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ENVIRONMENTAL ASPECTS OF WATER TREATMENT AT MODERN INDUSTRIAL ENERGY FACILITIES

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The need for water treatment in industrial applications is extremely pressing, both to ensure reliable and highly efficient production and to create favorable environmental conditions for operations. In today's rapidly evolving world, increasingly stringent requirements are being imposed on the quality of water for various purposes. Depending on the intended use of the water, these requirements are regulated by various normative documents: national standards, technical specifications, and so on. When planning and subsequently implementing water treatment technologies at enterprises, it is necessary to address several complex and important challenges. One such challenge is ensuring maximum efficiency of the technological process, that is, ensuring production conditions that enable the manufacture of products of the required quality and in sufficient quantities. Technological advancements, including those in water treatment, primarily affect the production cost of finished goods. Therefore, Ukrainian and, undoubtedly, global enterprises strive to equip their production facilities with advanced water treatment and purification systems that ensure high-quality treated water while remaining economically viable. Thus, the efficiency of water treatment and water preparation, along with a stable water supply, are important aspects of modern, highly efficient, and advanced manufacturing operations. High water consumption is characteristic of virtually all industrial sectors. Each industrial enterprise is equipped with an industrial water treatment system that precisely meets the water quality requirements of its specific sector. Thus, to ensure strict compliance of water quality with the necessary technological parameters of a given enterprise, it is extremely important to implement an effective and, at the same time, economically viable industrial water treatment system. *Key words:* water treatment, pollutants, industrial needs, energy enterprises, industry-specific enterprise.

Екологічні аспекти водопідготовки на сучасних промислових підприємствах енергетичного профілю. Феденко Ю.М.
Необхідність підготовки води для промислових потреб є вкрай актуальною, як для забезпечення надійного і високоефективного виробництва, так і для створення сприятливих екологічних умов його роботи. В сучасному світі, який динамічно розвивається, до якості води різного призначення висуваються все більш жорсткі вимоги. Ці вимоги регламентуються, в залежності від сфери використання води, різноманітними нормативними документами: державними стандартами, технічними умовами тощо. Під час планування і подальшого впровадження на підприємствах технологій водоочищення необхідно вирішувати низку складних і важливих завдань. Одним із таких завдань є забезпечення максимальної ефективності технологічного процесу, тобто забезпечення таких умов функціонування виробництва, завдяки яким можливо випускати продукцію належної якості і в достатній кількості. Розвиток технологій, зокрема й водних, в першу чергу відбивається на собівартості готової продукції. Тому українські і, безперечно, світові підприємства намагаються забезпечити свої виробничі потужності такими передовими системами водопідготовки та водоочищення, які б забезпечували високу якість очищеної води і при цьому були б економічно обґрунтованими. Таким чином, ефективність водоочищення та водопідготовки разом із стабільним водозабезпеченням та водопостачання є важливими аспектами сучасних високоефективних і передових виробництв. Активне споживання води характерне практично для всіх промислових галузей. Кожне галузеве підприємство оснащується такою промисловою системою водопідготовки, яка точно відповідає вимогам до якості води в певному сегменті. Таким чином, для досягнення суворої відповідності якості води необхідним технологічним параметрам певного підприємства, є вкрай важливим реалізувати ефективну і в той же час економічно обґрунтовану промислову водопідготовку. *Ключові слова:* водопідготовка, полютанти, промислові потреби, підприємство енергетичного профілю, галузеве підприємство.

Introduction. At first glance, the term "water treatment" seems simple and straightforward. However, it encompasses a wide variety of tasks and methods for addressing them. Industrial water treatment is of great importance for nearly all of today's technological processes, which are focused on maximizing the quality and full utilization of resources. It must be highly efficient, comprehensive, and professional. It encompasses a wide range of water treatment technologies for both drinking and industrial purposes. Water is treated to remove iron, softened, disinfected, and its taste and odor characteristics are improved, while the concentration of pesticides, radioactive contaminants, and other substances is reduced. The capacity of an industrial water treatment system can range from 100 liters to several hundred cubic meters per hour. Water is supplied to industrial facilities from various sources: rivers, lakes, groundwater, municipal water mains, and so on. Water treatment systems can be operated both within the city and outside its boundaries [1]. The main thing is that they effectively remove substances of various sizes dissolved in the water, and that the facility receives an effluent that meets all requirements, regulations, and standards. The following types of water treatment are distinguished:

