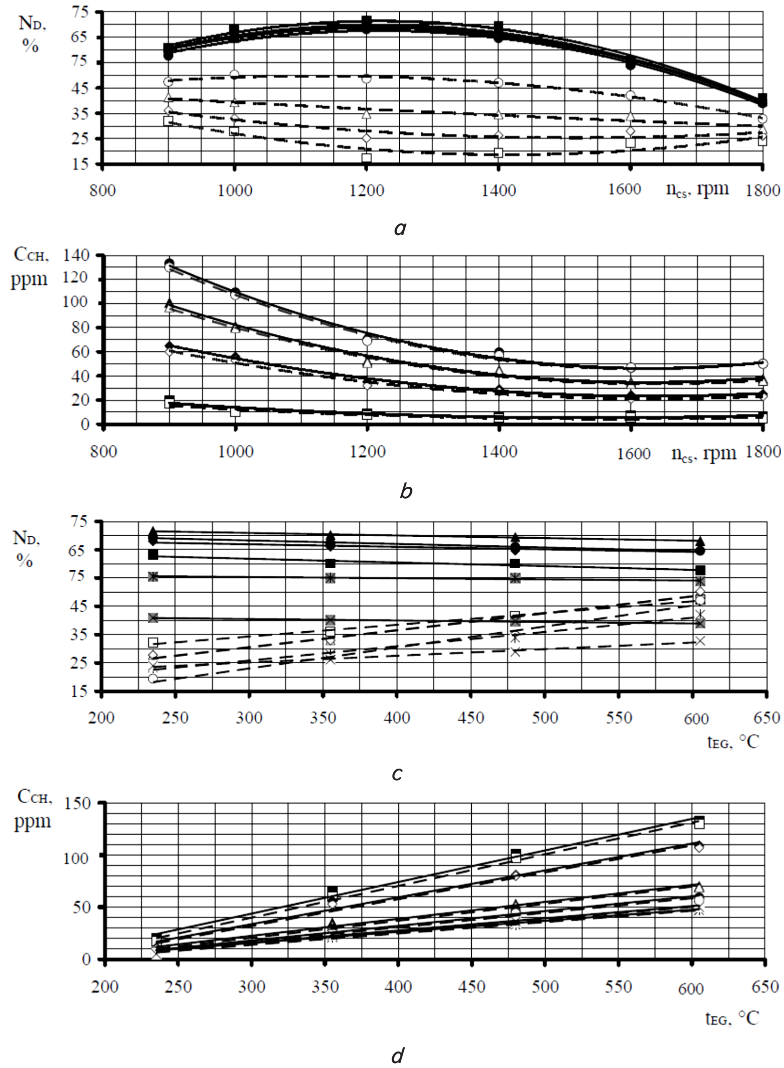

Fig. 1. External velocity characteristics of the diesel engine 2Ch10.5/12 for different places where DPF is installed: *a* – the dependence of coefficient of luminous flux damping N_D on rotation frequency of the crankshaft of the diesel engine; *b* – dependence of volumetric concentration of C_nH_m in EG on rotation frequency of the crankshaft of the diesel engine; *c* – dependence of coefficient of luminous flux damping N_D on temperature of dispersed medium of aerosol "Diesel EG-PM"; *d* – dependence of volumetric concentration of C_nH_m in EG on temperature of dispersed medium of aerosol "Diesel EG-PM". For *a*–*d*: ■, □ – t_{EG}=235 °C (L_{exh}=8.0 m); ◆, ◊ – t_{EG} = 355 °C (L_{exh}=5.0 m); ▲, Δ – t_{EG} = 480 °C (L_{exh}=1.5 m);●, ○ – t_{EG}=605 °C (L_{exh}=0.0 m); ■, ◆, ▲, ● – without DPF; □, ◊, Δ, ○ – with DPF; for d: ■, ◆, ▲, ● – $K_{CE}(G_{PM})$; □, ◊, Δ, ○ – $K_{CE}(N_D)$; □, ◊, Δ, ○ – $K_{CE}(C_{CH})$

Magnitudes t_{EG} also depend linearly on magnitude L_{exh}, and magnitudes t_{DPFint}, t_{DPFout}, Δt_{DPF} – nonlinearly (polynomials of the second power).

The maximum temperature of EG at the inlet to DPF t_{DPFint} and magnitude L_{exh} may be connected by the following dependence, obtained by description of the experimental data by the method of least squares (R^2 = 0.986) [45]:

$$t_{DPFint\,max} = 2{,}176 \cdot L_{exh}^2 - 61{,}272 \cdot L_{exh} + 591{,}2 \ \ °C. \qquad (4)$$

Results of this phase of engine tests are shown in Fig. 1, 2.

Fig. 1 shows experimentally obtained dependences of magnitudes N_D, C_{CH}, in the course of operation of the diesel engine D21A1 under modes of EVC (that is, in function n_{cs}) for different fixed values of L_{exh} (that is, in function t_{DPFint}) under condition of existence (designated by index of DPF) or absence (designated by index ICE) in the exhaust tract of DPF.

Fig. 2 shows dependences of magnitudes G_{PM} of the diesel engine 2Ch10.5/12 and $K_{CE}(N_D)$, $K_{CE}(C_{CH})$ and $K_{CE}(G_{PM})$ by EVC modes on values n_{cs} and t_{EG} for different fixed values of L_{exh}, obtained by calculation. Fig. 2, *d* also shows dependence of magnitude L_{exh} on t_{DPFint}, which corresponds to formula (4).

The curves, given in Fig. 1, 2, are described by polynomials of the first and second power by the method of least squares (R^2=0.997...0.960) [17, 45] and take the following form.

$$y = a \cdot x^2 + b \cdot x + c, \quad (5)$$

where y is the experimentally obtained indicators of operational efficiency of the diesel engine or DPF; x is the influence factor, in this case – n_{cs}, min^{-1}, at n_{cs}=[800, 1800] min^{-1}; a, b, c are the coefficients of approximating polynomial.

