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Incentive Effect and Optimization Path of Environmental Tax on Wastewater Treatment in the Papermaking Industry

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Abstract: *This article takes China's papermaking industry as the research object, analyzes the current status of wastewater treatment and the implementation characteristics of environmental protection tax, evaluates the incentive effect of environmental protection tax, points out existing problems, and proposes optimization paths. The papermaking industry is a high water-consuming and high-polluting industry. Since the implementation of the environmental protection tax in 2018, the industry has achieved significant emission reduction results, promoted the upgrading of wastewater treatment technology, and reshaped the pattern of the papermaking industry. However, there are still problems such as insufficient adaptability of the environmental protection tax to green development practices, insufficient coordination of management and administration, and lack of policy support for small and medium-sized enterprises. In the future, it is necessary to support green transformation through environmental protection taxes, strengthen supervision, monitoring and management, and combine green finance to promote the sustainable development of the industry.*

Keywords: *environmental tax; papermaking industry; waste water treatment*

1. Introduction

The paper-making industry, as an important basic industry in China's national economy, is also a typical high-water consumption and high-pollution sector. With the increasingly strict environmental protection requirements, the issue of wastewater discharge in the paper-making industry has attracted much attention. As the main tax type in the green tax system, the environmental protection tax, with its regulatory mechanism of "more pollution, more taxation; less pollution, less taxation; no pollution, no taxation", guides enterprises to voluntarily reduce pollution emissions and empowers ecological environment governance. The introduction of the "Environmental Protection Tax Law of the People's Republic of China" in 2018 effectively enhanced the social responsibility of enterprises, providing new impetus for paper-making enterprises to complete transformation and upgrading and achieve green development.

2. Current Situation of Wastewater Treatment in the Paper Industry and Characteristics of Environmental Tax Implementation

2.1 Overview of Wastewater Treatment in the Paper Industry

The pollutants in wastewater from the paper industry are closely related to the production process and raw material types. There are various methods for pulping, including chemical, semi-chemical, chemical-mechanical, and mechanical methods. The wastewater mainly comes from pulping and cooking waste (black liquor), washing wastewater, bleaching wastewater, and paper machine white water. Among them, black liquor generated during cooking is the most severely polluted, containing a large amount of organic substances, difficult-to-degrade fibers (such as lignin and its degradation products), and inorganic salts. The composition of washing wastewater is similar to that of black liquor but with a lower concentration. For example, if chlorine-based bleaching agents are used, the bleaching wastewater will produce toxic substances such as adsorbed organic halogens, phenols, and dioxins.

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As environmental protection requirements become increasingly strict, traditional monitoring methods have been unable to meet the needs of high-precision and real-time monitoring. Online monitoring technology has emerged, significantly improving the efficiency and accuracy of monitoring. In the wastewater pretreatment stage, enterprises monitor key indicators such as suspended solids (SS), chemical oxygen demand (COD), and pH value to effectively remove macromolecular pollutants, laying the foundation for subsequent deep treatment [1]. In the deep treatment stage, technologies such as biological treatment and advanced oxidation are adopted to further purify dissolved organic matter, nitrogen, phosphorus, and heavy metals.

The pollution treatment capabilities of paper enterprises vary. Although the paper industry in China has achieved rapid development, from the market composition perspective, there are still a large number of small enterprises, which have significant gaps in technical reserves and resource integration capabilities compared to large and medium-sized enterprises. Small paper enterprises have insufficient pollution treatment capabilities and lack financial support, resulting in limited direct pollution control effects and unable to meet environmental protection requirements.

2.2 Overview of Environmental Tax for the Paper Industry

Since January 1, 2018, China has implemented the "Environmental Tax Law", replacing the previous pollutant discharge fee system with environmental tax. This legal measure strengthens pollution control through legal means. In the paper industry, environmental tax is mainly levied on water pollutants (such as chemical oxygen demand, ammonia nitrogen, total phosphorus, suspended solids, etc.) and air pollutants. The tax rate standard adopts a differentiated design of "national set the bottom line, local can increase", aiming to create significant regional differences. According to the regulations, the basic tax rate for water pollutants is 1.4 yuan per pollution unit, and the basic tax rate for air pollutants is 1.2 yuan per pollution unit. Local governments can adjust within a 10-fold range to achieve regional differences.

