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SOME FEATURES OF AIR POLLUTION MONITORING AS A COMPONENT OF THE MICROCLIMATE OF THE PREMISES

Abstract. *The quality of living space largely depends on the quality of indoor air. The physical and chemical properties of the air people breathe can affect their health and comfort. Indoor air pollution in residential and workplace environments can occur due to various activities of occupants or employees, such as cooking, smoking, and using electronic devices, as well as emissions of pollutants from building materials and the use of certain products. Pollutants that can be present indoors include carbon monoxide, formaldehyde, volatile organic compounds, particulate matter, aerosols, biological contaminants, and more. To effectively monitor the quality of atmospheric air, it is necessary to determine the main sources of air pollution, which is the purpose of this study. Naturally, the quality of indoor air cannot be clearly separated from the ambient air quality. The first factor affecting the microclimate is the level of air pollution near the building. Air from the street enters the room through windows, doors, or the building's ventilation system. If the state of the surrounding environment is unfavorable, the concentration of harmful substances indoors may also exceed the norm. However, indoor sources of air pollution in any building can have a much greater impact on the health and comfort of the people inside it. Materials used in construction, such as concrete or mineral insulation, may contain ammonia, formaldehyde, and other substances that are released from building structures over time and deteriorate indoor air quality. Ensuring control and monitoring of indoor air quality is an extremely important task. This includes measuring concentrations of pollutants and identifying their sources. It is also important to adhere to standards and recommendations developed by health and environmental organizations to ensure safety and comfort indoors. To reduce indoor air pollution, various measures can be implemented, such as selecting appropriate building materials, and ventilation, installing purification systems, controlling sources of pollution, and limiting the impact of human activity.*
Keywords: air pollution, microclimate parameters, air quality monitoring, harmful substances.

1. Introduction

The question of the quality of a person's living space is extremely important, since people spend a significant part of the day (almost 90 % of the time) inside buildings: at home, at work or in educational institutions, without having information about the short-term and long-term consequences of staying in a particular room for their health [1]. The quality of the living space primarily depends on the quality of the air in the room. The parameters of the air that people breathe affect their health and comfort. The issue of indoor air quality is an important aspect of a healthy lifestyle, and its relevance has become especially acute in the past few years, when during the restrictions of the COVID-19 epidemic, people were forced to spend most of the day indoors, being exposed to accumulated pollutants.

According to the World Health Organization (WHO), indoor air pollution, both directly and indirectly, causes the premature death of almost 4 million people in the world every year [2]. In particular, the negative impact of indoor air without proper ventilation can lead to such symptoms as discomfort, feeling of suffocation, difficulty breathing, headache, drowsiness, and reduced mental and physical performance. A number of studies on monitoring and controlling the microclimate and air quality in schools [3], museums [4], universities [5], hospitals [6, 7], churches [8], airplane cabins [9], and subway platforms [10], and other objects with a relatively long stay of people during the day. Air samples, whether ambient or indoor, may show elevated concentrations of dust, nitrogen oxides, sulfur, carbon, and formaldehyde.

The term "sick building syndrome" or SBS was introduced to describe this phenomenon in 1982 [11]. The causes of the sick house syndrome are related to two main factors: firstly, improved construction technologies and the struggle for energy efficiency lead to the fact that building structures (walls, windows, doors, and floors) become almost airtight, and secondly, in the finishing premises and furniture production, synthetic materials are increasingly used, which ultimately leads to an increase in emissions of harmful substances into the air of residential premises and complicates their removal [12].

To implement effective monitoring of air quality, it is necessary to identify the main sources of air pollution, **which is the purpose of this study**. This will make it possible to prepare the ground for the development of monitoring systems that will be able to measure concentrations of pollutants in the premises and determine strategies for monitoring and improving the microclimate and air quality in the premises.

2. Methods and materials

Air pollution in living and working spaces can be caused by various activities of residents or employees, such as cooking, smoking, and use of electronic devices, as well as emissions from building materials and the use of certain products. Harmful substances that can be found indoors include carbon monoxide (CO), volatile organic compounds, solid fine particles, aerosols, biological pollutants (mold, dust, bacteria), and others. It should be noted that the composition of the air in the premises varies significantly depending on the sources of pollution, the rate of emissions, and the ventilation conditions.