The magnitudes of coefficients of approximating polynomials a, b and c for different magnitude y at different fixed values of magnitude L_{exh} (or $t_{DPFint\ max}$) in function of magnitude x are reduced to Table 1. At different fixed values of magnitude $t_{EG,}$ they are given in Table 2.

Therefore, we obtained approximated dependences of source data for the formation of values of a lay-out coefficient of DPF in the exhaust system of the diesel plant for the mathematical model of its operational effectiveness on the chosen influencing factors.

Table 1

Parameters of approximating polynomials

y	[y]	a	b	c	a	b	c
$x=n_{cs}$, $[x]=min.^{-1}$		$[y]/[x]^2$	[y]/[x]	[y]	$[y]/[x]^2$	[y]/[x]	[y]
At fixed values		L_{exh}=0,0 m ($t_{DPFint\ max}$=605 °C)			L_{exh}=1,5 m ($t_{DPFint\ max}$=480 °C)		
N_{D_ICE}	kW	$-8.697 \cdot 10^{-5}$	0.212	–61.6	$-8.634 \cdot 10^{-5}$	0.210	–58.6
N_{D_DPF}	kW	$-3.678 \cdot 10^{-5}$	8.289	3.1	$2.527 \cdot 10^{-6}$	$-1.882 \cdot 10^{-2}$	55.7
C_{CH_ICE}	ppm	$1.615 \cdot 10^{-4}$	–0.525	473.3	$1.221 \cdot 10^{-4}$	–0.397	357.1
C_{CH_DPF}	ppm	$1.610 \cdot 10^{-4}$	–0.521	466.6	$1.155 \cdot 10^{-4}$	–0.378	342.0
G_{PM_ICE}	kg/h	$-4.910 \cdot 10^{-8}$	$1.331 \cdot 10^{-4}$	$-6.6 \cdot 10^{-2}$	$-5.020 \cdot 10^{-8}$	$1.362 \cdot 10^{-4}$	$-6.7 \cdot 10^{-2}$
G_{PM_ICE}	kg/h	$-1.860 \cdot 10^{-8}$	$5.165 \cdot 10^{-5}$	$-2.1 \cdot 10^{-2}$	$-1.270 \cdot 10^{-9}$	$5.400 \cdot 10^{-6}$	$-4.6 \cdot 10^{-3}$
$K_{CE}(N_D)$	%	$-5.560 \cdot 10^{-5}$	0.146	–68.3	$-9.720 \cdot 10^{-5}$	0.256	–119.4
$K_{CE}(C_{CH})$	%	$-6.575 \cdot 10^{-6}$	$1.502 \cdot 10^{-2}$	–6.1	$4.981 \cdot 10^{-6}$	$-1.195 \cdot 10^{-2}$	9.8
$K_{CE}(G_{PM})$	%	$-8.060 \cdot 10^{-5}$	0.211	–99.2	$-1.197 \cdot 10^{-4}$	0.314	–142.2
At fixed values		L_{exh}=5.0 m ($t_{DPFint\ max}$=355 °C)			L_{exh}=8.0 m ($t_{DPFint\ max}$=235 °C)		
N_{D_ICE}	kW	$-8.968 \cdot 10^{-5}$	0.218	–63.2	$-9.391 \cdot 10^{-5}$	0.229	–68.4
N_{D_DPF}	kW	$2.669 \cdot 10^{-5}$	$-8.098 \cdot 10^{-2}$	86.8	$4.766 \cdot 10^{-5}$	–0.135	114.6
C_{CH_ICE}	ppm	$7.863 \cdot 10^{-5}$	–0.256	232.3	$2.912 \cdot 10^{-5}$	$-8.99 \cdot 10^{-2}$	74.7
C_{CH_DPF}	ppm	$7.400 \cdot 10^{-5}$	–0.242	218.4	$2.490 \cdot 10^{-5}$	$-7.789 \cdot 10^{-2}$	65.3
G_{PM_ICE}	kg/h	$-5.250 \cdot 10^{-8}$	$1.424 \cdot 10^{-4}$	$-7.1 \cdot 10^{-2}$	$-5.580 \cdot 10^{-8}$	$1.511 \cdot 10^{-4}$	$-7.6 \cdot 10^{-2}$
G_{PM_ICE}	kg/h	$7.140 \cdot 10^{-9}$	$1.709 \cdot 10^{-5}$	$-1.6 \cdot 10^{-2}$	$1.290 \cdot 10^{-8}$	$3.258 \cdot 10^{-5}$	$-2.4 \cdot 10^{-2}$
$K_{CE}(N_D)$	%	$-1.247 \cdot 10^{-4}$	0.328	–153.0	$-1.472 \cdot 10^{-4}$	0.387	–180.7
$K_{CE}(C_{CH})$	%	$-4.310 \cdot 10^{-6}$	1.499	–3.7	$1.174 \cdot 10^{-5}$	$2.049 \cdot 10^{-2}$	20.1
$K_{CE}(G_{PM})$	%	$-1.359 \cdot 10^{-4}$	0.356	–156.1	$-1.429 \cdot 10^{-4}$	0.373	–157.7

