# MONITORING OF INDUSTRIAL PREMISES WITH INSTALLED ELECTRICAL DISTRIBUTION DEVICES

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**Abstract.** The impact of hazardous substances on working conditions in the energy sector, where in addition to physical microclimate indicators there is thermal radiation, gas emissions, vapors, metal dust, and radioactive materials, leads to risks to air quality in industrial premises. A decrease in air quality can result in the deterioration of workers health and the development of chronic diseases. This work demonstrates the need for a comprehensive approach to monitoring air quality in the working area of industrial premises with installed electrical distribution devices. This approach combines the determination of microclimate sanitary standards with simultaneous control of air pollutants and thermal imaging analysis of equipment condition. Such approach helps prevent accidents by timely detection of deviations from normal operating conditions and ensures compliance with regulatory requirements for occupational safety. As part of the research, the proposed approach was tested in the working area of an industrial premises with installed electrical distribution devices, which made it possible to determine air pollution indicators, microclimate parameters, and equipment temperature under normal operating conditions.

**Key words:** Monitoring, Thermographic Analysis, Microclimate, Sanitary Standards, Air Quality, Energy Sector.

## 1. Introduction

Technological processes occurring in energy facilities lead to the release of harmful substances such as nitrogen oxides, sulfur oxides, dust, volatile organic compounds, and others. These substances primarily have a negative impact on the workers' health and the environment. The importance of maintaining good air quality in the working areas of production facilities and heat comfort for the employees' health is a pressing issue being studied by researchers in many countries around the world [1-12].

The World Health Organization (WHO) identifies the following sources of indoor air pollution: fine particulate matter in the air, formaldehyde, nitrogen oxides, ozone, carbon monoxide, and carbon dioxide [1]. Such a significant exceedance of carbon monoxide (CO) concentration levels in the working area of a production facility is extremely dangerous for the stuff health, as carbon monoxide has the ability to bind with hemoglobin in the blood, leading to a decrease in the oxygen supply to tissues. This, in turn, can cause serious consequences for the cardiovascular and nervous systems, and potentially be fatal. An excess of carbon dioxide ($CO_2$) can disrupt cognitive functions, as well as lead to neurological and cardiovascular problems. Nitrogen dioxide ($NO_2$) can cause long-term irritation of the respiratory tract, exacerbate asthma, and other chronic lung diseases, and intensify allergic reactions. Formaldehyde is classified as a carcinogen, and chronic exposure to it can increase the risk of developing oncological lesions in the nasopharynx and lymphatic system.

Studies [2-5] confirm that even slight exceedances of permissible pollution levels threaten overall well-being – resulting in chronic fatigue and decreased immunity, exacerbation of chronic illnesses, onset of allergic reactions, and nervous disorders. Prolonged exposure to indoor environments with polluted air leads to respiratory, cardiovascular, and oncological diseases.

Currently, fine particulate matter is considered the most common air pollutant worldwide. It is a microscopic mixture of solid and liquid particles consisting of a vast variety of chemical compounds and materials, including highly toxic substances. They are classified by size: those with a diameter of less than 10 micrometers (particulate matter – PM10) and those with a diameter of less than 2.5 micrometers (PM2.5). Systematic monitoring of fine particulate concentrations is currently being conducted in industrial settings as well as in emissions from enterprises and transport in the EU and the USA, and their negative impact on human health, ecosystems, infrastructure, and the planet's climate is being assessed at the national level [5,6].

In the civilized world, the protection of workers' lives and health is a priority in any enterprise, especially those with a heightened level of danger. One of the first steps is to provide workers with personal protective equipment for respiratory protection and to improve the ventilation system. This may include increasing air recirculation within the premises and installing modern filters such as HEPA (High Efficiency Particulate Air), which are capable of capturing fine particulate matter and gases at the molecular level. At the same time, a detailed diagnosis of the condition of the equipment used in production processes is necessary. This involves not only checking the technical condition of the equipment but also assessing its compliance with existing occupational health and safety protocols.