2.1 Main Standards

Microclimate is a set of factors that directly affect the comfort of staying indoors [13]. Optimal microclimate conditions are such parameters of the microclimate that, with long-term and systematic influence on a person, ensure a normal thermal state of the body without tension and disruption of thermoregulation mechanisms. In Ukraine, as well as in other countries of the world, there are a number of normative documents that determine the requirements for buildings in terms of microclimate in the premises of public and residential buildings. In addition, there are a number of documents that regulate the maximum permissible concentrations of harmful substances in atmospheric air and at the workplace.

• DSTU B EN 15251:2011 "Calculated parameters of the microclimate of premises for the design and assessment of the energy characteristics of buildings with regard to air quality, thermal comfort, lighting and acoustics of buildings". [14]

This standard provides examples of recommended categories for the design of buildings with mechanical heating and cooling systems. It defines four categories of buildings, depending on the average value of a person's thermal sensation and rationalizes the areas of application of these categories, taking into account the expectations and duration of a person's stay.

• DSTU B EN 15261:2012 "Calculation of microclimate parameters". [15]

• DSTU B EN ISO 7730:2011 "Ergonomics of the thermal environment". [16]

• DSN 3.3.6.042-99 "Sanitary norms of the microclimate of industrial premises". [17]

It should be noted that according to these standards, the microclimate of residential and public buildings is determined mainly by the so-called thermal conditions – temperature, humidity and air movement, which determine its cleanliness and freshness. These conditions are key aspects of air quality

for two main reasons [18]: 1) many problems associated with an unsatisfactory microclimate can be solved by adjusting relative humidity or temperature, and 2) construction materials in buildings at high temperatures can release into the air large amounts of pollutants. All these parameters of the microclimate in the room can be not only measured but also adjusted with the help of climate equipment. Normative documents determine the standards and methodology for calculating microclimate parameters in premises to ensure comfortable conditions for living and working.

These documents regulate the air temperature in the premises. In the warm period, a range of 22–25 °C is recommended. In the cold season, it is slightly lower: 20–23 °C for living rooms, 24–26 °C for the bathroom, 23–24 °C for children's rooms, and about 20 °C for all others during the warm period, a range of 22–25 °C is recommended. In the cold season, it is slightly lower: 20–23 °C for living rooms, 24–26 °C for the bathroom, 23–24 °C for children's rooms, and about 20 °C for all other premises [14, 15].

The recommended indoor air humidity is 40–60 % [14]. Exceeding this mark is already dampness, which can lead to damage to property and the appearance of mold. Humidity below the indicated level can have a negative effect on well-being (dryness of the throat and eyes, drying of the skin).

Sanitary standards specify optimal humidity indicators: 30–45 % in winter and 30–60 % in summer [17], in addition, it should be taken into account that children need more humid air than adults.

2.2 Pollutants and sources of their occurrence

Naturally, indoor air quality cannot be clearly separated from ambient air quality. The first factor affecting the microclimate is, of course, the level of atmospheric air pollution near the building. Air from the street enters the premises through windows, doors, or the ventilation system of the building. If the environmental conditions are unfavorable, the concentration of harmful substances in the room can also exceed the norm.

However, internal sources of air pollution in any room can have a much greater impact on the health and comfort of the person staying in it. In a new building, even before the renovation, it is important to conduct an air analysis. Materials used in construction, such as concrete, can contain ammonia and other substances that are released from building structures over time and degrade indoor air quality.

After the repair is completed, substances such as formaldehyde, phenol, benzene, styrene, chromium, acetone, xylene, and toluene may enter the room. They can be the origin of various building materials, varnishes, paints, glues, and other substances that are used during the repair or production of furniture. It is natural that the quality of air in residential or office buildings is significantly influenced by the quality of external atmospheric air, the activities of people indoors, as well as building and construction materials, equipment, and furniture. The sources of indoor air pollution are presented in Fig. 1 [18].

A review of studies [19–29] was carried out, and based on it, a list and analysis of the main pollutants, sources of their appearance in homes, as well as consequences for human health was built.

