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Modern Applications of Ozone Technology

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Abstract: The purpose of the work is to study and analyse the possibilities of using modern processes and devices of ozone technology in various spheres of society, industries, taking into account the factors of economic profitability and environmental safety. The research was carried out using general scientific methods of cognition, namely, system analysis, synthesis, abstraction, generalization, deduction, concretization, and formalization. In the course of the study, the factors of influence of ozonation processes on the exposure environment were studied, modern technological developments and solutions were analysed to minimize the risks associated with the dosage of ozone use, the possibilities of effective application of ozone technology in various industries, examples of successful adaptation of innovative developments in the field of ozonation are considered. As a result of the study, it was determined that the processes of disinfection, deodorization, and sterilization using ozone technology processes can significantly increase the level of quality and efficiency, taking into account the criteria of time and economic factors. The results of the study are of significant practical importance for raising the level of criteria for the success of cleaning processes that are inextricably linked with production, as well as the living conditions of modern society against the backdrop of a growing need for greening cleaning processes and neutralizing harmful substances.

Keywords: microbial inactivation; disinfection; application dosage; sterilization; deodorization; ozone, corona discharge

1. Introduction

Recently, mankind has faced growing global problems of environmental pollution. In this regard, engineering and management decisions of production and economic processes today are certainly guided by the factors of environmental friendliness, economic efficiency, and reduction of time costs in order to achieve the maximum expected effect. Modern ozone technologies meet such requirements, and therefore are gaining increasing popularity both in the world community, including in countries with developing economies. Minimal resources are required to generate ozone, so ozonation processes are available, safe enough to use, and receive a wide range of applications in production, everyday life, and agriculture. Ozone is a powerful antimicrobial agent that is widely used for disinfection in many industries, including the food industry, water treatment, pharmaceuticals, and medicine. Ozone is able to clean, disinfect and sterilize materials and surfaces, depending on the dosage of application and the characteristics of the medium used.

The problems of using ozone technology and the search for solutions to reduce the risks arising from the irrational use of ozone are devoted to many modern scientific papers and research, in particular to those by E. Epelle et al.[1)] and J. G. Collin et al.[2)]. Aqueous ozonation has attracted more research attention than gaseous ozone applications. Modern scholars Alhamid et al.[3)-5)], F. Beltran et al.[6)] and T. Manasfi[7)] are busy studying it. Purification of water with ozone was the pioneering application that demonstrated the potential of ozone and led to its growing utilization in other areas. The problem of finding optimal solutions to ensure the purity of drinking water, as well as wastewater, is especially relevant in the light of environmentally unstable water systems of our time. K. Gregersen et al.[8)] are actively studying the possibilities of ozone for practical use in aquaculture.

Many modern scientists are engaged in research on the development and implementation of ozonation mechanisms in the food industry, since this aspect of the application of ozone technology is very in demand and promising. The work of W. Xue et al.[9] is devoted to this issue. COVID-19 pandemic has stimulated new developments in the implementation of various ozone-based technologies for the disinfection of surfaces, materials, indoor environments, and also highlighted the therapeutic potential of ozone. This issue is raised in the works of scientists S. Thill and M. Spaltenstein[10]. Despite the rather high popularity of the topic of ozone technology in the modern scientific circles of the world community, the fact of its rather chaotic systematization and grouping for further study and practical application is indisputable.

The study is important for studying and generalizing the latest advances in the application of ozonation technologies and devices in various industries. It helped to determine the optimal engineering solutions for the implementation of ozone disinfection systems, focusing on the key parameters that affect the efficiency and stability of ozone. The purpose of the study was to study and summarize the latest advances in the use of ozone technologies and devices in various industries, as well as to determine the optimal engineering considerations necessary for the large-scale implementation of ozone decontamination systems, with an emphasis on key parameters that affect the efficiency and stability of ozone in long-term exposure, as well as the allocation of priority areas for further study of the issues under study, the development of recommendations for the practical application of ozone technologies in current areas of activity. Also, it was necessary to analyze the chemical substance in detail, what effect it has, how it is used and changed.

The results of the research will be of practical importance for the creation of favorable environmental conditions for the life of society and production processes through the optimization and rational application of modern ozonation technologies.