Table 2

Parameters of approximating polynomials

y	[y]	a	b	c	a	b	c
$x=t_{EG}$, $[x]=°C$		$[y]/[x]^2$	$[y]/[x]$	$[y]$	$[y]/[x]^2$	$[y]/[x]$	$[y]$
At values		n_{cs}=900 min^{-1}			n_{cs}=1000 min^{-1}		
N_{D_ICE}	kW	0	$-1.309 \cdot 10^{-2}$	65.7	0	$-9.037 \cdot 10^{-3}$	69.6
N_{D_DPF}	kW	0	$4.149 \cdot 10^{-2}$	21.9	0	$6.000 \cdot 10^{-2}$	12.5
C_{CH_ICE}	ppm	0	0.303	−47.3	0	0.258	−43.8
C_{CH_DPF}	ppm	0	0.304	−51.4	0	0.257	−45.2
G_{PM_ICE}	kg/h	0	$-4.447 \cdot 10^{-6}$	$2.1 \cdot 10^{-2}$	0	$-3.132 \cdot 10^{-6}$	$2.3 \cdot 10^{-2}$
G_{PM_ICE}	kg/h	0	$1.717 \cdot 10^{-5}$	$3.2 \cdot 10^{-3}$	0	$2.331 \cdot 10^{-5}$	$3.7 \cdot 10^{-5}$
$K_{CE}(N_D)$	%	$-6.078 \cdot 10^{-5}$	$-3.207 \cdot 10^{-2}$	59.8	$-1.172 \cdot 10^{-4}$	$-6.713 \cdot 10^{-5}$	65.4
$K_{CE}(C_{CH})$	%	$9.502 \cdot 10^{-5}$	−0.114	36.4	$7.371 \cdot 10^{-5}$	$-8.286 \cdot 10^{-2}$	24.7
$K_{CE}(G_{PM})$	%	$-9.772 \cdot 10^{-5}$	$-1.975 \cdot 10^{-2}$	73.0	$-1.690 \cdot 10^{-4}$	$3.025 \cdot 10^{-2}$	75.3
At values		n_{cs}=1200 min.$^{-1}$			n_{cs}=1400 min.$^{-1}$		
N_{D_ICE}	kW	0	$-9.063 \cdot 10^{-3}$	73.6	0	$-1.246 \cdot 10^{-2}$	72.0
N_{D_DPF}	kW	0	$8.356 \cdot 10^{-2}$	−3.5	0	$7.408 \cdot 10^{-2}$	0.828
C_{CH_ICE}	ppm	0	0.163	−26.3	0	0.142	−24.5
C_{CH_DPF}	ppm	0	0.163	−28.4	0	0.140	−25.3
G_{PM_ICE}	kg/h	0	$-3.976 \cdot 10^{-6}$	$2.6 \cdot 10^{-2}$	0	$-5.746 \cdot 10^{-6}$	$2.5 \cdot 10^{-2}$
G_{PM_ICE}	kg/h	0	$2.825 \cdot 10^{-5}$	$4.1 \cdot 10^{-3}$	0	$2.512 \cdot 10^{-5}$	$2.8 \cdot 10^{-3}$
$K_{CE}(N_D)$	%	$-1.525 \cdot 10^{-4}$	$2.363 \cdot 10^{-3}$	83.3	$-1.457 \cdot 10^{-4}$	$2.428 \cdot 10^{-2}$	79.2
$K_{CE}(C_{CH})$	%	$5.937 \cdot 10^{-6}$	$-3.240 \cdot 10^{-2}$	18.6	$1.834 \cdot 10^{-4}$	−0.190	52.1
$K_{CE}(G_{PM})$	%	$-2.363 \cdot 10^{-4}$	$7.457 \cdot 10^{-2}$	81.9	$-2.26 \cdot 10^{-4}$	$6.476 \cdot 10^{-2}$	80.7
At values		n_{cs}= 1600 min^{-1}			n_{cs}= 1800 min^{-1}		
N_{D_ICE}	kW	0	$-4.132 \cdot 10^{-3}$	56.6	0	$-5.179 \cdot 10^{-3}$	42.1
N_{D_DPF}	kW	0	$5.049 \cdot 10^{-2}$	10.7	0	$2.370 \cdot 10^{-2}$	18.0
C_{CH_ICE}	ppm	0	0.106	−16.1	0	0.117	−19.4
C_{CH_DPF}	ppm	0	0.109	−19.0	0	0.120	−21.6
G_{PM_ICE}	kg/h	0	$-1.281 \cdot 10^{-6}$	$1.7 \cdot 10^{-2}$	0	$-1.241 \cdot 10^{-6}$	$1.1 \cdot 10^{-2}$
G_{PM_ICE}	kg/h	0	$1.705 \cdot 10^{-5}$	$4.1 \cdot 10^{-4}$	0	$7.796 \cdot 10^{-6}$	$3.0 \cdot 10^{-3}$
$K_{CE}(N_D)$	%	$-1.157 \cdot 10^{-4}$	$4.846 \cdot 10^{-4}$	64.1	$-7.900 \cdot 10^{-5}$	$-2.197 \cdot 10^{-3}$	46.1
$K_{CE}(C_{CH})$	%	$-6.087 \cdot 10^{-5}$	$1.088 \cdot 10^{-2}$	15.4	$5.876 \cdot 10^{-5}$	$-9.200 \cdot 10^{-2}$	34.6
$K_{CE}(G_{PM})$	%	$-1.751 \cdot 10^{-4}$	$3.877 \cdot 10^{-2}$	71.5	$-1.088 \cdot 10^{-4}$	$7.347 \cdot 10^{-3}$	56.7