General trends in researching the issue of air quality in production facilities can be summarized into two main directions: determining the concentration of harmful substances and improving ventilation and air conditioning systems. For example, in the materials [7-9], the authors evaluate the negative impact of emissions and the diffusion of typical pollutants, such as high-temperature particles, droplets, and harmful gases, emphasizing the sources of pollution and their control. They also propose methods for forecasting air quality in production facilities, including enhanced zonal control methods and new local ventilation technologies.

In articles [10-12], limit values for major pollutants defined by the WHO and microclimate parameters – temperature and relative humidity – are assessed. Examples of national regulations are provided, and recommendations regarding indoor environmental quality set by the International Society of Indoor Air Quality and Climate (ISIAQ) are analyzed.

The study [10] presents a new approach to energy-optimal control of indoor air quality and proposes models for controlling pollution and energy consumption in ventilation systems. However, it does not systematically consider the additional heat emissions from operating power equipment, which not only serve as a source of variation in microclimate parameters but may also signal potential emergency situations in energy facilities.

## 2. Drawbacks

The specifics of production processes in the energy sector involve high heat generation and increased humidity, necessitating the adaptation of general standards to specific conditions. In Ukraine, the standard DSN 3.3.6.042-99 "Sanitary Standards for the Microclimate of Production Facilities" [13] is currently in effect, which addresses key aspects of ensuring optimal working conditions and establishes permissible microclimate parameters at the workplace. The main parameters regulated by the standard are air temperature, relative humidity, and air velocity. Adhering to the requirements of standard [13] is critically important for reducing the risk of occupational diseases and improving labor productivity.

However, to ensure safe working conditions and protect health, it is necessary to consider not only the physical but also the chemical characteristics of the surrounding environment. DSN 3.3.6.042-99 regulates the microclimate in production facilities, including energy sector facilities, but does not take into account air pollution indicators.

The values of maximum allowable concentrations (MAC) of hazardous substances are regulated by the Order of the Ministry of Health of Ukraine dated 07/09/2024, No. 1192 "On Approval of State Sanitary Standards for the Permissible Content of Chemical and Biological Substances in the Workplace Air " [14]. The list of hazardous chemical substances and compounds contains 1875 items, while the list of biological substances includes about 50 objects. All substances are divided into four classes: extremely hazardous, highly hazardous, moderately hazardous, and low hazardous, with established maximum single and average shift norms for MAC, as well as an assessment of the types and risks of harmful effects on the worker's body. The document does not contain information regarding fine particulate matter PM2.5 and PM10; instead, it includes dust of various physicochemical compositions.

To ensure safe working conditions for staffs in harmful environments at enterprises of all forms of ownership in Ukraine, the Ministry of Emergency Situations establishes requirements for protection against the effects of chemical substances, including: the implementation of forced ventilation systems, the use of personal protective equipment, regular monitoring of air quality, and periodic medical examinations [15].

## 3. Goal of the study

Thus, the analysis of global experience and domestic regulatory frameworks demonstrates the necessity of a conscious approach to maintaining microclimate conditions in production and the systematic analysis the chemical composition of air in the workplace for the critical concentrations of hazardous substances presence. This is primarily related to ensuring occupational safety, protecting workers' health, and considering the overall environmental impact. However, it should be noted that one of the sources of increased concentrations of harmful chemical substances, particularly in energy enterprises, may be a violation of the operating conditions of energy equipment, which in turn requires additional measures for assessing its condition and functionality. Therefore, a comprehensive approach to monitoring production premises with installed electrical distribution devices is advisable.

## 4. Research method and methodology

To form a comprehensive approach to this research, the following tasks were identified:

- prevention of accidents through timely detection of deviations from normal operating modes;
- ensuring compliance with the requirements of regulatory documents regarding occupational safety and environmental protection.

Based on the tasks set, the comprehensive approach to monitoring production premises in energy facilities (Fig. 1) should include the determination of sanitary standards for microclimate along with simultaneous air quality control and thermographic analysis [16,17,18].

To test the proposed comprehensive approach, experimental studies were conducted in the working area of an industrial premises with installed electrical distribution devices, with a total area of 14.4 m², photos of which are shown in Fig. 2.