From the perspective of regional distribution, environmentally sensitive areas and economically developed provinces usually implement higher tax rates. For example, Beijing has raised the water pollutant tax rate to 10 times the benchmark (14 yuan per pollution unit) to strengthen pollution control; Guangdong and Jiangsu provinces in the coastal areas set the water pollutant tax rate at 2.8 - 6 yuan per pollution unit, and the air pollutant tax rate at 2.8 - 6 yuan per pollution unit; while provinces in the central and western regions such as Shanxi and Gansu mostly levy at the benchmark or slightly higher (1.4 - 2.8 yuan), aiming to balance economic development and environmental protection. This differentiated design aims to guide high-pollution enterprises to transfer to regions with larger environmental capacity, while also compelling the paper industry to optimize production processes and improve pollution control levels. The policy also stipulates that if the emission concentration of enterprises is lower than 50% of the national standard, they can enjoy a 50% tax reduction; if they exceed the standard, they need to pay double the tax. In addition, local governments can further strengthen supervision of key polluting enterprises, forming a "heavy pollution - high burden" constraint mechanism.

2.3 Divergent Responses of Paper Industry Enterprises to Environmental Tax

With the tightening of environmental protection policies, the responses of paper-making enterprises to environmental taxes have shown significant differences. Large enterprises, leveraging their financial and technological advantages, actively adopt advanced oxidation, membrane separation, and biological enhancement technologies for deep treatment to achieve emission reduction and efficiency improvement[2]. For instance, advanced oxidation technology decomposes refractory organic substances through strong oxidants, membrane separation technology utilizes a combined ultrafiltration and reverse osmosis process to achieve wastewater reuse and zero discharge, and biological enhancement technology introduces efficient microorganisms to enhance treatment efficiency. These technologies not only meet environmental protection requirements but also reduce long-term tax burdens, forming a virtuous cycle of "technology upgrade - cost saving - policy compliance". However, enterprises with medium and low-end production capacity, mainly small-sized ones, face issues such as insufficient pollution control capabilities and lack of funds[3]. Some enterprises, unable to bear the cost of technological transformation, choose to pay taxes passively, treating environmental taxes as a fixed cost, but may be eliminated by the market due to a decline in competitiveness in the long run; other enterprises take risks by concealing emission data and evading supervision, further exacerbating environmental risks. Such enterprises often suffer from weak tax planning capabilities, misunderstandings of policies, incomplete information disclosure, or even penalties due to improper use of tax incentives, forming a vicious cycle of "insufficient pollution control - increased tax burden - illegal risks". Policy uncertainty further amplifies

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this differentiation trend. The environmental protection industry heavily relies on tax incentives, but policy adjustments may cause a sudden increase in enterprise tax burdens. Tax compliance issues for cross-border business (such as transfer pricing) also increase operational risks. Additionally, some enterprises, due to short-sighted management decisions, overly rely on tax incentives and neglect technological investment, or lack professional teams leading to ineffective planning schemes, exacerbating tax risks. In the future, the industry needs to optimize pollution control efficiency through technological innovation and system integration, and establish multi-dimensional tax risk review mechanisms to achieve a balance between environmental compliance and sustainable development.

3. Evaluation of the Incentive Effect of Environmental Taxes on Wastewater Treatment in the Paper Industry

3.1 The emission reduction achievements of the paper industry are remarkable

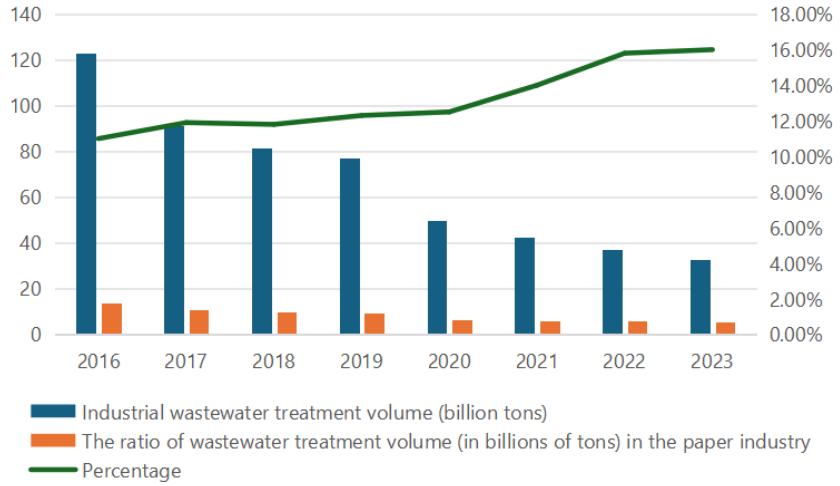

Fig.1 Statistics of Chemical Oxygen Demand Emissions from Industrial Waste water in the papermaking Industry from 2016 to 2023.

