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Study on "Zero Emission" Technology of Water Saving and Environmental Protection of Industrial Cooling Circulating Water

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Abstract

Under the background of global water shortage and increasingly serious environmental pollution problems, the efficient and environmentally friendly utilization of industrial cooling circulating water has become the key to realize industrial sustainable development. In this paper, the problems, present situation and development trend of "zero emission" technology for water saving and environmental protection of industrial cooling circulating water are deeply discussed. The research points out that although the technology faces many challenges in water quality treatment, energy consumption control, technology integration, investment cost and maintenance management, it is expected to gradually overcome these challenges through technological innovation, policy support and market promotion. This paper analyzes the problems encountered in the practical application of the existing technology, such as scaling corrosion, chemical pollution, high concentration multiple operation risk and the high cost and complexity of the new water-saving technology, and puts forward corresponding countermeasures and suggestions. In terms of technical development trend, intelligent monitoring and control system, high-efficiency water-saving technology, optimization of bypass filtration technology and expansion of application scope of closed cooling circulation system will become the focus of future research. At the same time, the breakthrough of "zero emission" treatment technology, such as the progress of membrane concentration and evaporation concentration technology, will also promote the development of industrial cooling circulating water treatment in the direction of high efficiency and low energy consumption. The research in this paper provides strong theoretical support and practical guidance for industrial water saving, environmental protection and sustainable development, aiming at promoting the wide application of "zero emission" technology and helping the green transformation of industrial production.

Keywords

"Zero emission"; water saving; environmental protection; industrial cooling circulating water.

1. INTRODUCTION

As an indispensable resource, cooling circulating water plays a vital role. It is not only a key factor to ensure the normal operation of production equipment, but also directly affects the quality and production efficiency of products. However, with the increasingly severe global

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water shortage and environmental pollution, how to use industrial cooling circulating water efficiently and environmentally has become an urgent task [1].

The use of industrial cooling circulating water is often accompanied by a large amount of water consumption and wastewater discharge. This not only aggravates the shortage of water resources, but also may cause irreversible damage to the environment [2]. Therefore, it is of great significance to explore and practice the water-saving and environmental protection "zero emission" technology of industrial cooling circulating water for realizing the sustainable development of industrial production.

This paper discusses the problems, present situation and development trend of water saving and environmental protection "zero emission" technology of industrial cooling circulating water. Through comprehensive analysis of relevant research results and technical progress at home and abroad, the challenges and shortcomings of current technology are revealed, and targeted countermeasures and suggestions are put forward. At the same time, the future development direction of this technology is prospected, which provides strong theoretical support and practical guidance for industrial water saving, environmental protection and sustainable development.

2. ANALYSIS OF TECHNICAL PROBLEMS OF "ZERO EMISSION"

2.1. Difficulties in technical realization

Table 1. Technical difficulties and influence analysis of "zero discharge" of industrial cooling circulating water

category	**content**
Difficulties in technical realization	(1) It is difficult to treat water quality: the efficient removal of various pollutants (suspended solids, dissolved solids, microorganisms, etc.) accumulated in industrial cooling circulating water. (2) High energy consumption: "zero emission" technologies such as reverse osmosis, evaporation and crystallization require high energy consumption, which increases the operating cost and the difficulty of technology promotion. (3) Complex technology integration: the "zero emission" system needs to integrate various technologies (pretreatment, membrane separation, evaporation and crystallization, etc.), which increases the difficulty of system design and operation. (4) High investment cost: the construction of "zero emission" system requires a large initial investment, which poses a burden to small and medium-sized enterprises. (5) High maintenance and management requirements: the "zero emission" system requires high professional skills and management level of operators, and improper operation affects the efficiency and stability of the system [5].
impact analysis	(1) Difficulty in popularization: high energy consumption and high investment cost make enterprises more cautious when adopting "zero emission" technology, which limits the rapid popularization of technology. (2) Limited application scope: enterprises with insufficient capital and technical strength are limited in applying "zero emission" technology, which affects the overall energy saving and emission reduction effect of the industry [6]. (3) Rising operating costs: High energy consumption and complicated maintenance management lead to rising operating costs, which affects the economic benefits of enterprises and the continuous application of technologies. (4) Technical progress demand: continuous innovation and progress are needed to reduce costs, improve efficiency and promote the wide application of "zero emission" technology.