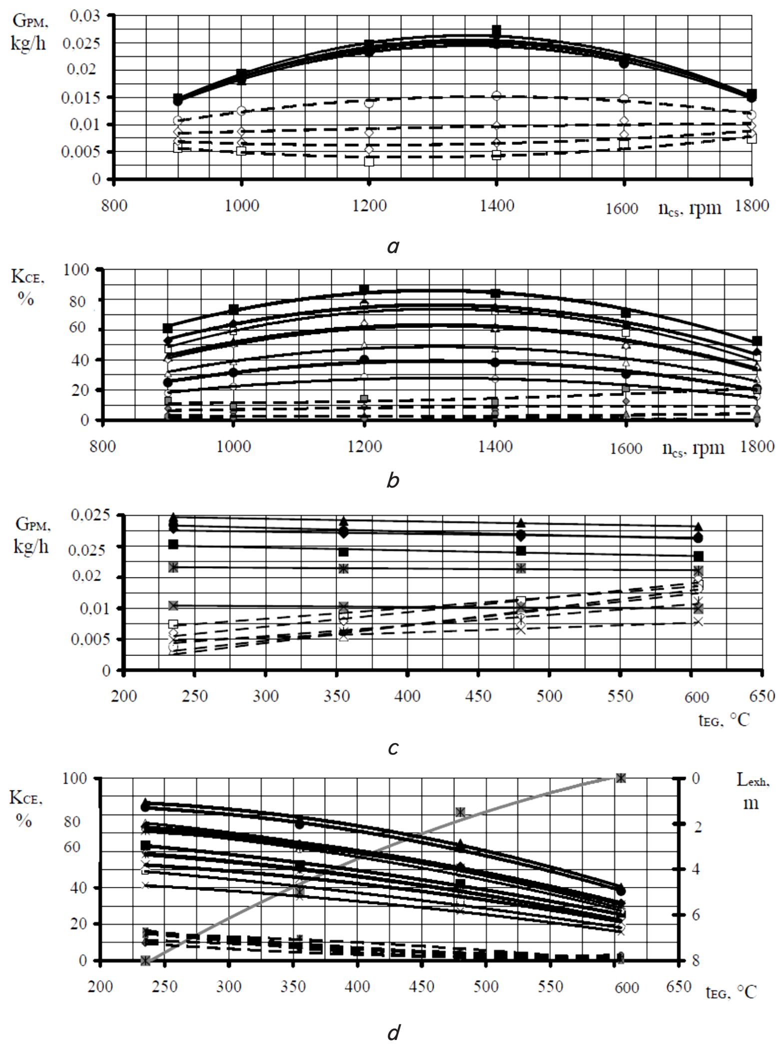

Fig. 2. Dependence of mass exhaust of PM from EG of the diesel engine 2Ch10.5/12 and operational efficiency of DPF by different components of PM on rotation frequency of the cranckshaft and temperature of EG at the inlet to the housing of DPF (places where DPF is installed along the exhaust tract of the diesel engine): *a* – dependence of mass exhaust of PM with EG flow on rotation frequency of the cranckshaft of the diesel engine; *b* – dependence of coefficient of cleaning of EG flow on rotation frequency of the cranckshaft of the diesel engine; *c* – dependence of mass exhaust of PM with EG flow on temperature of dispersed medium of aerosol "Diesel EG-PM"; *d* – dependence of coefficient of efficiency of cleaning the EG flow on temperature of dispersed medium of aerosol "Diesel EG-PM". For *a, b*: ■, □ – t_{EG}=235 °C (L_{exh}=8.0 m); ◆, ◊ – t_{EG}=355 °C (L_{exh}=5.0 m); ▲, Δ – t_{EG}=480 °C (L_{exh}=1.5 m); ●, ○ – t_{EG}=605 °C (L_{exh}=0.0 m); for *a, c*: ■, ◆, ▲, ● – without DPF; □, ◊, Δ, ○ – with DPF; for *b, d*: ■, ◆, ▲, ●, ∗, × – $K_{CE}(G_{PM})$; □, ◊, Δ, ○, ∗, × – $K_{CE}(N_D)$; □, ◊, Δ, ○, ∗, × – $K_{CE}(C_{CH})$; ∗ – L_{exh}; for *c, d*: ■, □, □ – n_{cs}=900 min^{-1}; ◆, ◊, ◊ – n_{cs}= 1000 min^{-1}; ▲, Δ, Δ – n_{cs}=1200 min^{-1}; ●, ○, ○ – n_{cs}= 1400 min^{-1}; ∗, ∗, ∗ – n_{cs}=1600 min^{-1}; ×, ×, × – n_{cs}=1800 min^{-1}

6. Discussion of results of research into a lay-out coefficient

Fig. 1, *a* shows that dependence N_D on L_{exh} is insignificantly small, which is caused by the measurement of smoke density of EG and coagulation of PM. Such dependence for N_{D_DPF} is of essential character and both quantitatively and qualitatively changes the form with maximum for the form with minimum, and the extremum is shifted from value n_{cs} 1200 to 1400 min^{-1}. This is due to the peculiarities of operational process of the diesel PICE with DPF.

Fig. 1, *b* shows that dependence C_{CH_ICE} on L_{exh} bears significant character and is approaching a horizontal straight line; it is conditioned by the process of condensation C_nH_m on PM. Dependence C_{CH_DPF} on L_{exh} almost repeats the one given above, which means low efficiency of cleaning of EG flow from gaseous C_nH_m with the help of the examined DPF.

Fig. 2, *a* shows that dependence G_{PM} on L_{exh} bears the character, similar to dependence N_D on L_{exh}, due to the peculiarities of formula of recalculation of magnitudes N_D and C_{CH} in G_{PM}, described in [17, 46].

The same applies to dependences $K_{CE}(N_D)$, $K_{CE}(C_{CH})$ and $K_{CE}(G_{PM})$ on L_{exh} in Fig. 2, *b*, which is the total effect of the above.

On the whole, Fig. 1, *c, d* and Fig. 2, *c* show that dependences of magnitudes N_D, C_{CH} and G_{PM} on magnitude t_{DPFint} are linear in nature, and such dependence for magnitude $K_{CE}(G_{PM})$ is not linear in character, which differs little from the linear (Fig. 2, *d*).

The two latter dependences may be described by the following formulas.

$$G_{PM\_ICE} = -3{,}304\cdot 10^{-6}\cdot t_{DPFint} + 2{,}038\cdot 10^{-2}\ \text{kg/h}; \quad (5)$$

$$G_{PM\_DPF} = 1{,}978\cdot 10^{-5}\cdot t_{DPFint} + 2{,}235\cdot 10^{-3}\ \text{kg/h}; \quad (6)$$

$$K_{CE}(G_{PM}) = -1{,}683\cdot 10^{-4}\cdot t^2_{DPFint} + 3{,}266\cdot 10^{-2}\cdot t_{DPFint} + 73{,}2\ \%. \quad (7)$$

Influence of magnitudes $t_{DPFint\,max}$ and n_{cs} on magnitude k_L is illustrated in Fig. 3.

It shows that such influence in both cases is non-linear in nature and may be described by the following formula.

$$k_L = -5{,}579\cdot 10^{-6}\cdot t^2_{DPFint\,max} + 1{,}167\cdot 10^{-3}\cdot t_{DPFint\,max} + 2{,}3; R^2 = 0{,}99848. \quad (8)$$

It should be noted that for magnitude $K_{CE}(G_{PM})$, coefficient k_L is, in fact, similar to the complex of coefficients of the mathematical model of hydraulic resistance of DPF: of temperature coefficient k_t and of lay-out coefficient k_L. The fundamental difference between them in this case cannot be detected by the available experimental data. This is due to the lack of data on the physical simulation of the process of cleaning of EG flow from PM with the help of developed FE [45].