- testo 440 device with a thermo-anemometer and the following technical specifications: air speed 0…30 m/s (accuracy ±0.03 m/s ± 4% of measured value), temperature 20…+70 °C (accuracy ±0.5 °C) ;
- testo 605i thermo-hygrometer with the following technical specifications: relative humidity 0 ... 100% (accuracy ±2% RH (35 ... 65% RH))
- UNI-T UTi220 thermal imager with the following technical specifications: temperature measurement range from -10°C to 400°C, resolution 200×150 pixels, accuracy: ±2°C or ±2% of the measured value;
- prototype of the measuring module based on the ESP8266EX microcontroller, using low-cost sensors for pollutants, the characteristics of which are given in Table 1.

In the working zone, the following parameters were determined:

- temperature was determined in accordance with clause 6.4.5 of EN 12599:2012 [19], and was 18.5°C, which corresponds to the range of 17 – 19 °C recommended by DSN 3.3.6.042-99 for work of medium difficulty [13];
- the air velocity was determined in accordance with clause 6.4.4 of standard EN 12599:2012 [19], was 0.2 m/s, and meets the established norms [13].
- relative air humidity in the premises during the study, determined in accordance with clause 6.4.6 of standard EN 12599:2012 [19], was 43%, which is close to the lower limit acceptable by standard DSN 3.3.6.042-99.

Low relative humidity prevents damage to the installed equipment; this indicator is acceptable for non-permanent workplaces of employees in the working zone (the personnel spend less than 50% of their working time or less than 2 hours continuously) [13].

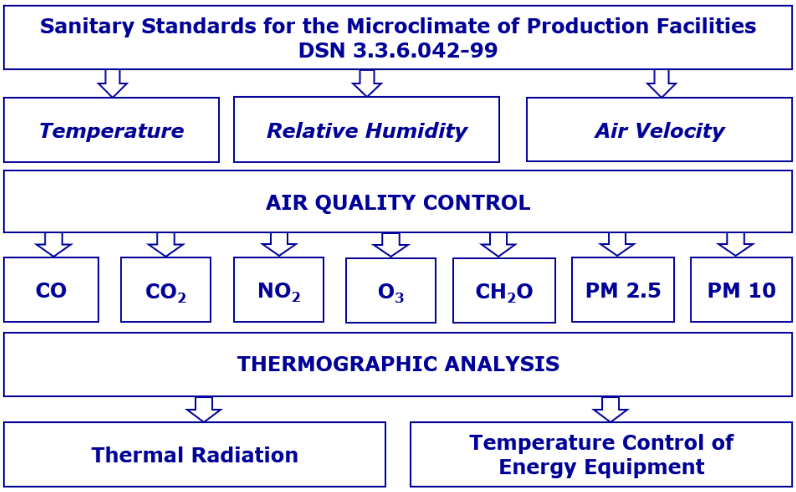


*Fig. 1. Comprehensive approach to monitoring production locations in energy facilities*

**Table 1.** Technical characteristics of pollutant sensors

| Pollutants | Sensor | Units | Measuring range | Accuracy |
|---|---|---|---|---|
| Carbon monoxide CO | MICS-6814 | ppm | 1…1000 | ±10% |
| Carbon dioxide $CO_2$ | MH-Z19 | ppm | 0…5000 | ±10% |
| Nitrogen dioxide $NO_2$ | MICS-6814 | ppm | 0.01…10 | ±10% |
| Fine particulate matter PM 2.5 | PMS 5003 | $\mu g/m^3$ | 0-1000 | ±10 $\mu g/m^3$ (0-100 $\mu g/m^3$); ±10% (100-1000 $\mu g/m^3$) |
| Coarse particulate matter PM 10 | PMS 5003 | $\mu g/m^3$ | 0-1000 | ±10 $\mu g/m^3$ (0-100 µg/m3); ±10% (100-1000 µg/m3) |
| Ozone $O_3$ | ZE25-O3 | ppb | 0…10000 | ±15% |
| Formaldehyde | ZE08-CH2O | ppb | 0…5000 | ±15% |