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The water-saving and environmental protection "zero emission" technology of industrial cooling circulating water faces many challenges (as shown in Table 1), including efficient water purification technology needed to deal with accumulated pollutants such as suspended solids, dissolved solids and microorganisms; Supporting high energy-consuming processes such as reverse osmosis and evaporative crystallization will increase the operating cost; The design and operation complexity of integrating pretreatment, membrane separation and evaporation crystallization; And the need for a large initial investment in the construction of the system, which constitutes an economic burden for SMEs [3-4]. This kind of system also requires the operators to have high-level professional skills and management ability to ensure the effective operation of the system and avoid efficiency reduction or failure caused by improper operation.

These difficulties have significantly affected the popularization and application of "zero emission" technology. High energy consumption and investment cost make enterprises more cautious in adopting this technology, thus limiting its rapid popularization. For enterprises with limited capital and technical strength, it may be unrealistic to apply this technology, thus affecting the progress of energy conservation and emission reduction in the whole industry. At the same time, high energy consumption and complicated maintenance management increase the operating cost, which may weaken the economic benefits of enterprises and further hinder the continuous use of technology [7]. Therefore, in order to overcome these challenges and promote the wide application of "zero emission" technology, it is necessary to reduce costs and improve efficiency through continuous technological innovation.

2.2. Problems existing in the prior art

Industrial cooling circulating water system is an indispensable part of industrial production, and its application of water saving and environmental protection technology is of great significance to sustainable development. However, at present, these technologies face many problems and shortcomings in practical application (Figure 1).

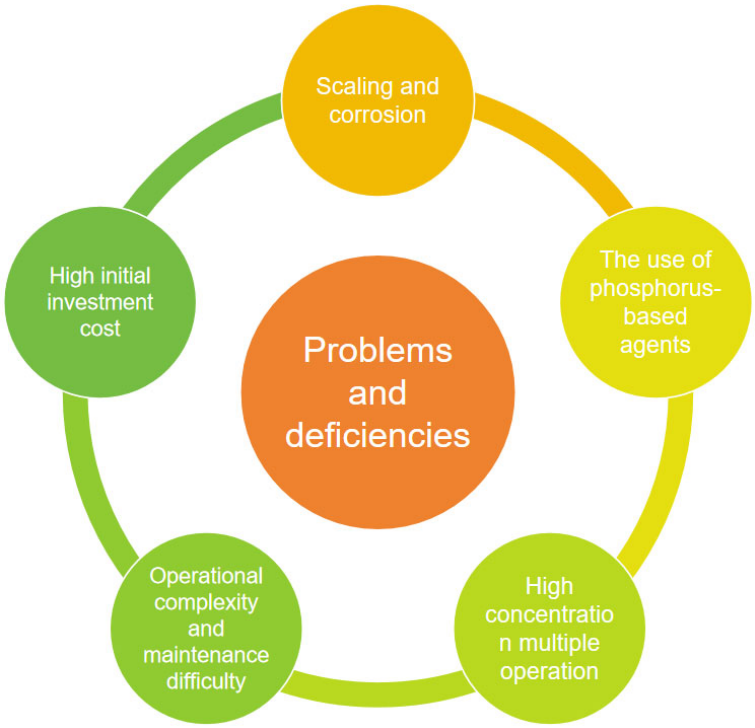

Figure 1. Problems and shortcomings in the prior art

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The industrial cooling circulating water system faces the problems of scaling and corrosion, which not only reduces the heat exchange efficiency of equipment and increases energy consumption, but also shortens the service life of equipment and increases the maintenance cost. Although phosphorus chemicals can effectively control these problems, their use promotes microbial reproduction, leads to environmental pollution and eutrophication, and is easy to form calcium phosphate scale, which affects the water-saving effect. In addition, high concentration multiple operation is helpful to improve the utilization rate of water resources, but it also increases the risk of scaling, which requires more effective scale inhibition technology and more monitoring and maintenance [8]. At the same time, although some advanced water-saving technologies have achieved remarkable results, they have increased operating costs due to complex operation and difficult maintenance, and high initial investment has constituted an economic burden for SMEs. Therefore, these factors together restrict the wide application of water-saving and environmental protection technologies.