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local. Shallow water treatment addresses specific technological processes according to their characteristics and requirements. It involves the removal of iron and mechanical impurities using regenerative treatment methods, often combined with settling and filtration. Not all impurities are removed because of this treatment; general treatment. This method handles virtually all impurities and provides comprehensive water supply to all areas of the enterprise, including wastewater treatment. Water that has undergone such treatment is discharged into water bodies, so its purification must prevent harm to the ecosystem. In addition, water treatment is generally divided into domestic and industrial categories. Domestic water treatment (which should be noted, is somewhat simpler and less costly) is characterized by a pronounced regional principle (proximity of consumers and service specialists, and territorial ties to watersheds). It is not uncommon for there to be specific technological nuances not typical of other regions. Industrial water treatment is a completely different matter, more complex and, naturally, more expensive [2, 3]. There are no standard solutions here. This is a case where individual qualitative and quantitative parameters take priority. This field has its own specific characteristics and requires a professional approach. Regional factors are of little significance. Guarantees for all necessary parameters are specified in a personalized contract. This allows us to achieve a balance in the quality-practice-price chain. Industrial water treatment must ensure precise compliance with technological requirements, considering the quality parameters of the source water, including filtration rate, contact time, redundancy of technical equipment, safety of use, and so on.

Review and analysis of the main pollutants in water used for the energy sector. The key challenges of water treatment at industrial facilities are determined by the composition of the water supply. Considering this, let's consider two points: Water hardness, or the content of dissolved alkaline earth metals, primarily calcium and magnesium referred to as hardness salts. Hardness salts are particularly hazardous in processes involving water heating. Because of them, the surfaces of equipment in general, and heating elements in particular, become coated with a hard deposit that is difficult to remove and, over time, turns into scale (calcium deposits that adhere firmly and gradually increase in volume) [4, 5].

This is precisely what leads to reduced thermal conductivity, increased fuel and energy consumption, overheating of equipment, rapid breakdowns, and emergencies. To remove scale that has already been formed, it is necessary to purchase and use special cleaning agents. Acid solutions work quite well for this task, including hydrochloric, sulfuric, sulfamic, orthophosphoric, adipic, and several other acids dissolved in water at specific concentrations. Less aggressive cleaning gels are also effective. However, each cleaning session entails new expenses and downtime. Moreover, if something is done incorrectly (for example, choosing a cleaner incompatible with the equipment's materials or miscalculating concentration), it can accelerate equipment failure [6–8].

The best solution to this problem on an industrial scale is the installation of special water-softening filters. Presence of corrosive impurities. Corrosive impurities, various gases, acids, and salts, including sulfates, chlorides, oxygen, carbon dioxide, and others, when present in excess, catalyze corrosion processes on the surfaces of machinery and in piping systems, leading to rapid clogging and damage. Such problems are addressed through various types of degassing, comprehensive water treatment, pH adjustment, iron removal, and demineralization. In general, for the most effective water treatment at industrial facilities, it is important to have a thorough understanding of all possible types of contaminants that affect water quality and the methods for combating them: mechanical. Fine, insoluble impurities in the form of silt, sand, clay, and sludge [9].

The presence of inert debris degrades the quality and organoleptic properties of the water and adversely affects its physical and chemical parameters. Over time, suspended particles form a sediment that blocks the cross-sections of water supply pipes, leading to system failures. Mechanical impurities are removed through sedimentation and filtration. The equipment used for this purpose (settling tanks and filters) can vary widely, but the principle of operation is the same: mechanical sedimentation under the influence of gravity and pressure filtration; chemical methods. Dissolved substances present in water in significant quantities (the hardness salts, as well as iron and organic compounds). Bringing salt levels down to acceptable values in industrial water treatment focuses on mandatory treatment with ion-exchange resins, which results in the removal of excess calcium and magnesium ions from the water (softening). To remove iron, manganese, or non-ferrous metal ions, oxidation is carried out by bubbling oxygen into the water, followed by the precipitation of insoluble forms at the bottom of the tank or reservoir [10–12].