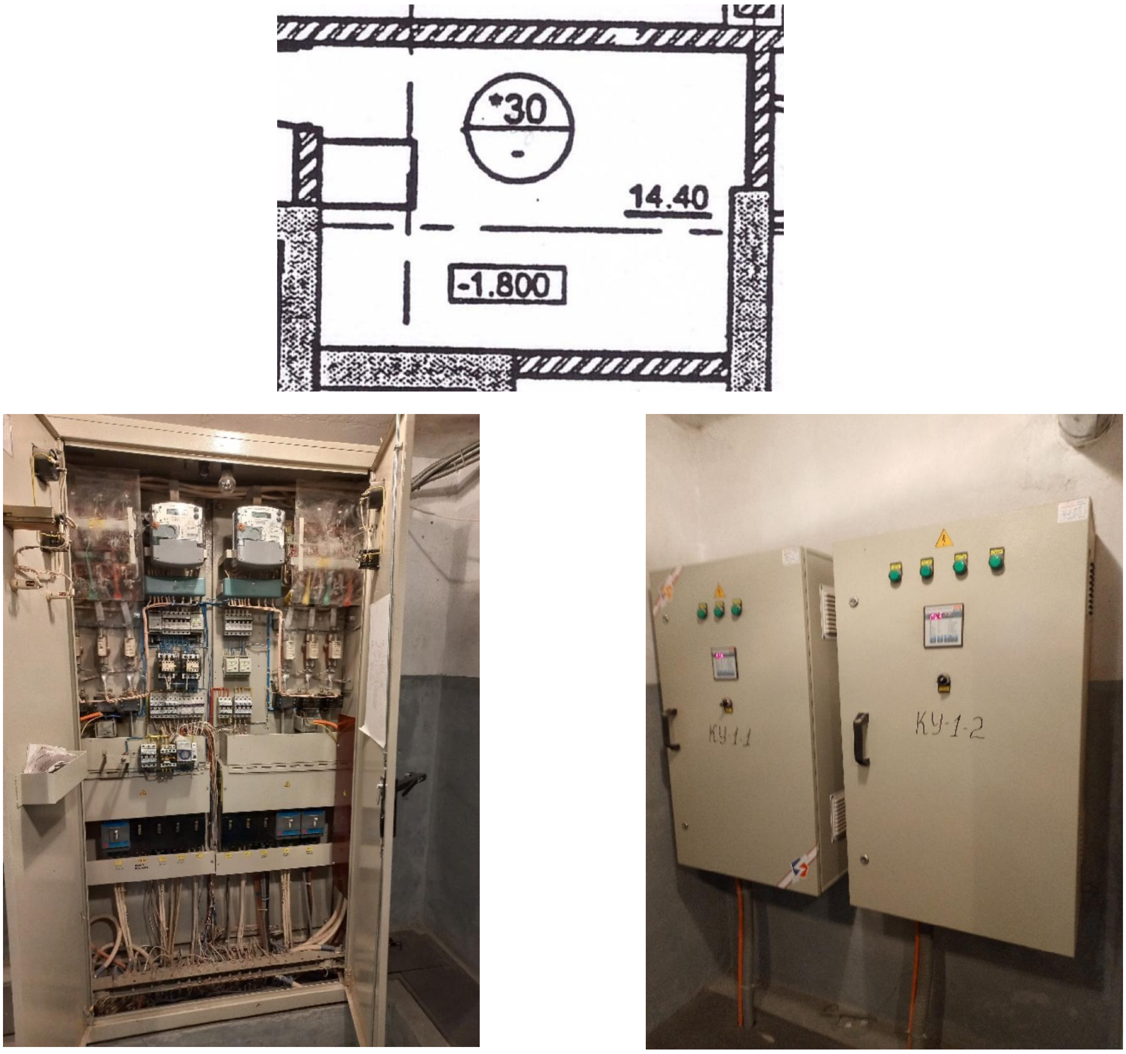


*Fig. 2. General layout and equipment installed in the working area of the industrial premises*

## 5. Results and discussion

In Fig.3 the results of thermographic analysis the working area and installed electrical equipment are presented.