The new water-saving and environmental protection technology faces the challenge of high cost and technical complexity. The research and application of this kind of technology requires enterprises to make a lot of initial investment in equipment purchase, installation and debugging and personnel training. The complexity of operation requires professional technicians to manage and maintain, which increases the operating cost, and the high concentration multiple operation and the application of new scale inhibition technology also enhance the frequency and difficulty of monitoring and maintenance. The water-saving and environmental protection "zero emission" technology of industrial cooling circulating water faces many challenges in practical application. It needs to solve these problems step by step through technical innovation, policy support and market promotion to promote the sustainable development of industrial cooling circulating water system.

3. DEVELOPMENT TREND AND COUNTERMEASURES OF "ZERO EMISSION" TECHNOLOGY

3.1. Technical development trend

(1) Development of intelligent monitoring and control system

With the development of Internet of Things and sensor technology, industrial cooling circulating water system is moving towards a new stage of intelligent monitoring and control. In the future, the system will be equipped with high-precision and high-sensitivity sensors to monitor key parameters including water temperature, water quality (pH value, conductivity, turbidity, microbial content, etc.), flow rate and pressure in real time, and optical sensors can more accurately detect the concentration of specific pollutants. Through dense and intelligent sensor network and wireless communication technology, data can be transmitted and shared quickly, so that operators can obtain system information and find potential problems immediately [9]. Intelligent control systems based on big data analysis and artificial intelligence algorithms will also be widely used, automatically analyzing monitoring data to predict water quality changes and equipment failures, and automatically adjusting control strategies, such as pump flow, cooling tower fan speed and dosage, to optimize cooling efficiency, reduce resource waste, ensure the system is in the best operating state, and help achieve the goal of "zero emission".

(2) Innovation of efficient water-saving technology

High efficiency heat exchanger will become the focus of research and development. Using new materials and advanced manufacturing processes, such as heat exchangers coated with nano-materials, can significantly improve the heat exchange efficiency and reduce the amount of cooling water. At the same time, the development of heat exchangers with special structures,

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such as microchannel heat exchangers, whose compact structure and efficient heat transfer performance can greatly reduce the volume of cooling system and the circulation of cooling water.

The compound cooling system of air cooling and water cooling will be more widely used [10]. In some areas where water resources are scarce, air cooling and water cooling equipment can be automatically switched or cooperated according to different working conditions and environmental conditions through reasonable configuration. For example, when the temperature is low or the equipment load is small, the air cooling system is given priority to reduce the evaporation loss of cooling water; When the temperature is high and the load is high, the water cooling system will intervene in time to ensure the cooling effect of the equipment and realize the optimal utilization of water resources.

Bypass filtration technology will be continuously optimized. The new by-pass filtration materials and filtration process can remove suspended solids and microorganisms in circulating water more effectively, improve the stability of water quality and prolong the service life of circulating water. For example, the bypass filtration system using membrane separation technology can accurately control the filtration accuracy, intercept tiny impurity particles, and reduce the demand for sewage discharge and water replenishment caused by water quality deterioration.

The application scope of closed cooling circulation system will be expanded. Compared with the open system, close system can effectively avoid the direct contact between cooling water and outside air, reduce the evaporation of water and the entry of pollutants, and significantly improve the recycling rate of water resources. In the future, the design of close system will pay more attention to energy saving and compactness, making it suitable for more types of industrial equipment and places, and providing strong support for realizing "zero emission".

(3) Breakthrough of "zero emission" treatment technology

The progress of membrane concentration and evaporation concentration technology is promoting the development of industrial cooling circulating water treatment to high efficiency and low energy consumption. In terms of membrane technology, the improvement of reverse osmosis membrane performance-including higher desalination rate, lower pollution rate, enhanced chemical resistance and high temperature resistance-and the application of new membrane components such as forward osmosis membrane will greatly increase the concentration multiple of cooling water and reduce the amount of wastewater by using natural osmotic pressure difference to reduce energy consumption. Evaporative concentration technology improves the efficiency and stability of the system by improving the design, such as using mechanical vapor recompression (MVR) evaporator to recover the heat of secondary steam, and combining with pretreatment processes such as softening and desilication. In addition, the integration of advanced oxidation technology, biological treatment and adsorption technology can effectively decompose refractory organic matter, and ensure that wastewater reaches the standard for discharge or reuse; However, resource recovery technologies, such as ion exchange, electrochemical deposition to recover metals, and crystallization and evaporation to recover salts, have realized the "eat dry and squeeze clean" of valuable resources in wastewater, which not only reduces pollutant emissions, but also brings economic benefits to enterprises and promotes the sustainable development of "zero emission" technology.