2. Materials and Methods

In the process of conducting scientific research, a number of general scientific methods of cognition were used. In particular, when studying scientific literary sources and publications in specialized publications devoted to the issues under study, methods such as system analysis, synthesis, and generalization were used. The theoretical basis of the study is scientific works and research results of modern scientists, analytical materials, publications in scientific and metric bases. With the help of the generalization method, a set of measures was carried out in order to identify the typical features and patterns of the problem under study, the possibilities of optimizing the situation and finding the most beneficial solutions in economic and environmental aspects. The emphasis was on the latest developments and research on the issue under study in recent years, as well as examples of successful implementation of ozonation technologies in various industrial production processes.

The study is based on the hypothetical-deductive method. An assumption has been made about the feasibility and safety of using modern innovative processes and devices of ozone technology in various areas of production processes and life support. The deductive method was used to confirm the formulated hypothesis. The general scientific method of deduction was also used to determine the essence of the ozonation method as a multifactorial process. The use of the hypothetical-deductive method made it possible to formulate a scientific theory that takes into account the results derived during the experimental activities of scientists, and also uses logical conclusions, which together made it possible to formulate conclusions about confirming the hypothesis of the universality of ozonation as a modern and affordable way to process various media. In addition, in the process of research, the method of ascent from the abstract to the concrete was used, in the form of a sequential transition from general abstract data on the processes and apparatuses of ozone technology and the properties of ozone as a chemical substance to specific examples of the use of ozonation in various production processes, agriculture, the medical industry, ensuring favourable conditions for the life and activities of society.

To determine the effectiveness, features, and benefits of certain technological solutions in the process under study, a systematic approach was used. With its help, the study is focused on revealing the integrity of the object of study, a comprehensive search for solutions. Particular attention is paid to the variability of approaches and the need to foresee possible difficulties in practical implementation in the conditions of the economic reality of developing countries. The main directions of optimizing the synergy of the resource and environmental components of the processes of ozone technology have been developed.

The synthesis method was used to form conclusions on the expediency of using ozone technologies in certain industries and households. The abstraction method in the course of the study was applied in the formation of a representation of the process of monitoring, management and control in the field of ozone technologies, concurrently, the concretization method was used in determining the efficiency factors for the use of ozone and the economic feasibility of its use, as well as to fix the benefits of using ozone along with classical methods-analogues.

In the process of forming conclusions based on the results of the study, the formalization method was also used. The conclusions are focused on the active practical application of the research results in the process of optimizing the environmental component in the processes of cleaning, disinfection, sterilization, and optimization of microbiological indicators in various fields of application.

3. Results

3.1. Properties and Characteristics of Ozone

Ozone (O_3) is a gas, a highly active allotropic form of oxygen with a characteristic pungent odour. Gaseous ozone at room temperature has a bluish colour, although this fact remains subtle at commonly produced concentrations. Ozone is more unstable than atmospheric oxygen, which implies that it does not accumulate to a significant extent and must be produced when necessary, using ozone generation systems[2)]. Significant oxidizing abilities and rapid degradation due to the instability of the compound make it effective against a wide range of microorganisms, providing faster microbial inactivation kinetics compared to other types of oxidizers.

In addition, a feature of ozone is its effectiveness against particularly resistant microorganisms, for example, *Clostridium difficile*. Ozone compounds react with organic substances 3000 times faster and are safer than chlorine[11)]. In addition to disinfection, ozone has deodorizing, and bleaching properties, which expands the possibilities of its use in various industries. But today, the most common reason for its use is still the need for disinfection. Its widespread use for these purposes is due to the high activity of ozone both in water and in the air, which makes it possible to use it depending on the specific characteristics of the process or substrate to be disinfected. Additionally, the sensitivity of ozone to organic substances present in the environment increases its consumption, thereby reducing the concentration for the target exposure.

3.2. Ozone generation methods and efficiency

Ozone generation in the air is carried out using ultraviolet radiation (185 nm) and corona discharge methods[12)]. The second is considered more efficient, especially for large-scale production. In the aquatic environment, ozone is generated using electrolytic methods or by bubbling gas through water[13)]. Both methods of ozone formation stimulate the formation of ozone bubbles of different sizes, which makes it possible to achieve certain stability of ozone compounds in the aquatic environment. In addition, the destruction of such bubbles on the surface of the treated substrate increases the antimicrobial effectiveness of the entire process.