According to the thermographic analysis data, the maximum temperature of the equipment during operation did not exceed the established standard and was 28.7°C. This indicates the absence of damage and overloads on the equipment. Furthermore, no sources of significant thermal radiation were identified that would require additional individual protective equipment.

The results of the air quality monitoring are presented in Table 2.

**Table 2.** The air quality monitoring results

| **Pollutants** | **Concentration** | **Maximum allowable concentration mg/m³ [14]** |
|---|---|---|
| Carbon monoxide CO | 0,591 ppm (0,68 mg/m$^3$) | 20 |
| Carbon dioxide $CO_2$ | 1202 ppm (2163 mg/m$^3$) | 8000 |
| Nitrogen dioxide $NO_2$ | 0,015 ppm (0,03 mg/m$^3$) | 2 |
| Fine particulate matter PM 2.5 | 7,5 µg/m$^3$ | * |
| Coarse particulate matter PM 10 | 14,4 µg/m$^3$ | * |
| Ozone $O_3$ | 42 ppb (0,08 mg/m$^3$) | 0,1 |
| Formaldehyde | 14 ppb (0,02 mg/m$^3$) | 5 |

* Fine particulates PM 2.5 and PM 10 are regulated based on their physicochemical composition as moderately and slightly hazardous substances (classes 3 and 4) [14].