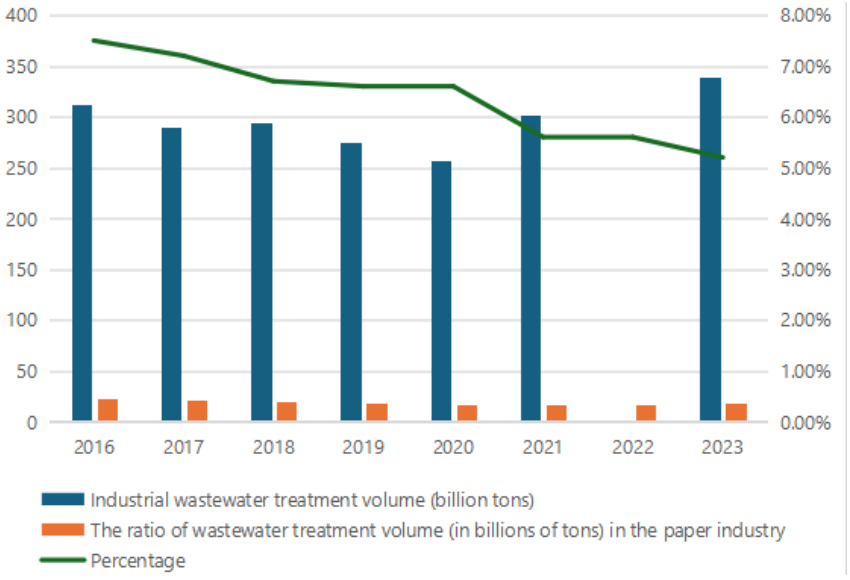

Fig.2: Statistics of Waste water Treatment Capacity and Discharge in the papermaking Industry from 2016 to 2023.

Since the implementation of the environmental protection tax, the paper industry, as an important source of industrial wastewater and chemical oxygen demand (COD) emissions, has achieved remarkable emission reduction results. According to the statistics in the "Environmental Statistics Annual Report 2016-2023" of the Ministry of Ecology and Environment, from the perspective of total emissions, the

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COD emissions of the industrial sector have continuously decreased from 910,000 tons in 2017 to 326,000 tons in 2023, with a reduction rate of 64.2% (see Figure 1), reflecting a significant overall pollution control effect. Although the COD emission proportion of the paper industry fluctuated slightly in some years, it generally showed a downward trend. It rose slightly from 11.90% in 2017 to 11.80% in 2018, and then increased to 16% in 2023, indicating that its emission reduction speed is still lagging behind the overall level of the industry. However, it also shows that the industry is continuously promoting governance through structural adjustment.

At the same time, the volume of industrial wastewater treatment has shown a fluctuating upward trend, increasing from 28.957 billion tons in 2017 to 33.91 billion tons in 2023 (see Figure 2). The treatment capacity has increased by approximately 17.1%, reflecting the enhancement of pollution control infrastructure investment and operational efficiency. Considering the changes in emissions and treatment volumes, the concentration of pollutants has also shown a downward trend, with a significant reduction in the load of COD per unit of wastewater. The environmental protection tax has effectively incentivized enterprises to adopt a dual-governance strategy of end-of-pipe treatment and process optimization by increasing the emission cost. This changing trend indicates that the environmental protection tax policy not only promotes the expansion of wastewater treatment scale in the paper industry but also enhances the efficiency of pollutant removal, providing data support and practical paths for deepening the green transformation of the industry.

3.2 Upgrading of Paper Industry Wastewater Treatment Technology

Under the incentive effect of environmental protection tax on wastewater treatment in the paper industry, the iteration of wastewater treatment processes and the application of advanced technologies have become the key to the industry's green transformation[4-5]. The environmental protection tax uses economic levers to encourage enterprises to actively optimize wastewater treatment, promote process upgrading and the implementation of new technologies, achieving a win-win situation of environmental and economic benefits. In terms of process iteration, paper enterprises, based on the cost constraints of environmental protection tax, deeply optimize the traditional wastewater treatment process. In the treatment of pulp and paper wastewater, by strengthening the solid-liquid separation stage, upgrading efficient clarification and filtration equipment, improving the efficiency of fiber resource recovery, reducing pollutant emissions, and lowering the subsequent treatment load, while recovering resources to offset the pressure of environmental protection tax costs. For different wastewater sections, detailed segmented treatment processes are refined, adjusting the microbial community to adapt to the water quality, improving the efficiency of biochemical treatment, reducing pollutants at the source, and lowering the base for calculating environmental protection tax.

In terms of physical and chemical methods, a new stepped multi-level screening device has been applied in a certain paper mill, dynamically adjusting the density of sieve holes to adapt to different pulp fiber sizes, reducing equipment blockage, improving fiber retention rate, helping with fiber recovery and reuse, and reducing raw material consumption and the generation of wastewater pollutants[6]; ozone catalytic oxidation technology has broken through the treatment of organic chlorides in bleaching wastewater, introducing transition metal catalysts, strengthening the destruction of the benzene ring structure, deep degradation of harmful substances, reducing wastewater toxicity, and lowering the risk of environmental protection tax payment. In the field of biological methods, a new two-phase anaerobic reactor has been put into use in the anaerobic treatment section, through physical separation of the acid-producing phase and the methane-producing phase, alleviating the inhibition of volatile fatty acids on methane bacteria, stabilizing the reaction environment, improving anaerobic treatment efficiency, accelerating the decomposition of organic matter; in aerobic treatment, surface microporous structure composite fillers are promoted, promoting microbial attachment and efficient oxygen transfer, enhancing microbial activity, improving the ability to degrade pollutants, ensuring the effluent meets the water quality standards, and reducing the penalty for excessive discharge.

