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PROBLEMS OF ATMOSPHERIC AIR POLLUTION IN THE PROCESS OF INDUSTRIALIZATION AND ITS IMPACT ON HUMAN HEALTH

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Abstract: This research provides a comprehensive analysis of atmospheric quality degradation resulting from escalating technogenic loads during intensive industrialization and its cumulative impact on public health. The study scientifically elucidates the cytotoxic and genotoxic properties of industrial pollutants, specifically nitrogen and sulfur dioxides, polycyclic aromatic hydrocarbons, and fine particulate matter PM2.5 and PM10. The article examines the role of ambient air pollution not only in the pathogenesis of respiratory and cardiovascular disorders but also its detrimental effects on immunobiological reactivity and the stability of the human gene pool. Furthermore, the paper proposes strategic pathways for modernizing environmental monitoring systems and implementing innovative technological solutions for industrial emission mitigation and waste management.

Keywords: Industrialization, atmospheric degradation, technogenic pollutants, particulate matter PM2.5, cumulative impact, pathogenesis, immunobiological reactivity, environmental monitoring, carcinogenic factors, technosphere safety.

INTRODUCTION

The current stage of human civilization is characterized by unprecedented technological progress and rapid industrialization processes. However, this economic growth is accompanied by extensive use of natural resources and increased anthropogenic pressure on ecosystems. The degradation of atmospheric air quality on a global scale today threatens not only the ecological balance, but also the survival of humanity as a biological species. The technosphere regions emerging as a result of the combination of industrial sectors with urbanization processes have become the main source of toxic compounds and ultrafine dispersed particles.

The composition of pollutants resulting from scientific and technological progress is becoming more complex every year, and their negative impact on the components of the biosphere is becoming cumulative. Studies show that atmospheric air pollution is a global problem that knows no borders and has the property of spreading over long distances through transboundary migrations. The excess of industrial emissions is causing a change in the microclimate in populated areas and an increase in carcinogenic factors that cause irreparable harm to the gene pool of the human population.

The main purpose of this study is to analyze the trends in the decline of atmospheric air quality in industrialized areas and scientifically substantiate the complex impact of man-made pollutants on human health. The article also examines the relationship between the decrease in immunobiological reactivity and the mechanisms of the development of various pathologies from a theoretical and practical perspective. To eliminate these problems, the issues of radical reform of the environmental monitoring system and the introduction of innovative and technological solutions at industrial facilities are considered to be of strategic importance.

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Main part:

In the modern stage of development, rapid industrialization processes are causing not only economic growth, but also global ecological crises resulting from an increase in technogenic loads. In particular, in areas where industrial clusters and large energy facilities are located, a sharp degradation of atmospheric air quality is observed. Technogenic pollutants released into the atmosphere, including nitrogen and sulfur dioxides, as well as various polycyclic aromatic hydrocarbons, weaken the natural regeneration capacity of the environment and create a complex ecotoxicological situation.

The most dangerous and cytotoxic components of air pollution include extremely small dispersed PM2.5 and PM10 particles. Due to their physicochemical properties, these dispersed particles have the ability to penetrate deep into the human body and negatively affect all vital organs through the circulatory system. Scientific studies show that these particles cause genotoxic changes at the cellular level, directly threatening the stability of the gene pool. As a result, the human population is experiencing an increase in carcinogenic factors and an increase in hereditary pathologies.

The impact of atmospheric pollution on human health is cumulative and over a long period of time reduces the immunobiological reactivity of the body. Not only respiratory and cardiological diseases, but also chronic depression of the immune system play an important role in the pathogenesis. In addition, shortcomings in ensuring the safety of the technosphere are creating epicenters of allergic and oncological diseases among the population. Therefore, the modernization of the environmental monitoring system and the implementation of innovative and technological solutions for the disposal of industrial waste are urgent tasks today.

The long-term impact of man-made pollutants in the atmosphere on the human body is not limited to the respiratory system, but also undermines the stability of the genetic apparatus in the cell nucleus. In particular, polycyclic aromatic hydrocarbons and heavy metal compounds have mutagenic properties, causing errors in the process of DNA replication. This process, in turn, creates the basis for functional disruption of the gene pool and an increase in congenital anomalies in future generations. Thus, the increase in man-made loads is becoming the main factor in the biological crisis at the population level.