1. Particulate Matter (PM, including dust)

Airborne particles are carbon particles that adsorb organic chemicals and reactive metals. The most dangerous fraction of dust that can harm human health is fine dust with a size of less than 2.5 microns – the so-called $PM_{2.5}$ particles. The diameter of such particles is 20 times smaller than the diameter of a hair. Due to their small size, they are able to float freely in the air, without settling on surfaces for a long time. The WHO considers 25 μg/m^3 as the maximum permissible dust concentration of the $PM_{2.5}$ fraction [19–20].

Sources of pollution: external (particles formed during the combustion of automobile fuel, abrasion of tires and asphalt, can pass from the street environment into the premises through windows, doors and ventilation systems) and internal (particles are formed as a result of internal activities – cooking, smoking, operation of machines and other household activities) [21–22].

Consequences: Particles can affect the lungs and heart, causing serious health problems.

Fig. 1. Sources of indoor air pollution in a home [18]

2. Volatile Organic Compounds (VOCs)

VOLs include gases that are emitted from liquids or solid materials. The development of technologies leads to an increase in the list of OLs that enter the air of apartments and office premises. This list includes aromatic hydrocarbons, ethers, ketones, alcohols, and acetates, as well as one of the most common VOLs – phenol and formaldehyde [18, 20].

Sources of pollution: plywood, chipboard, and furniture made from them, paints, glues, rubber, plastics, synthetic fabrics, tobacco smoke, etc. [23].

Consequences: The concentration of OLs in the indoor environment is usually at least 10 times higher than outdoors. They can cause irritation and health hazards, in particular, cancer with long-term exposure.

3. Formaldehyde (CH2O)

Formaldehyde is a toxic, allergenic, and carcinogenic substance. It is classified as a Class 2 hazard substance (highly hazardous). Despite its hazardous nature, formaldehyde is commonly found in indoor air in small concentrations.

Sources of pollution: furniture, particleboard, polymer materials, construction and finishing materials, cigarette smoke, and the combustion products of household gas. In small amounts, formaldehyde is also found in exhaled air as a metabolic byproduct.

Consequences: At sufficiently high concentrations, formaldehyde irritates the mucous membranes of the eyes, throat, and respiratory tract, leading to headaches and nausea. The irritant effect threshold for formaldehyde on the upper respiratory tract is 2.4 mg/m³. Symptoms of formaldehyde poisoning can include pallor, weakness, loss of consciousness, depression, difficulty breathing, and sometimes nocturnal seizures. Chronic exposure to formaldehyde can cause weakness, constant headaches, weight loss, loss of appetite, irregular heartbeat, and insomnia. Formaldehyde is especially dangerous for children.

4. Nitrogen oxides (NOX)

Sources of pollution: The main oxides of nitrogen are nitrogen oxide (NO) and nitrogen dioxide (NO_2), which are associated with combustion sources such as gas stoves and heaters.

Consequences: On average, NO and NO_2 concentrations in buildings without combustion sources are half of outdoor concentrations, but indoor levels often exceed outdoor levels in spaces with gas stoves and heaters. NO is converted to NO_2 under the influence of oxidants, and therefore NO_2 is usually considered as a major pollutant [18, 24].

5. Ozone (O3)

Sources of pollution: Ozone is a strong oxidizer, which is mainly formed during photochemical reactions in the atmosphere. Indoor sources of ozone include the operation of electrical appliances, such as photocopiers and air blowers [25].

Consequences: Ozone can interact with other chemical pollutants to cause irritation and damage to materials. The main routes of exposure to humans are inhalation and skin contact.

6. Sulfur dioxide (SO2)

Sources of pollution: Sulfur dioxide (SO_2) is the most common gas among the group of sulfur oxides (SO_x) in the atmosphere. The main sources of SO_2 emissions are coal burning processes and it mixes with aerosols and PM particles, forming a complex group of air pollutants. Usually, SO_2 levels in buildings are lower than outside [26].

Consequences: May affect respiratory function.

7. Carbon oxides (COx)

Indoor carbon monoxide (CO) is mainly produced during combustion processes such as cooking or heating. In addition, CO can also enter the premises through infiltration from the street.