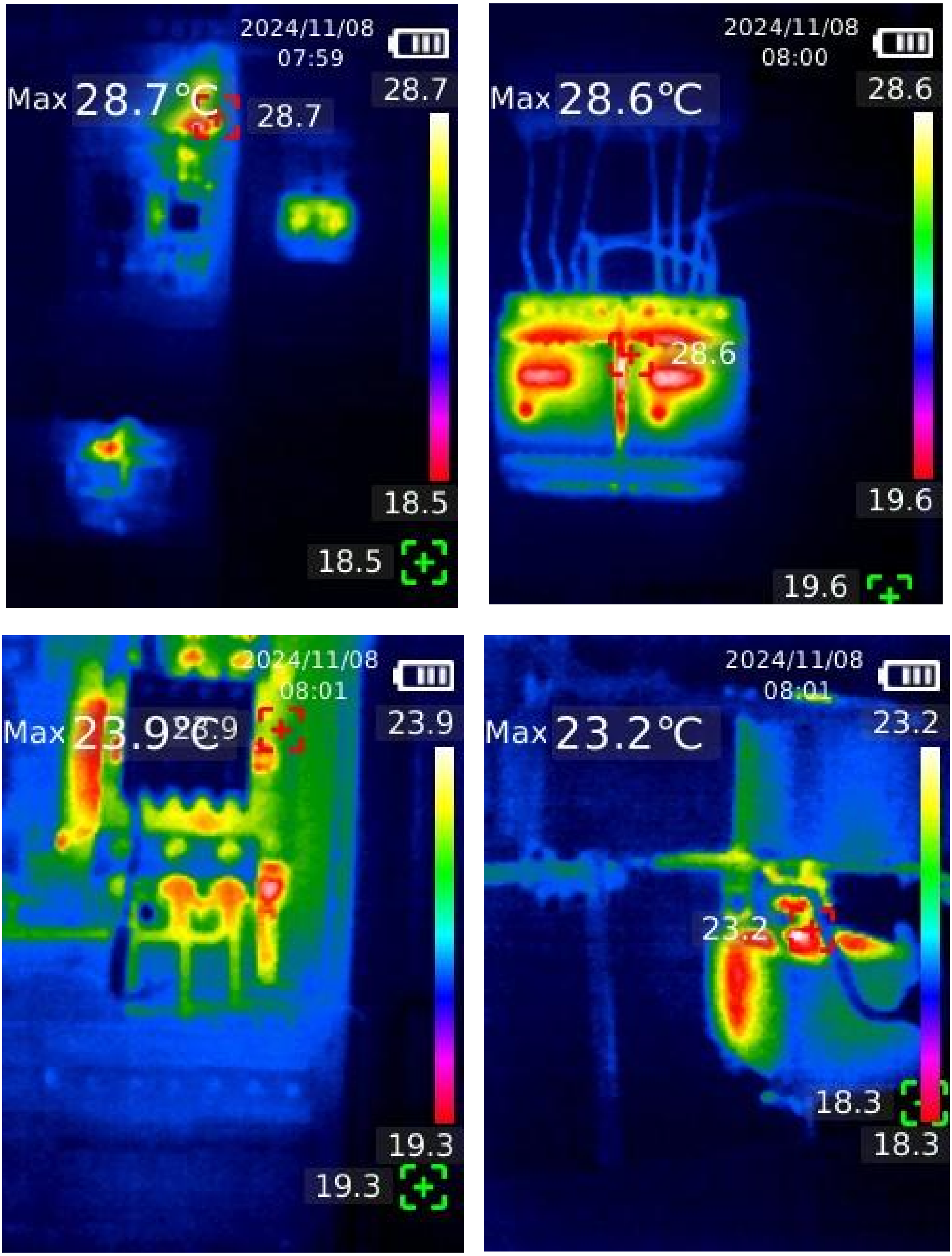


*Fig. 3. The thermographic analysis results*

The obtained results of air quality monitoring indicate compliance with the regulated values of maximum allowable concentrations of chemical substances in the air in the working zone at this facility.

Therefore, a comprehensive study of microclimate parameters, thermographic analysis of the working area, and the established electrical equipment, combined with analysis of the air pollution, is an essential measure for monitoring and preventing emergency situations. It is recommended to include this in the protocol for monitoring the condition of production premises with installed electrical distribution devices.

## 6. Conclusions

A new comprehensive approach to monitoring production facilities with installed electrical distribution devices has been proposed. This approach includes the determination of sanitary norms for the microclimate while simultaneously monitoring air quality, which is critically important for maintaining healthy working conditions, combined with thermographic analysis for diagnosing and timely detecting technical malfunctions of equipment.

As part of the study, the proposed approach was tested in the working area of an industrial facility with installed electrical distribution devices. This allowed for the determination of air pollution indicators, microclimate parameters, and equipment temperature under normal operating conditions.

This work was carried out as part of the project "Development of methods and means for monitoring the environmental condition of energy facilities based on wireless sensor networks" (0123U100127).

At the next stages of the work, it is planned to determine the air exchange rate in the rooms according to ISO 9869. The measurement module will be improved by adding temperature, relative humidity, and air velocity sensors. The module will be set to monitoring mode, saving information every 10 minutes. Thermal imaging will be conducted in monitoring mode at a frame rate of 9 Hz to develop recommendations for the frequency of tests.

## Conflict of Interest

The authors state that there are no financial or other potential conflicts regarding this work.

## References

[1] WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. 2021. [Online]. Available: https://apps.who.int/iris/handle/10665/345329.

[2] The costs to health and the environment from industrial air pollution in Europe – 2024 update Briefing no. 24/2023 EN. [Online]. Available: https://www.eea.europa.eu/publications/the-cost-to-health-and-the.

[3] Thangavel P, Park D, Lee YC. "Recent Insights into Particulate Matter ($PM_{2.5}$)-Mediated Toxicity in Humans: An Overview", Int J Environ Res Public Health. 2022 Jun 19;19(12):7511. DOI: 10.3390/ijerph19127511.

[4] Zaporozhets A.O. "Correlation Analysis Between the Components of Energy Balance and Pollutant Emissions", Water, Air, and Soil Pollution, 232 (3), art. no. 114? 2021. DOI: 10.1007/s11270-021-05048-9.

[5] Maliarenko O.Ye., Maistrenko N.Yu., Stanytsina V.V. "Forecast of Thermal Energy Consumption Considering Wartime Realities and Post-War Recovery for the Mid-Term Perspectiv", Energotehnologii i Resursosberezenie, 82 (1), p. 5-22, 2025. DOI: 10.33070/etars.1.2025.01.

[6] Deng, Y., Wang, J., Sun, L. "Effects of Ambient $O_3$ on Respiratory Mortality, Especially the Combined Effects of $PM_{2.5}$ and $O_3$", Toxics, 11(11), 892, 2023. DOI: 10.3390/toxics11110892.