3.3. Factors influencing the antimicrobial efficacy of ozone

The antimicrobial properties of ozone depend not only on the environment of use, but also on certain parameters. For gaseous ozonation, these are the temperature, pressure and relative humidity of the environment. Alongside this, the effectiveness of the use of aqueous ozone is affected by additional parameters – the level of acidity, conductivity, and composition of the organic medium. In addition, other key factors affecting the efficiency of the ozonation process are the type and properties of the material to be dehydrated, the nature of the microorganism, the method of environmental pollution, the method of ozone generation, and the dose of exposure. Parameters can significantly affect the process, changing the stability of ozone in the environment of its use, or the possible effectiveness of microbial inactivation.

The overall efficiency of microbial inactivation with ozone can be increased by optimizing the conditions. For example, low temperatures increase the stability of ozone in air and water, thereby reducing the rate of spontaneous decomposition to oxygen. The use of additives (e.g. carbonate salts) improves the stability of aqueous ozone for long-term microbial inactivation. Also, the penetration of ozone into a porous medium can be achieved by creating a pressure difference. In addition, the application of ozone nanobubbles also has great potential to improve the antimicrobial efficacy and stability of ozone[4),12)].

Ozone is a substance that is characterized by high rates of adsorption by silica gel and alumina gel, and this property makes it possible to effectively extract ozone from various gas mixtures and solutions, as well as increase the safety of handling it when high concentrations are required. In addition, a relatively new direction in working with high concentrations of ozone is the use of freons. Dissolved in freon, concentrated ozone can be safely stored for a long time. The property of ozone to actively interact with organic compounds is used in the chemical industry. Thus, it becomes possible to obtain artificially various fatty acids, amino acids, polymers. The interaction of ozone and aromatic hydrocarbons makes it possible to develop new methods for deodorizing air and water. Meanwhile, the reaction of ozone with sulphur-containing compounds is the basis of modern methods for cleaning waste gases and wastewater, which is especially important for production processes focused on the implementation of the principles of a circular green economy.

In industrial conditions today, ozone is produced by an electrolytic method, using ultraviolet radiation, or by electrosynthesis using a corona discharge. The latter method is recognized as the most efficient, while differing in the optimal ratio of energy costs to the concentration of generated ozone. A corona discharge is formed when the electric field around the conductor is characterized by a high degree of inhomogeneity. Subsequently, an active ionization process takes place in the air, which, moreover, is accompanied by a glow. In this case, the conductor is surrounded by a kind of visual “crown”, which does not reach the edge of the opposite electrode. Methods of supply (direct and alternating current, pulses) and electrode charge (negative, positive) determine the different types of “corona”. The simplicity of the design and the absence of a dielectric barrier in the discharge space justify the popularity of corona discharge ozonizers. At the same time, the amount of ozone generated in the corona discharge is 15-25 g/kWh, and such indicators can satisfy the needs of using the ozonator in various areas of activity. It should be noted that a corona discharge with a thin-wire cathode makes it possible to form a prolonged discharge along the cathode, which significantly reduces the density of the discharge current, and also more evenly distributes the energy release in the gas and heat removal from it. This feature helps to increase the efficiency of the ozone generation process, given its tendency to decay at the slightest increase in temperature.

3.4. Main applications of modern ozone technologies

In the light of the current versatility of the phenomenon of effective use of ozone in modern technological solutions, some priority and appropriate areas of its functional application should be highlighted (Figure 1).