Consequences: High levels of CO can lead to adverse health effects, including effects on cardiovascular and neurobiological functions, as well as destabilization and even sudden death.

Carbon dioxide (CO_2), a colorless and odorless gas, is a component of the Earth's atmosphere and also the main metabolite of humans. The concentration of CO_2 in ambient air is approximately 400 ppm and is mainly the result of burning fossil fuels. The indoor CO_2 level is used as an indicator of indoor air quality and for ventilation control. Indoor CO_2 concentration should be below 700 ppm to ensure human health.

Consequences: It has been established that CO_2 exposure to the body can cause headaches, drowsiness, fatigue, and difficulty concentrating [27].

8. Aerosols

Sources of pollution: Primary aerosols (originating from various indoor and outdoor sources) and secondary (formed by reactions of gases and particles indoors) [28]

Consequences: Effects on the organs of the respiratory system and effects on the heart and nervous system.

9. Toxic metals

Sources of pollution: internal (due to the use of certain devices and building materials, such as floor coverings, varnishes, and paints) and external (through windows and ventilation) [29].

Consequences: risk of cancer, cardiovascular disease, and other health problems

10. Pesticides

Sources of pollution: internal (use of pesticides to protect wooden building materials in coatings) and external (air pollution with pesticides of external origin) [30].

Consequences: Short-term (skin and eye irritation, dizziness, headache, nausea) and long-term (risk of cancer, asthma and diabetes).

11. Radon

Radon is a radioactive inert gas formed during the decay of radionuclides of the radium group. It has a half-life of about four days. It is believed that radon accounts for about 50 % of the dose received by a person due to the natural radiation background. There is no safe concentration of radon [31].

Sources of pollution: Building materials (concrete, stone, brick). Natural gas and water sources. Release radon from the surrounding air.

Consequences: Increased risk of lung cancer, particularly with long-term exposure to high levels of radon.

12. Biological pollutants

Sources of pollution: Biological allergens (animal fur, cockroaches, bedbugs, mites, pollen). Microorganisms (viruses, fungi, bacteria) [32].

Consequences: respiratory infections, respiratory allergic diseases, wheezing.

In the Table 1 summarizes the main standards of the WHO regarding the permissible concentration of some common pollutants [33]. These standards are commonly used to monitor air quality inside households, schools, hospitals, public buildings and offices.

Table 1. WHO recommendations on indoor air quality and monitoring the concentration of pollutants

Polluting substances	Concentration (mg/m^3)	Permissible exposure time
CO	100 60 30 10	15 minutes 30 minutes 1 hour 8 hours
CO_2	1800	1 hour
NO_2	0,4 0,15	1 hour 24 hours
PM	0,15 0,05	24 hours 1 year
O_3	0,15–0,2 0,1–0,12	1 hour 8 hours
SO_2	0,5 0,35	10 minutes 1 hour
Lead	0,0005–0,001 0,0015	1 year 3 month
Formaldehyde	0,1	30 minutes
Radon	100	1 year

Indoor air quality has a great impact on the health and well-being of people who live or work there. Various sources of pollution, such as particulates, volatile organic compounds, gases and biological agents, can lead to serious health consequences, including respiratory diseases, allergies, chronic diseases, and even cancer.

3. The main methods and means of monitoring air quality in premises

Ensuring control and monitoring of indoor air quality is an extremely important task. This includes measuring pollutant concentrations and identifying their sources. It is also important to follow standards and recommendations developed by health and environmental organizations to ensure indoor safety and comfort. Various measures can be implemented to reduce indoor air pollution, such as appropriate selection of building materials, ventilation, installation of cleaning systems, control of pollution sources, and limitation of human activity.

Indoor air quality monitoring can be done using sensors, such as gas analyzers [32–34], and is an important component of efforts to improve the quality of the indoor environment. Modern sensor technologies make it possible to measure the concentrations of various pollutants, such as gases and particles, with high accuracy and in real-time.

The main advantages of using gas analyzers and sensors for indoor air quality monitoring include:

1. Real-time: Sensors are capable of providing immediate information on pollutant levels, allowing for prompt response to pollution and remedial action.