Lay-out coefficient for present mathematical model k_L by definition (which is the physical essence) is equal to ratio of values of $K_{CE}(G_{PM})$ at different fixed values $L_{exh}\neq 0$ (or $t_{DPFint\,max}\neq$ $\neq t_{DPFint\,max}(M_{Tmax})$, that is, by partial velocity characteristic) to values $K_{CE}(G_{PM})$ at L_{exh}=0 (or $t_{DPFint\,max}=t_{DPFint\,max}(M_{Tmax})$, that is, at EVC), at constant values of n_{cs}

The mathematical model of operational efficiency of DPF itself (formula (1)) describes results of experimental research. This is executed by taking EVC as a basis, when placing DPF directly behind the exhaust collector along the exhaust tract of the diesel engine at L_{exh}=0 (basic EVC – formulas (2) and (3)). The impact of global change in maximum temperature of EG flow at the inlet to the housing of DPF $t_{DPFint\,max}$, caused by a change in the place of location along exhaust tract at $L_{exh}\neq0$ (formula (4)) and local changes in temperature t_{DPFint} at EVC itself, is taken into account by multiplying values $K_{CE}(G_{PM})$ at basic EVC n_{cs}=const on lay-out coefficient k_L (formula (8)).

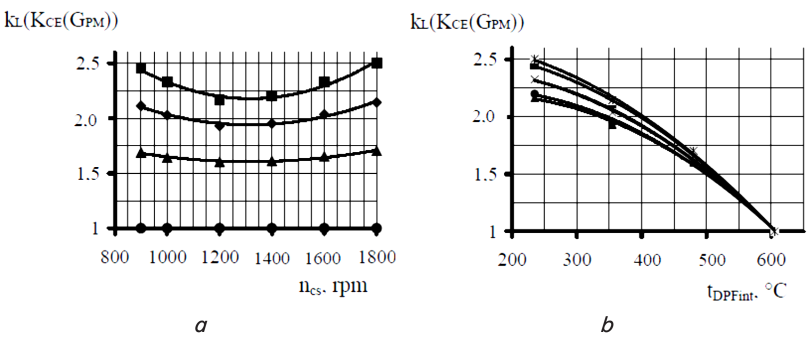

Fig. 3. Dependence of lay-out coefficient k_L on magnitudes n_{cs} (*a*) and $t_{DPFint\,max}$ (*b*): for *a*: ■ – L_{exh}=8 m; ◆ – L_{exh}=5 m; ▲ – L_{exh}=1.5 m; ● – L_{exh}=0.0 m; for *b*: ■ – n_{cs}=1400 min^{-1}; ◆ – n_{cs}=1200 min^{-1}; ▲ – n_{cs}=1000 min^{-1}; ● – n_{cs}=900 min^{-1}; ✱ – n_{cs}=1800 min^{-1}; × – n_{cs}=1600 min^{-1}; *a* – dependence of lay-out coefficient k_L on magnitudes n_{cs}; *b* – dependence of lay-out coefficient k_L on magnitudes $t_{DPFint\,max}$

7. Conclusions

1. It was established that the rational location of DPF along the length of the exhaust tract of the diesel engine is around the value L_{exh}=5.0 m. In this case, dependence for N_{D_DPF} on L_{exh} is essential in nature, because quantitatively and qualitatively, it changes the form with maximum to the form with minimum, and extremum is shifted from value of n_{cs} of 1200 to 1400 min^{-1}. This is due to peculiarities of operational process of the diesel engine PICE and DPF.

2. We established an influence of the global change in maximum temperature of EG flow at the inlet to the housing of DPF $t_{DPFint\,max}$ and local change in temperature t_{DPFint} by EVC. In this case, in the course of research, we considered by multiplying the values of $K_{CE}(G_{PM})$ by the basic EVC at n_{cs}=const on the value of a lay-out coefficient.

3. The mathematical model of operational efficiency of the PM filter for diesel plants was improved by considering a lay-out coefficient. This allows us subsequently to predict operational characteristics of DPF of any structure with regard to the place of its location in the exhaust tract of the diesel engine along the flow.

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ABSTRACT AND REFERENCES

ECOLOGY

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RESEARCH INTO PROCESSES OF WASTEWATER TREATMENT AT PLANTS OF MEAT PROCESSING INDUSTRY BY FLOTATION AND COAGULATION (p. 4-9)

Lyudmyla Savchuk
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-5396-4546

Zenoviy Znak
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-3871-4063

Oksana Kurylets
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-5691-9222

Roman Mnykh
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0003-3248-919X

Roman Olenych
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-5990-4958

The aim of present research was to select the rational method of purification of highly concentrated wastewater of meat processing enterprises. For this purpose, the optimal parameters of flotation and reagent treatment were determined. The study was conducted with two types of wastewaters. The first was formed within a week during washing meat and the equipment. Another, more concentrated and highly alkaline, was formed once a week during washing meat-smoking facilities.

Less polluted wastewater should be cleaned by flotation, followed by the reagent deposition. Flotation within 1.5...2 hours eliminates almost half of the chemical consumption of oxygen. By the reagent method, using hydrated calcium oxide, previously activated by ultrasound, and the coagulant sulfate $FeSO_4$, we achieved a decrease in the CCO practically to standard indicators.

For the purification of more concentrated wastewater with high alkalinity, only reagent treatment is required, because of very intense foaming and carrying out the liquid phase (50...70 %) during flotation. Calcium hydroxide, activated by acoustic oscillations of ultrasonic range, should be used as reagents and iron (II) sulfate should be used as a coagulant.

Based on the performed studies, the technology of wastewater treatment at meat processing enterprises with incomplete production cycle was proposed. It covers the following main stages: wastewater neutralizing, preliminary rough treatment on the bulk filter, stage-by-stage reagent treatment, filtering, and decontamination.