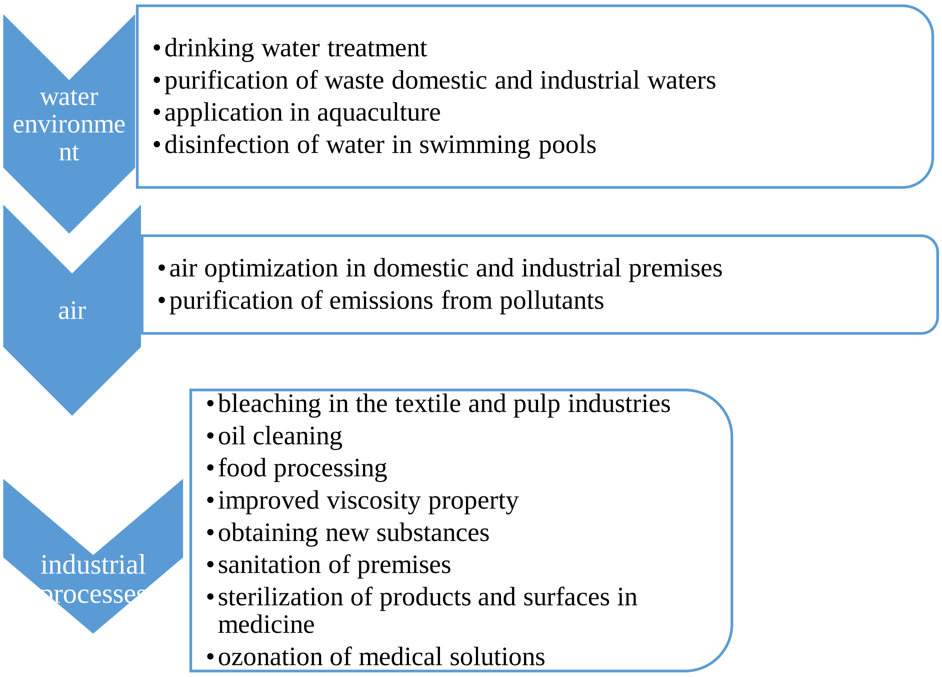

Fig. 1: Main areas of application of modern ozone technologies.

For a broader understanding, it will be useful to consider some of the potential challenges and limitations associated with the use of ozone in various applications to provide a more balanced view of the practical implementation of the technology:

– Ozone is a strong oxidizer and can be toxic when inhaled in high concentrations. This requires careful dosage control and monitoring of ozone levels.

– The cost of ozone generation equipment can be quite high. A thorough cost-benefit analysis is required.

– The effectiveness of ozone decreases in the presence of organic substances, which requires attention when designing cleaning systems.

– Ozone decays quickly, so it is difficult to transport and store. This complicates logistics.

– Ozone can accelerate the corrosion of some materials, such as rubber, which requires attention when choosing construction materials.

– The products of ozone's reactions with organic matter can have negative effects if not properly disposed of.

– Personnel safety when working with ozone requires special training and safety measures.

3.5. New approaches and applications of ozone

Purification of drinking water – one of the most common applications of ozone in industry is the purification of drinking water, in particular for the removal of heavy metals, disinfection, taste, and odour neutralization (Figure 2).

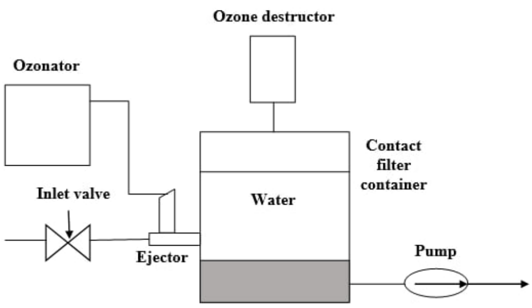

Fig. 2: General scheme for the purification of the aquatic environment using ozonation.

The mechanism of the effect of ozone is believed to be in the destruction of bacterial protein compounds. It is carried out by the phenomenon of ozone diffusion, while the action occurs quickly while maintaining the required concentration of ozone. In addition, ozone oxidizes compounds of mineral and organic origin present in water, with their subsequent splitting. Alongside this, effective elimination of various odours and tastes is observed. That is, it can be argued that with the help of ozone, unwanted substances are neutralized, including stable compounds. Ozone shows particular effectiveness in water purification from phenols, hydrogen sulphide, sulphur, cyanide, and a number of other substances that give the water an unpleasant odour. Additional advantages of ozonation for drinking water treatment are its ability to minimize the amount of disinfection by-products, ensure the proper level of water quality aesthetics (colour, taste, transparency, smell), and its exceptional ability to decompose a number of emerging pollutants that threaten water supply[14)].

3.6. Ozone applications in various industries

Wastewater treatment – the widespread use of ozone for drinking water treatment has given impetus to the expansion of ozonation into other industries, including wastewater treatment[15)]. The use of ozone technologies for this purpose makes it possible to reduce the formation of sludge and effectively remove persistent compounds, for example, compounds of phenols, carboxylic acids, and synthetic dyes[16)]. The growing use of ozone technologies for wastewater treatment in recent years can be explained by the trend towards lower costs of ozone production and its environmental benefits compared to chlorine.