2. Accuracy: Modern gas analyzers provide high measurement accuracy, which allows you to reliably determine the concentrations of various pollutants.

3. Monitoring of different pollutants: Gas analyzers can be configured to measure different types of pollutants, including gases, particles, moisture, etc.

4. Alerts and automatic control: Some sensors can send alerts or activate automatic air purification systems when certain pollution levels are reached.

5. Remote monitoring: Some sensors can be connected to the Internet, which allows you to remotely monitor air quality and receive data through smartphones or computers [35].

Thanks to modern technologies, indoor air quality monitoring is becoming more accessible and effective thanks to sensors and gas analyzers. This helps provide a safe and healthy environment for people who are indoors [36–38].

4. Conclusions

Indoor air quality monitoring is an important component of ensuring a healthy and safe environment for living and working. Modern technologies and appropriate compliance with standards can help improve the quality of the indoor environment and reduce the risk to people's health.

It has been established that the internal environment can be contaminated with various substances that have a potentially negative impact on human health. Therefore, indoor air quality monitoring is necessary for the timely detection and elimination of pollution. There are standards and regulations that define acceptable levels of pollution for various substances in the indoor environment. Compliance with these standards is important to ensure a healthy indoor environment.

One way to improve indoor air quality is to reduce sources of pollution. This can be achieved by choosing safer building materials, using smokeless heating and ventilation systems, etc.

Modern information and measurement systems based on gas-analyzing devices and sensors allow effective monitoring of air quality and prompt response to pollution, in particular, using automatic control of microclimate parameters.

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ДЕЯКІ ОСОБЛИВОСТІ МОНІТОРИНГУ ЗАБРУДНЕННЯ ПОВІТРЯ ЯК СКЛАДОВОЇ МІКРОКЛІМАТУ ПРИМІЩЕНЬ

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Анотація. *Якість життєвого простору у значній мірі залежить від якості повітря в приміщенні. Фізичні та хімічні властивості повітря, яким люди дихають, впливають на їх здоров'я та комфорт. Забруднення повітря у житлових та робочих приміщеннях може виникати через різноманітні дії мешканців чи співробітників, такі як приготування їжі, куріння, використання електронних приладів, а також викиди забруднюючих речовин від будівельних матеріалів і використання певних товарів. Забруднюючі речовини, що можуть знаходитися у приміщеннях, включають оксид вуглецю, формальдегід, органічні леткі сполуки, тверді дрібнодисперсні частки, аерозолі, біологічні забруднюючі речовини тощо. Для здійснення ефективного моніторингу якості атмосферного повітря необхідно визначити основні джерела забруднення атмосферного повітря, що і є метою даного дослідження. Природно, що якість повітря в приміщенні не можна чітко відокремити від якості повітря довкілля. Перший чинник, що впливає на мікроклімат, – це рівень забруднення атмосферного повітря поблизу будівлі. Повітря з вулиці потрапляє в приміщення через вікна, двері або систему вентиляції будівлі. Якщо стан навколишнього середовища є несприятливим, концентрація шкідливих речовин в приміщенні також може перевищити норму. Проте внутрішні джерела забруднення повітря в будь-якому приміщенні можуть мати значно більший вплив на здоров'я і комфорт людини, яка перебуває в ньому. Матеріали, що використовуються в будівництві, такі як бетон чи мінеральні утеплювачі, можуть містити аміак, формальдегід та інші речовини, які з часом виділяються з будівельних конструкцій і погіршують якість повітря в будинку. Забезпечення контролю та моніторингу якості повітря у приміщеннях є надзвичайно важливим завданням. Це включає в себе вимірювання концентрацій забруднюючих речовин та визначення їх джерел. Важливо також дотримуватися стандартів та рекомендацій, розроблених організаціями з охорони здоров'я та екології, щоб забезпечити безпеку та комфорт у приміщеннях. Для зменшення забруднення повітря в приміщеннях можна реалізувати різні заходи, такі як відповідний вибір будівельних матеріалів, вентиляція, встановлення очисних систем, контроль за джерелами забруднення та обмеження впливу людської активності.*
Ключові слова: забруднення повітря, параметри мікроклімату, моніторинг якості повітря, шкідливі речовини.

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