In the process of industrial waste disposal, it is necessary to abandon traditional treatment devices and switch to high-tech filters and closed-cycle production systems. As innovative and technological solutions, it is recommended to use electrostatic precipitators and catalytic neutralizers that capture dispersed particles in the air at the ionic level. At the same time, digital monitoring systems based on artificial intelligence are of particular importance in ensuring the safety of the technosphere. These systems allow predicting the dynamics of the spread of pollutants and taking prompt preventive measures in ecologically hazardous areas. At the current stage, the modernization of the environmental monitoring system involves not only technical equipment, but also the introduction of strict emission quotas for regional industrial clusters. An integrated approach to preventing atmospheric degradation requires the coordination of legal mechanisms for nature protection with technological innovations. Studies confirm that only through a comprehensive environmental audit and the implementation of the principles of the "green economy" can we minimize man-made loads and preserve the health of the human population.

The long-term impact of man-made pollutants on the human body creates a complex pathogenetic chain. Toxic compounds in the atmosphere not only damage the mucous membranes of the respiratory system, but also systematically weaken the immunobiological reactivity of the body. In particular, as a result of the reduction in the activity of alveolar

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macrophages by dispersed particles, the body's protective barrier against external infections weakens. This process stimulates chronic inflammatory reactions and creates conditions for the development of cardiological and hematological pathologies. Also, due to the cumulative nature of pollutants, a state of endotoxicosis is formed in the body, which disrupts the regeneration ability of cells and general metabolic stability. At the present stage, a radical modernization of the monitoring system is required to stabilize the ecological situation in industrialized regions. Since traditional control methods cannot fully reflect the real-time dynamics of pollutants, the introduction of innovative technological solutions, including automated sensor networks, has become necessary. As a strategic direction for ensuring the safety of the technosphere, it is proposed to use nanomaterials and photocatalytic purification devices in the disposal of industrial waste. These technologies allow to neutralize carcinogenic factors in the air at the molecular level. Also, the impact of atmospheric degradation on the human environment can be minimized by vertical landscaping and the creation of "green filters" around industrial areas.

Conclusion:

In conclusion, the degradation of atmospheric air quality in conditions of intensive industrialization poses a serious technogenic threat to the health of the human population and the stability of the gene pool. Theoretical analyses show that nitrogen and sulfur dioxides, polycyclic aromatic hydrocarbons, and ultrafine PM2.5 and PM10 particles emitted from industrial clusters have a cumulative effect on the body, causing cytotoxic and genotoxic changes at the cellular level. This process not only plays a decisive role in the pathogenesis of respiratory and cardiological pathologies, but also weakens the immunobiological reactivity of the body and leads to a decrease in general health indicators.

At the same time, the scientific data identified during the study confirm that a radical modernization of the environmental monitoring system is an urgent task to ensure the safety of the technosphere. Atmospheric pollution can be minimized by using innovative technological solutions for industrial waste disposal, in particular, filtration devices based on nanomaterials, and digital control of production processes. As a final conclusion, it should be noted that the widespread implementation of the principles of the "green" economy is of strategic importance in order to maintain a stable ecological environment and protect the gene pool of the population.

In order to eliminate the negative consequences of atmospheric degradation, it is extremely important not to be satisfied with only technical restrictions, but also to digitally transform industrial facilities and introduce "smart" environmental management systems. Within the framework of innovative technological solutions for industrial waste disposal, it is necessary to implement intelligent filters and closed-loop regenerative systems that trap harmful pollutants. This, in turn, will ensure the safety of the technosphere and restore the natural balance of regional ecosystems.

Also, the strategy for protecting public health requires strengthening preventive measures aimed at maintaining the stability of the gene pool. It is necessary to improve the state screening system, which regularly monitors the immunobiological reactivity of the population living around industrial clusters. The final analysis shows that only by integrating the results of scientific research into production, as a priority area of the state environmental policy, can the quality of atmospheric air be improved to international standards. This integrated approach will remain the most effective mechanism for achieving sustainable development goals in the future.

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