Keywords: highly concentrated wastewater, mechanical treatment, floatation, coagulants, cavitation, biological treatment.

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USING THE ASSESSMENT METHOD OF ENVIRONMENTAL RISK OF A PROJECT IN STRATEGIC TERRITORIAL PLANNING (p. 11-17)

Tatyana Boyko
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-9710-8055

Iryna Dzhygyrey
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-8360-447X

Alla Abramova
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine
ORCID: http://orcid.org/0000-0003-3475-8584

Considering the growing need for using strategic approaches to evaluation of ecological safety on the stage of project designing, the methods of assessment of impacts on the environment (AIE)

need radical revision. Such changes are necessary to be directed to supplementing existing methods with the standards and regulations of development of territorial and strategic AIE. Therefore, the studies in the field of strategic environmental analysis (SEA), aimed at establishing relationships between SEA and AIE were conducted. It was found that it is a challenge that SEA bears a descriptive character, and at present, the intense work on drafting the laws on SEA in Ukraine is in process.

The tool of supporting strategic environmental assessment of projects of development of territorial formations and urbo-ecosystems of different scales in conjunction with the AIE was proposed. This procedure is based on the application of techniques based on the use of indices and environmental risks, as well as the project approach. The applied approach will allow us to establish a relationship between a project, ecosystem and the territory.

Keywords: strategic environmental assessment, assessment of impacts on environment, environmental risk.

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DEVELOPMENT OF THE UNIFIED TECHNIQUE FOR THE MONITORING OF OCCUPATIONAL HAZARDS AT KRYVBAS MINING ENTERPRISES (UKRAINE) (p. 18-27)

Darya Zaikina
Kryvyi Rih National University, Kryvyi Rih, Ukraine
ORCID: http://orcid.org/0000-0002-9485-2524

The basic indexes of efficiency of the HSE management system were estimated. The algorithm is the basis for mathematical modeling of a control occupational health and safety management system. The developed algorithm, in contrast to the existing ones, involves a series of steps to determine the effectiveness of the system of labor protection management and identification of the factors of injury at an enterprise. The essence of the method lies in the fact that the resulting method makes it possible to determine the level of the OH and the effectiveness of the HSE management system.

We have formed a mathematical optimization model to increase the security of the working environment, taking into account the nonlinearity of the dependencies between the effectiveness of measures, which normalize the factors of the work environment, and their cost.

The analysis of seniority and age groups was conducted, as well as dust, noise, vibration, and temperature gradients in the underground conditions. The analytical relations between the coefficients of the state of occupational health and safety and risk levels were established, which provides an opportunity to determine the effectiveness of the occupational health and safety management system in the future. It has been shown that the social effect when using the proposed method is 11 %.

The developed unified technique differs from the existing ones by the next proposed additional steps:

– the of hazardous and harmful production factors were proposed;

– a generalized ratio of the condition of occupational health and safety was proposed.

All of these components, in turn, will allow improving the assessment of working conditions at an enterprise and determining whether the HSE management system is functioning properly.

The developed method is useful in the development of mathematical and software modeling in occupational health and safety management. The results of the study can be used by implementing the recommendations proposed for the mining industry and other industries.

Keywords: production factors, industrial injuries, occupational diseases, occupational risk management.

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MODELING OF DESTRUCTION PROCESSES DURING RECYCLING OF RUBBER-TECHNICAL WASTE USING THE TECHNOLOGY OF MULTI-CONTOUR CIRCULATION PYROLYSIS (p. 28-35)

Serhiy Ryzhkov
Admiral Makarov National University of Shipbuilding, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0001-9560-2765

Lyudmila Markina
Admiral Makarov National University of Shipbuilding, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0003-3632-1685

Marharyta Kryva
Admiral Makarov National University of Shipbuilding, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0001-9492-3268

We performed modeling of the processes of destruction during recycling of rubber-technical waste in line with the technology of multi-contour circulation pyrolysis. The purpose of the present

study is to develop a mathematical model for the process of thermal recycling of rubber-technical waste in line with the technology of multi-contour circulation pyrolysis.

We developed a scheme of destructive transformations of the starting mass of waste, taking into account kinetics of the process of thermal decomposition of rubber and material flows of the formed phases in the equipment.

We constructed a mathematical model of kinetic regularities and of the rate of destruction of rubber-technical waste depending on the concentration of original and resulting components. Kinetic parameters and the reaction rate are used for subsequent modeling of the recycling process and for determining the end products of waste decomposition.

Result of present research and theoretical modeling is the calculations of the concentration of gaseous and condensed substances – products of thermal decomposition of the original mass of waste, formed in the range of 450–600 °C.

Application of the given model is necessary when optimizing temperature modes of the equipment. The use of the model might be promising while creating industrial plants with a set productivity. It could also provide the possibility of recycling of different types of organic waste and their mixtures in line with the technology of multi-contour circulation pyrolysis.

Modeling that was performed justifies the reasons and foundations to control the process of repeated condensation and recirculation of heavy condensed flows of vapor and gas mixture. Therefore, if one knows the original composition of vapor and gas mixture from the reactor, it is possible to optimize cooling temperatures in contours to obtain the end product of required quality.

Keywords: thermal destruction, recycling of rubber-technical wastes, material balance, concentration of vapor and gas mixture.

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STUDY OF USING THE ANIONITES IN LOW-WASTE PROCESSES OF WATER PURIFICATION FROM PHOSPHATES (p. 36-41)

Nikolai Gomelya
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine
ORCID: http://orcid.org/0000-0003-1165-7545

Alona Petrychenko
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-0499-1468

Anna Trokhimenko
Admiral Makarov National university of
Shipbilding, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0002-0835-3551

Yana Martyniuk
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-9747-969X

Among the existing methods for removing the phosphates from water, the most effective and cheap is the method of ion exchange. The advantage of this method is the possibility to process regeneration solutions with obtaining the liquid fertilizers or other useful products.