Application in aquaculture – the practical application of ozone to reduce organic matter in recirculating aquaculture systems is also under intense scrutiny from scientists and stakeholders. It has been established that ozone actively contributes to the flocculation of organic substances, thereby reducing the content of suspended particles, chemical oxygen demand and dissolved organic carbon. Concurrently, the load on biofilters and oxygen generators is also reduced, algae toxins are removed, and the organoleptic characteristics of water are improved. The toxic effect of ozone in high concentrations explains the feasibility of using modern proportional-integral control systems to automatically adjust the ozone concentration in recirculating aquaculture systems. Today, ozone technologies in aquaculture are widely used to prepare water for the cultivation of various aquatic organisms (disinfection), to prevent and eliminate parasitic lesions, to purify water from toxic and harmful substances (herbicides, heavy metals, phenols, pesticides) in intensive fish breeding farms.

Water treatment in sports and health pools – the processes of disinfection of swimming pools in developing countries are based mainly on chlorination, which provokes negative consequences for human health and a decrease in water temperature. This method of water treatment has not met international requirements for a long time. An innovative task is to transfer swimming pools to ozonation, which simultaneously solves the issues of disinfection, improvement of organoleptic indicators and physical properties of water, deodorization, while meeting current environmental safety standards (Figure 3).

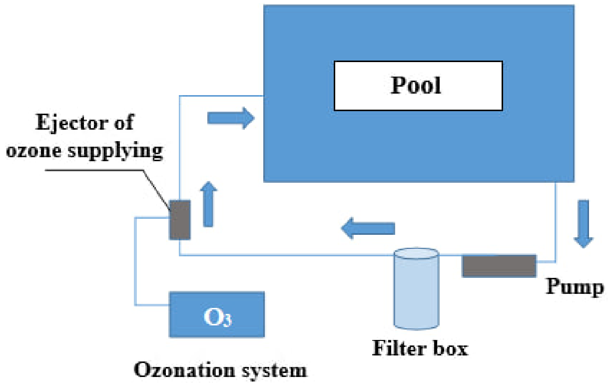

Fig. 3: Cleaning the water basin with systems ozonation.

Food industry – today, special attention is paid to the possibilities of using ozone technologies in the food industry, since the inactivation of pathogenic microorganisms is of paramount importance for the food industry. Methods of ozonation play a huge role in the organization of the system of transportation and storage of food[13)]. The situation is catalysed by the introduction in most developed countries of strict regulations aimed at limiting the use of chlorine. Minimal residual properties contribute to the recognition of ozone technologies as progressive and priority for use, capable of improving the safety and quality of food products[17)].

Medicine – some current research is focused on the process of ozone sterilization of personal protective equipment, as well as other ways to effectively use the sterilizing properties of ozone against the backdrop of the COVID-19 pandemic. Since viruses are unable to repair oxidative damage, ozonation is considered a good method for their inactivation. In addition to the possibilities of disinfection and sterilization provided by modern ozone technologies, the possibility of therapeutic applications of ozone should be explored. Indeed, despite the fact that ozone is a powerful oxidizing agent, studies show that it has a paradoxical activity when interacting with organic molecules, which creates a pronounced anti-inflammatory and antioxidant effect[18)].

Optimization of quantitative and qualitative parameters of air – the problem of air purification and deodorization is relevant, requiring technical solutions with mandatory consideration of environmental requirements. Already at a low concentration of ozone (0.005-0.01 mg/m^3), the air acquires the quality of freshness. Alongside this, the safety of the system is ensured by using an ozone generator with limiting the level of ozone concentrations at the output of the device. Moreover, modern air ozonation can be carried out using a dry or wet method. In the case of using the dry method, ozone is supplied using ozone generators built into the supply ventilation system. The principle of the wet method is that the air is treated with ozonized water in a special section of the air conditioner or scrubber. The most effective is the purification using ozone processes from substances that are easily transformed. These include, for example, benzene, acetone, phenols, sulphur compounds, naphthalene, formaldehydes, toluene, and methane. Ozonation also suppresses unpleasant odours (sulphates, ammonia, hydrogen sulphide). The process is highly effective (up to 90%), occurs at low doses and in a short period of time. With the help of ozonation, an effective bactericidal air purification from viruses and bacteria, fungal spores and mould is carried out. The efficiency of the process is 90-100%.

Emission cleaning – emissions from industrial processes contain significant concentrations of nitrogen oxide, sulphur, and volatile organic matter. There are also emissions of sulphur oxide, fluorine compounds, vanadium, and other harmful substances. The efficiency of the process of cleaning off-gases today is increased with the help of special solutions saturated with ozone. The use of aqueous ozone solutions is especially effective for cleaning emissions and exhaust gases with a very high content of pollutants at the enterprises of the chemical, petrochemical, food, biological industries, and pharmaceutical industries.