The process is accelerated using coagulants, which aggregate fine particles into larger particles that can be filtered or settled. To remove organic impurities, oxidation is performed using ozone, chlorine, and other powerful oxidizing agents. Surfactants are effectively removed by sorption filters, such as those containing activated carbon. Mineralization is normalized using reverse osmosis technology, which is based on the membrane principle. The pore size of the membranes is so small that only water molecules and dissolved gases can pass through them. This acts as an excellent barrier against mineral impurities. These impurities remain in special compartments until they are discharged into the drainage system; bacterial contaminants. This refers to bacteria and microbes that can cause infectious diseases in humans and animals [13, 14].

Chlorine, fluorine, and ozone are most used for water disinfection. One of the common, relatively new options is ultraviolet treatment, which effectively eliminates pathogenic microorganisms; radioactive contaminants. These are ions of radioactive metals (strontium, cesium, osmium) that contaminate the water. Fortunately, such contaminants are quite rare. When it comes to typical industrial water treatment, the decontamination stage is not included. This issue is addressed infrequently, not universally, and, for the most part, on a case-by-case basis [15].

The operations of power generation companies inherently require enormous amounts of water. This is arguably the most water-intensive industrial sector. Most of the water (more than 90%) is used to operate various cooling systems (turbine condensers, air and oil coolers, etc.). It serves as a heat transfer fluid and is often the working fluid in power plants. It is used to generate steam. For different types of boilers and operating pressures, the quality of the feedwater affects the quality of the water in the boiler after evaporation (boiler water) in different ways, as well as the frequency of blowdowns, which in turn determines the likelihood of salt deposits forming on the inner surfaces of the tubes, deposits that lead to excessive gas consumption. If the power generation system includes turbine units, the requirements for feedwater are even higher, as deposits may also form on the turbine blades during electricity generation [16].

Effective water treatment in such cases prevents or at least minimizes the overconsumption of natural gas required to generate the necessary energy. Wastewater at power facilities consists of any water flows removed from the cycle. This includes not only discharge water from cooling systems, but also water from steam generation systems, spent chemical solutions used for flushing and equipment preservation, regeneration and rinse streams from water treatment plants, materials containing petroleum products, as well as solutions and suspensions generated during the cleaning of heating surfaces [17]. The primary objective of water treatment at power plants is water desalination (partial or deep), the purpose of which is to remove impurities that cause deposits on heat exchange surfaces and equipment corrosion. Technological methods used include neutralization, flotation, sorption, coagulation, and flocculation. Water mixtures are settled, dewatered, and disinfected. Mechanical and biochemical treatment are also relevant here [18]. However, ion exchange technologies and evaporators are currently considered somewhat outdated in this context. Among their drawbacks are environmental unfriendliness, high energy consumption, and low automation. The latest trend is membrane-based technological solutions based on the principles of nanofiltration and reverse osmosis, or combined systems integrated with traditional methods [19–21].

Choosing the right technology is the most important prerequisite for the reliable operation of power plants, savings on operating costs, and a reduction in harmful environmental impacts. Thermal power plants naturally face heightened safety requirements, which depend in no small part on the quality of feedwater and recirculating water [22]. Proper water treatment is one of the key factors in preventing inefficiency and hazards. When performed correctly, it creates a barrier against scale formation, corrosion, and iron oxide deposits, thereby helping to address significant operational challenges.

Conclusions. The quality of water used by industrial enterprises largely determines the quality of the products they manufacture. Water purity must be monitored. If the water does not meet technical requirements, the production area dedicated to water treatment must be improved. Various filters (sedimentation, adsorption, mechanical), continuous-action water softening systems, dosing systems, disinfection systems, and other equipment are essential for achieving high-quality results.

Water contaminants can be highly diverse, and the choice of a water treatment method for a specific industrial facility depends primarily on the intended use of the water within its production facilities.

At thermal power plants, heightened safety requirements are naturally imposed, which depend in no small part on the quality of feedwater and recirculating water. Proper water treatment is one of the key factors in preventing inefficiency and hazards. When performed correctly, it creates a barrier against scale formation, corrosion, and iron oxide deposits, thereby helping to solve significant operational challenges.

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