The processes of sorption of phosphates on the weak-base and strong-base anionites are investigated. We examined the dynamics of sorption of phosphates from the model solutions in the distilled and tap water depending on the form of ionite. The influence is established of the competing compounds of sulphates and chlorides in tap water on the effectiveness of removal of phosphate-anions. We explored the processes of regeneration of strong-base anionite in the phosphate and phosphate-sulfate form. The regeneration of anionite in the phosphate form was carried out with the 10 and 15 % solutions of sodium chloride and the 10 % solution of ammonium chloride. In order to regenerate anionite in the sulphate-phosphate form, the solutions of sodium chloride were used at concentration 10 %. The regeneration solutions contained sodium phosphate or ammonium phosphate, sodium phosphate-sulphate, respectively.

We established that the effective sedimentation of phosphates occurs at molar ratio $(NH_4)_3PO_4$ and $MgCl_2$ 1:1, at optimum value pH=9. The optimal dosage of magnesium chloride and the value of pH are determined. This will provide 99.99 % sedimentation of phosphates from the regeneration solutions in the form of insoluble sediment. We proposed a method for removal from the regeneration solutions of the interfering compounds of sulphates in the form of gypsum, which will make it possible to repeatedly use these solutions for the regeneration of anionite. The essence of this method is the addition of chloride calcium to the solution, resulting in gypsum falling out into the sediment. The excess of calcium is removed in the form of calcium carbonate when soda is added.

Keywords: ion exchange, anionite, selectivity, phosphate-ions, sulphate-ions, ammonium chloride, regeneration of ionite.

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ASSESSMENT OF THE POLLUTION DEGREE OF THE DNEPR RIVER AND DEVELOPMENT OF MEASURES FOR ITS DECREASE (p. 41-49)

Aleksandr Kasimov
Ukrainian Research Institute of Metals, Kharkiv, Ukraine
State Enterprise «Ukrainian Scientific and Technical Center of Metallurgical Industry «Energostal», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-2882-6843

Iryna Stalinska
O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv
ORCID: http://orcid.org/0000-0003-2882-6843

Kateryna Sorokina
O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-2882-6843

The basin of the Dnepr river (Ukraine) has more than 350 ponds for industrial waste water and sludge, which, in the absence of environmental protection measures, have a significant negative impact on the environment.

The results of studies to determine the degree of the negative impact of ponds for industrial waste water and sludge on the water basin of the Dnepr river were given. It is revealed that the average annual concentrations of main pollutants exceeded the maximum permissible concentrations. The connection of pollution of the water basin with the flow of filtrates and surface flows from the territory of ponds for industrial waste water and sludges was defined.

The migration path of filtrates with soluble compounds of heavy metals in soil was studied. The obtained data were used to develop the scheme of entry of heavy metal ions from industrial waste water into surface and ground waters, the volume of the pond for industrial waste water and sludge.

The analysis of measures to improve the water quality in the Dnepr river in the area of location of one of the largest metallurgical enterprises in Ukraine – "Zaporizhstal" – was carried out.

It is shown that to reduce the negative impact of waste water and sludges from the main processes of "Zaporizhstal" on the water basin of the Dnepr river, it is expedient to modernize the gas cleaning equipment of the sinter plant and hydrotechnical facilities of recirculating water supply cycle for wet gas cleaning of blast furnaces.

The necessity of performing a set of research works for studying the properties of accumulated deposits of scale in the areas of its discharge into the sludge pond with the purpose of its further utilization is proven.

Keywords: water basin protection, waste water treatment, heavy metals, sludge utilization.

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ESTABLISHMENT OF THE MECHANISM AND FIREPROOF EFFICIENCY OF WOOD TREATED WITH AN IMPREGNATING SOLUTION AND COATINGS (p. 50-55)

Yuriy Tsapko
National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine
V. D. Glukhovsky Scientific Research Institute for Binders and Materials
Kyiv National University of Construction and Architecture, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-9118-6872

Aleksii Tsapko
National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0003-2298-068X

Description of the behavior of fireproof means and coatings, including those swelling, in the moment of the formation of a thermal insulating structure is a special and complex task. In general, it covers both stages of the process of thermal protection: both heat transfer and subsequent swelling of the coating, which is formed during fire protection. In necessitates studying conditions for the formation of barrier to thermal conductivity and the establishment of a mechanism of fire protection from layer to a layer of coke. Given this, we examined the process of fire protection with work of an impregnating solution and at swelling of a fireproof coating. Data that we obtained revealed that the formation of volatile products under the effect of coating at high temperature occurs with the formation of noncombustible substances. We established experimentally that under the action of heat flow on the fireproof samples, intense release of inert gases occurs, as well as a reduction in the combustible, which leads to the effectiveness of fire protection in reverse order. It was found in the course of conducted tests that the intensity of the formation of noncombustible gases shifts toward elevated temperature with the formation of coked cellular material. Results of determining a swelling capacity of coating for the intumescent system demonstrated that under the influence of high-temperature flow, material combustion and weight loss of the coating is reduced by more than twice due to the formation of high-temperature compounds; in this case, the time to reach a limit temperature grows as well. A coating under the influence of high temperature forms a significant coefficient of swelling, contributes to the formation of a thermal insulating layer of coke, which prevents wood from burning, as well as the passage of high temperature to the material. In general, the efficiency of wood fire protection revealed that the goods belong to the materials that are difficult to combust, which spread the flame over surface slowly and with low smoke-generating capacity.

Keywords: protection means, fire resistance, volatile products, loss of weight, surface treatment, efficiency of protection.

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RESEARCH OF THE EFFECTS OF VARIOUS GASES ON CAVITATION-BASED REMOVAL OF ORGANIC POLLUTANTS FROM DISTILLERY WASTEWATER (p. 56-62)

Taras Falyk
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0003-3556-8627

Liliya Shevchuk
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0001-6274-0256

Irena Nykulyshyn
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-3394-0395

Stepan Melnyk
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-0629-9723

The tendency to preserve water resources and rationally use natural waters promotes finding new methods and improving the existing methods of wastewater treatment. Using the phenomenon of cavitation to intensify the treatment processes we have proposed saturating the cavitation zone with various gases such as nitrogen, oxygen, and the mixture of nitrogen and oxygen in the ratio of 1:1.