[7] Wang, Y., Zhang, T., Cao, Z., Wang, Z. "Indoor Air Quality in Industrial Buildings", In: Zhang, Y., Hopke, P.K., Mandin, C. (eds) Handbook of Indoor Air Quality. Springer, Singapore, 2022. DOI: 10.1007/978-981-16-7680-2_80.

[8] Stanytsina V., Zaporozhets A., Artemchuk V. "Demand Forecasting Mathematical Models for Residential Electricity Consumption Considering Ambient Temperature", In Studies in Systems, Decision and Control, 559, p. 127-145, 2024. DOI: 10.1007/978-3-031-66764-0_6.

[9] Sani Dimitroulopoulou, Marzenna R. Dudzińska, Lars Gunnarsen, Linda Hägerhed, Henna Maula, Raja Singh, Oluyemi Toyinbo, Ulla Haverinen-Shaughnessy. "Indoor air quality guidelines from across the world: An appraisal considering energy saving, health, productivity, and comfort", Environment International, Volume 178, 2023, 108127, ISSN 0160-4120. DOI: 10.1016/j.envint.2023.108127.

[10] Hari S. Ganesh, Kyeongjun Seo, Hagen E. Fritz, Thomas F. Edgar, Atila Novoselac, Michael Baldea. "Indoor air quality and energy management in buildings using combined moving horizon estimation and model predictive control", Journal of Building Engineering, Vol. 33, 2021, 101552, ISSN 2352-7102, DOI: 10.1016/j.jobe.2020.101552.

[11] Zaporozhets, A., Eremenko, V., Redko, O. "Metrological assessment of the indirect method of measuring the concentration of oxygen in the air" *in Proc. of the Int. Conf. on Advanced Optoelectronics and Lasers, 2019, 640-643*. DOI: 10.1109/CAOL46282.2019.9019506.

[12] Zaporozhets, A.O., Sverdlova, A.D., Ivaschenko, T.G., Kovach, V.O., Artemchuk, V.O. "Electronic circuits of measuring modules of air pollution monitoring system based on low-cost sensors". *IOP Conference Series: Earth and Environmental Science*, 1049, 012016, 2022. DOI: 10.1088/1755-1315/1049/1/012016.

[13] DSN 3.3.6.042-99 Sanitarni normy mikroklimatu vyrobnychykh prymishchen [Online]. Available: https://zakon.rada.gov.ua/rada/show/va042282-99#Text.

[14] State medical and sanitary standards for the permissible content of chemical substances in the air of the working area (approved by the order of the Ministry of Health dated 07/09/2024 No. 1192). Ukrainian. [Online]. Available: https://zakon.rada.gov.ua/laws/show/z1107-24#Text

[15] Pro zatverdzhennya Vymoh do robotodavtsiv shchodo zakhystu pratsivnykiv vid shkidlyvoho vplyvu khimichnykh rechovyn. Order of the Ministry of Emergencies of Ukraine dated 22/03/2012 No. 627. Ukrainian. [Online]. Available: https://zakon.rada.gov.ua/laws/show/z0521-12#n14.

[16] Hardware and software for monitoring thermal energy generation, transportation and consumption facilities: monograph (in Ukrainian). Edt. Babak V.P. Kyiv, Institute of Thermal Engineering NAS of Ukraine, 2016. ISBN 978-966-02-7967-4.

[17] Babak, V., Dekusha, O., Kovtun, S., Burova, Z., Parkhomenko, G. "Computational Fluid Dynamics Model of the Heat Transfer at Thermal Resistance control of Building envelope", *CEUR Workshop Proceedings, 3513, p. 363-373, 2023.* [Online]. Available: https://dblp.org/rec/conf/icst2/BabakDKBP23.

[18] Karpenko D., Yevtukhova T., Novoseltsev O. "Method for Assessing the Efficiency of the District Heating System Under Market Conditions", Vidnovluvana Energetika, 79 (4), p. 6-16, 2024. DOI: 10.36296/1819-8058.2024.4(79).6-16.

[19] European Committee for Standardization (CEN). EN 12599:2012: Ventilation for buildings - Test procedures and measurement methods for taking-over of completed ventilation and air conditioning systems. Brussels: CEN, 2012