3.7. Ozone technologies in agriculture

Agricultural activity – modern ozone technologies used in various fields of agriculture can be divided into two main areas according to the principle of impact – stimulation of the vital activity of living organisms (refurbishment of premises) or its suppression (disinfection, purification of emissions). The difference in effect is determined by the dosage of ozone, so careful monitoring of the maximum allowable concentrations, in this case, is a critical factor in the influence of ozone. Considering the diversity of areas of application of ozone technologies, it can be argued that the properties of ozone deserve maximum attention for use not only for drinking water purification, industrial emissions, wastewater, and specific air treatment. Ozone equipment has been successfully used in bleaching (for example, cellulose), industrial oxidation, product modification or synthesis of new substances, to improve the viscosity property (starch, for example), surface treatment, as a powerful disinfectant for medical purposes, as well as to increase shelf life of food products. Modern ozonation technologies, to meet specific requirements, often combine ozone generators with ultraviolet radiation, or pre-oxidation processes with hydrogen peroxide, resulting in the desired effect of powerful oxidative reactions.

Based on the results of the study, a generalization of the information received was carried out, and basic proposals and recommendations were developed for the practical implementation of the best solutions in real modern production processes, various spheres of society, as well as in the field of medicine. Possible negative consequences of incorrect operation of processes and devices of ozone technology are predicted, primarily provoked by an irrational dosage of application, and preventive measures are proposed for their timely elimination or prevention.

4. Discussion

Significant anthropogenic pressure on the environment, combined with the growing need for effective innovative cleaning methods, which simultaneously have eco-friendly qualities, stimulates the search, development, and improvement of technical solutions in the field of ozone technologies. There is a trade-off between the target efficiency of pollutant removal, the formation of by-products and energy requirements when choosing the optimal purification method[1)]. Despite some limitations, the use of ozone shows superiority over classical chlorine[19)]. It has been observed that ozone increases the performance of a biofilter to remove a wide range of contaminants during drinking water purification[5)]. S.N. Malik et al. focus on increasing the efficiency of the biofilter when removing chlorobenzene in the case of an ozone content below 120 mg/m^3 [20)]. L. Varga and J. Szigeti emphasize the importance of assessing and controlling the dosage of ozone in the form of continuous monitoring, in order to timely record changes in dissolved organic carbon and alkalinity during biofiltration with ozone for drinking water treatment[21)]. After all, excessive dosing of ozone can adversely affect the performance of the biofilter. In addition, researchers insist that one of the main reasons for the need to monitor and control the dosage of ozone used to treat drinking water is the need for its complete decomposition before the ozone reaches the point of consumption. This assumption is consistent with the results of the current study.

Wastewater ozonation successfully replaces such technological processes as coagulation with rapid filtration, adsorption at the stage of tertiary treatment, combinations of other physical and chemical methods, and biological treatment. At the same time, selectivity towards certain pollutants, rather low reaction rate and relatively higher costs are some disadvantages of ozonation today[20)]. This has led to the popularization of the hybrid ozonation process, which combines ozone with other compounds and processes, thus achieving effective purification. They are also called advanced oxidation processes, and include the use of ultraviolet ozone, sonolysis, electrocoagulation, the use of photocatalysts and homogeneous metal ion catalysts, as well as heterogeneous metal oxide catalysts, including activated carbon[4)]. The main goal of such hybridization is the further decomposition of ozone, with the subsequent formation of hydroxyl radicals for the oxidation of stable compounds[7)].

The effectiveness of using hybrid ozone technologies has been confirmed by practical studies. In series of studies, catalytic ozonation, including a combination of ozone and granular activated carbon, was found to significantly improve the removal efficiency of micropollutants in urban wastewater[5]. In addition to the high adsorption capacity of activated carbon and the oxidizing capacity of ozone during catalytic ozonation, a characteristic feature of the process is the possibility of converting ozone into secondary oxidizers. This facilitates the subsequent degradation of pollutants, eventually converting these compounds into water and carbon dioxide[16]. In extensive studies by F. Beltran et al., the high efficiency of catalytic ozonation for the removal of disinfection by-products in drainage structures is demonstrated[6]. The issue of applying modern ozone technologies for industrial wastewater treatment was actively dealt with by scientists S.N. Malik et al.[20]. Their research demonstrates the feasibility of using ozone technologies for the mineralization of a wide range of pollutants from various chemical industries.