The study focuses on the impact of the nature of bubbled gases, both with ultrasonic treatment and without it, on the changes in the chemical oxygen demand (COD). The calculated effective rate constants for the destruction of organic compounds in distillery wastewater have proved that the highest value of 1.2 10^{-4} sec^{-1} is achieved through bubbling nitrogen in the cavitation zone. The use of nitrogen alone allows reaching the effective rate constant value of 0.7 10^{-4} sec^{-1} vs. 0.2 10^{-4} sec^{-1} in case when ultrasound is used alone. The highest degree of water treatment in cavitation conditions (63 %) is achieved in the presence of nitrogen, and the lowest (38.8 %) – of the mixture of nitrogen and oxygen in the ratio of 1:1.

The differences in the effects of various bubbled gases on distillery wastewater are revealed depending on the electronic excitation energy of water molecules and the formation rates of radicals H and HO that are strong oxidants of the process.

It is determined that the destruction of organic impurities in distillery wastewater can be described with the use of the first-order kinetic equation. The research has confirmed the synergistic effect of the joint action of cavitation and nitrogen in the distillery wastewater treatment. The study has determined the relative series of the effects of the nature of certain gases on the cavitation treatment of distillery wastewater and proved that the most effective nitrogen dioxide can increase the degree of the wastewater treatment by 46 % compared to the effect of ultrasound alone. Given the growing problem of inadequate industrial and domestic wastewater treatment, the development of innovative technologies is particularly important. The use of the proposed cavitation technology for the treatment of wastewater from distillery plants can reduce or even completely eliminate the negative impact of contaminants on the environment.

Keywords: cavitation treatment, wastewater, gas nature, chemical oxygen demand (COD), the degree of destruction of organic compounds.

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ASSESSMENT OF IMPROVEMENT OF ECOLOGICAL SAFETY OF POWER PLANTS BY ARRANGING THE SYSTEM OF POLLUTANT NEUTRALIZATION (p. 63-73)

Sergij Vambol
National University of Civil Protection of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-8376-9020

Viola Vambol
National University of Civil Protection of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-8229-3956

Olexandr Kondratenko
National University of Civil Protection of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-9687-0454

Yana Suchikova
Berdyansk State Pedagogical University, Berdyansk, Ukraine
ORCID: http://orcid.org/0000-0003-4537-966X

Olga Hurenko
Berdyansk State Pedagogical University, Berdyansk, Ukraine
ORCID: http://orcid.org/0000-0003-3562-7818

The purpose of the study is to determine the physical essence of numeric values of a layout factor of the particulate matter filter in the exhaust system of the diesel plant for the mathematical model of its operational efficiency. Physical essence of this factor is that it makes it possible to take into account the influence of temperature of exhaust gases of the diesel engine at the inlet to the housing of the filter, which affects the course of processes of condensation of products of incomplete combustion of fuel on particulate matters and coagulation of particulate matters themselves in the flow of exhaust gases and, as a consequence, dimensions of particulate matters. The temperature of exhaust gases in such statement varies depending on location of the filter along the exhaust tract of the diesel engine (due to processes of extension of exhaust gases flow and heat exchange with the environment), as well as by the modes of external velocity characteristic of the diesel engine. Such influence was explored experimentally at the engine test bench with the autotractor diesel engine 2Ch10.5/12. The methods of obtaining the source data for the construction of the coefficient were described. Ecological parameters of exhaust gases of the diesel engine for different locations of the filter, received by direct and indirect measurements, were approximated by the linear regression method and formed the basis for the definition of numeric values and the formula to determine layout factor of the exhaust system. We established and mathematically described quantitative and qualitative relationships between indicators of operational efficiency of the particulate matter filter and the temperature of exhaust gases of the diesel engine 2Ч10.5/12 at the inlet to the filter.

Keywords: technogenic ecological safety, diesel engine, particulate matter filter, efficiency of cleaning, nanomaterials.

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INVESTIGATION OF SURFACE WATER QUALITY IN MAGNITOGORSK INDUSTRIAL AREA FOR THE ENVIRONMENTAL ESTIMATION OF TECHNOGENIC WATERCOURSE STATE (p. 74-81)

Yuliya Somova
Nosov Magnitogorsk State
Technical University, Magnitogorsk, Russia
ORCID: http://orcid.org/0000-0003-0856-4612

Elena Degodia
Nosov Magnitogorsk State
Technical University, Magnitogorsk, Russia
ORCID: http://orcid.org/0000-0002-4220-7371

Yelena Kasatkina
Nosov Magnitogorsk State
Technical University, Magnitogorsk, Russia
ORCID: http://orcid.org/0000-0003-4563-8588

Aleksey Periatinsky
Nosov Magnitogorsk State
Technical University, Magnitogorsk, Russia
ORCID: http://orcid.org/0000-0003-0393-8128

Aleksandr Kudriashov
Nosov Magnitogorsk State
Technical University, Magnitogorsk, Russia
ORCID: http://orcid.org/0000-0002-3614-8838

It was established that the average chemical indicators of water (ml/l) were as follows: 760 for mineralization, 73 for chlorides, 54 for sulfates, and water pH was not more than 8. Taking into account the indicators of the groundwater quality in this area, it can be said that the general pollution resistance of natural waters is low.

The main indicators characterizing quality and use of water from this source were considered. Coming of industrial effluents from ore mining and processing facilities and metallurgical production of the integrated metallurgical plant has led to a significant change in the physicochemical parameters of the aquatic environment, which limits this water use.

In general, the irrigation indices calculated in this work comply with the norms. However within the city limits (pond-cooler), water is characterized by an elevated pH (>8), which is already a limitation for the use of pond water for irrigation. It should be noted that water containing CO_2>1.5 mg-equ./l and pH>8.4 has limitations for irrigation of crops.

The obtained data are important for the use of water for the needs of population and the city-forming Magnitogorsk Metallurgical Works PJSC.

Keywords: geological structure, industrial effluents, hydrotechnical test; pH value, heavy metals, mineralization, irrigation indicators.

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