3.2. Countermeasure and suggestion

(1) Government level

At the government level, by formulating strict "zero emission" policies and regulations for water conservation and environmental protection, the responsibilities of enterprises for water conservation and environmental protection are clarified, and penalties are imposed on

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enterprises that fail to meet the standards to strengthen policy guidance. At the same time, the government has introduced incentives such as tax incentives and financial subsidies, such as tax relief for enterprises adopting advanced "zero emission" technologies and financial support for companies investing in related systems, so as to encourage enterprises to actively develop and apply new water-saving and environmental protection technologies.

(2) Infrastructure construction and supervision

Increase investment in infrastructure construction of sewage treatment and reclaimed water reuse in industrial areas to provide external conditions for enterprises to achieve "zero emission". Build a centralized sewage treatment plant, improve the recycling rate of reclaimed water, and reduce the cost of treating cooling circulating water in enterprises. Strengthen the supervision of cooling circulating water discharge in industrial enterprises and establish a perfect monitoring system. The advanced monitoring technology is adopted to monitor the cooling circulating water outlet of the enterprise in real time to ensure that the enterprise reaches the standard of "zero discharge".

(3) Enterprise level

At the enterprise level, we should strengthen the innovation and application of water-saving and environmental protection "zero emission" technology for cooling circulating water, develop technologies suitable for our own production characteristics by increasing R&D investment and cooperating with scientific research institutions, and actively introduce advanced technologies and equipment, upgrade and transform existing systems, and choose mature technical solutions with high cost performance. Enterprises also need to establish and improve the internal water resources management system, formulate detailed operating procedures, clarify job responsibilities to ensure the stable operation of the system, strengthen the training of employees in water conservation and environmental protection, improve their awareness and skills, and reduce the waste of resources and environmental pollution caused by human errors.

(4) Scientific research institution level

Strengthen the basic research on water-saving and environmental protection "zero emission" technology of industrial cooling circulating water, and explore new treatment principles and methods. For example, the mechanism of microorganism in cooling circulating water treatment is deeply studied, and a new treatment process based on microorganism technology is developed. Work closely with enterprises to carry out application development research. According to the actual needs of enterprises, the research results of the laboratory will be transformed into practical technologies and products, and the popularization and application of "zero emission" technology will be accelerated.

Pay attention to the cultivation of professional technical talents of cooling circulating water, water saving and environmental protection, and set up relevant professional courses in universities and vocational colleges to provide talent reserves for the development of the industry. Actively carry out technical exchange activities at home and abroad, and timely understand and master the international advanced "zero emission" technology trends. By holding academic conferences and technical seminars, we will promote the sharing and exchange of technical information and promote the development of "zero emission" technologies in China.

4. CONCLUSION

This study discusses the challenges, present situation and development trend of water saving and environmental protection "zero emission" technology of industrial cooling circulating water. The main obstacles to realize this technology include high-efficiency water treatment demand, high energy consumption and operation cost, complex technology integration, high initial

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investment and strict maintenance and management requirements, especially for small and medium-sized enterprises. There are still some problems in practical application, such as scaling, corrosion and microbial reproduction, which affect the efficiency and life of equipment and increase energy consumption and maintenance costs. Although the use of phosphorus-based chemicals can control these phenomena, it may cause environmental pollution.

In order to meet the above challenges, the research suggests that the government should encourage technological innovation by formulating strict policies and regulations and providing economic incentives; Strengthen infrastructure construction and supervision to ensure that enterprises meet the standards; Enterprises need to strengthen internal management and staff training, and improve the awareness and technical level of water conservation and environmental protection; Scientific research institutions should focus on basic research, explore new methods and cooperate with enterprises to develop applied technologies to promote information sharing. Looking forward to the future, the development trend of "zero emission" technology includes intelligent control system, high-efficiency water-saving technology innovation, application of composite cooling system and progress of membrane concentration and evaporation concentration technology, which will promote the development of industrial cooling circulating water treatment in the direction of higher efficiency and lower energy consumption. Through multi-party cooperation, it is expected to overcome the current challenges and support the goals of industrial water saving, environmental protection and sustainable development.

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