Analysing the above scientific works, it is worth noting that scientists do not actually pay attention to the economic aspect of the introduction of hybrid ozone technologies, although it is the complex environmental and economic assessment of projects that often has a decisive influence on the process of making production and managerial decisions. Only a few researchers argue that the use of improved oxidation processes is more cost-effective than the independent use of ozonation[20)-23].

In the food industry, ozone is used not only to improve the sanitary and hygienic conditions of production. In world practice, considerable experience has been accumulated in the use of ozone directly for the processing of products. The works of many modern scientists are devoted to the study and further development of new solutions. Ozone treatment is also recommended as an optimal alternative to pasteurization. R. Ribeiro et al. demonstrate the effectiveness of ozone to control the growth of fungi (*Fusarium verticilloides, pencilium* spp. and *Aspergillus flavus)* and as a detoxifying agent against fumonisins[24]. Here it is necessary to focus on an issue often overlooked in scientific studies of this kind, namely, a comparative analysis of the potential impact on human health in the event of the introduction or replacement of classical methods of food processing with alternative ozonation.

Ozone is also widely used to remove food residues from various surfaces in the food industry, since the need for effective cleaning is due to the risk of biofilm formation on the surfaces of food equipment[21]. Analysing the results of scientific research, it should be noted that the use of aqueous or gaseous ozone for food processing depends on the type of products and storage purposes[13]. The use of modern ozone technologies is not limited to the most demanded ones, such as water purification or food processing[25),26]. Ozone is also used in various ways in the textile industry. In addition, it has been noted that the efficiency of ozone processes in the textile industry is significantly increased when combined with ultrasonic energy[27)-31].

A promising direction for studying the possibilities of effective application of ozone processes and technologies is the direction of medicine[32]. To date, despite the significant sterilizing potential of ozone, its use for the sterilization of medical devices has been studied at a very low level. One of the few scientific works in this area is the study of S. Thill and M. Spaltenstein[10]. Scientists have developed an ozone sterilization system using excimer lamps, the result of which was the complete sterilization of the studied samples. The fact that filtration properties are preserved when using ozone is also reported in the works of other scientists, and, undoubtedly, this property of ozone should be used as actively as possible as an alternative to classical methods of chemical treatment, which often have a prolonged negative impact on human health[22),33)-35]. It is clear that gaseous disinfectant properties are the preferred method for sterilizing medical devices[1),36),37]. This is due to the high diffusion and permeability of the gas compared to disinfection based on immersion in a liquid disinfectant. The use of ozone in various industries and other areas of life is expected to increase in the near future.

5. Conclusions

In the study, it was possible to analyse the multifactorial nature of the existing system for the application of processes and devices of ozone technology, to study the possibilities of optimizing existing technological solutions and eliminating risk factors associated with the dosage of application. The main vectors of further research have been developed, and the need for systematization of research and practical information in the field of modern ozone technologies has been substantiated. It has been proven that ozonation in various forms of the process itself is an optimal alternative to the classical methods of disinfection, sterilization, and treatment of water and air, as well as surfaces. It has been established that no analogue of ozone with this kind of efficiency for the safe processing of food products has been found at the moment. The wide-scale application of ozone-related disinfection technologies has been limited to date by insufficient progress in the development of automated systems that can reduce disinfection cycle times, determine optimal ozone dosage requirements, i.e. exposure concentration and time, and monitor application during disinfection operations.

Further research is needed on the use of gaseous and aqueous ozone in the food industry, the medical industry, and for the treatment of drinking water. The development of new equipment adapted to contact with ozone is required. Progressive modern developments in the field of chemical reaction kinetics are needed to accurately predict the formation of transformation products and by-products in the treatment of drinking water and wastewater using existing and new oxidation technologies. The integrated application of these computational methods with innovative analytical methods optimizes the relative toxicity assessment, thus ensuring the safe application of hybrid oxidation processes. Particular attention should be paid to the need to define specific ozone dosage requirements; as erroneous ozone concentrations lead to detrimental results compared to the intended result. It is the indicators of concentration and duration of exposure that are the key factors determining the successful use of ozone.

Effective monitoring, implementation of innovative high-tech solutions in ozone processes will create conditions for maximizing the benefits of this cost-effective and environmentally friendly method. Thus, the introduction of modern processes of ozone technology is one of the most progressive technological processes aimed at creating environmentally favourable conditions for the life of society and production processes.

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