Integrated treatment and resource utilization technologies have also achieved remarkable results. The membrane technology and biological treatment coupling system precisely separates pollutants, retains useful small molecule organic substances, realizes wastewater resource utilization, such as recycling small molecules for the preparation of high-value chemicals[7]. The process of extracting wood fiber resources is controlled by parameters such as pH value and temperature to separate wood fibers for the preparation of spices, resins, etc., thereby enhancing the utilization rate of resources. The value-added from resource utilization is used to offset the cost of environmental protection taxes. Large and medium-sized industrial enterprises adopt membrane treatment technology to reuse production wastewater, thereby reducing the emission of taxable water pollutants and directly lowering the amount of

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environmental protection tax to be paid. In the long run, the virtuous cycle of "reduction in emissions - tax savings - resource recycling" brought about by the initial investment in technology can offset the environmental protection tax and even generate additional economic benefits (such as reducing the cost of purchasing new water, obtaining government environmental protection subsidies).These technological applications enable enterprises subject to environmental protection taxes to achieve simultaneous improvement in both wastewater treatment and economic benefits through process iterations and technological innovations, providing a reference path for the green development of the paper industry.

3.3 Environmental Protection Tax Reshapes the Paper Industry Landscape

The implementation of the environmental protection tax is profoundly reshaping the market landscape of the paper industry. Currently, the industry concentration is low, with the top 10 enterprises accounting for only 42% of the total output, far below the international level, while small enterprises with an annual output of less than 30,000 tons still account for 68% of the total. The environmental protection tax has significantly increased the survival pressure of small enterprises through a differentiated tax burden mechanism: their cost-effective "pre-treatment + enhanced physicochemical treatment" processes can only maintain basic treatment effects, but in the context of increasing compliance costs due to the upgrading of organic matter and dioxin treatment standards, the continuous rise in compliance costs has exceeded the affordability of enterprises with insufficient capital and technical reserves. The imbalance in regional distribution further exacerbates this predicament; for example, the transportation distance of sugarcane bagasse pulp in Guangxi exceeds 1,500 kilometers, and the combined logistics costs and environmental protection tax burden force 68% of small-capacity production capacity to accelerate their exit from the market. On the contrary, large-scale enterprises adopt a full-process governance model of "source reduction - process control - end-of-pipe resource utilization" to enhance wastewater reuse rates through fiber recycling, white water recycling, and dual-membrane treatment. They also utilize resource recovery technologies such as extracting lignin from black liquor and recovering sodium sulfate to generate additional profits, effectively offsetting environmental protection tax burdens. Leading enterprises further reduce unit governance costs through intelligent control systems, promoting the industry's development towards clustering and intensification. The environmental protection tax thus becomes a hidden driver for industry consolidation, facilitating the concentration of advantageous resources towards leading enterprises and significantly enhancing market concentration.

4. Implementation Issues of Environmental Tax in Wastewater Treatment in the Paper Industry

4.1 Inadequate Adaptation of Environmental Tax to Green Practices in Paper Production

Environmental tax has certain issues in adapting to green practices such as clean production and waste recycling in paper production. In clean production and waste recycling, enterprises utilize technologies to reduce pollution and turn waste into resources. However, environmental tax is calculated based on pollutant emissions and does not provide sufficient incentives for innovative emission reduction. It is difficult to match the circular economy model. When developing green products such as biomass materials, enterprises invest heavily, but environmental tax lacks preferential policies for the research and development stage, making it difficult to alleviate financial pressure. When optimizing production processes and supply chain management, enterprises reduce pollution throughout the process. However, the tax collection and management of environmental protection tax are not connected to the green aspects of the supply chain, making it impossible to precisely incentivize full-chain emission reduction. These issues make environmental protection tax difficult to effectively align with the green innovation rhythm of paper enterprises, weaken the incentive for wastewater treatment, and require solving coordination problems to better support industry green development.

4.2 Inadequate Coordination of Environmental Tax Collection and Management in the Paper Industry

The effective collection and management of environmental protection taxes heavily rely on accurate environmental monitoring data and strict law enforcement mechanisms. However, at present, there is still a significant lack of coordination in the monitoring and law enforcement processes within the paper industry. On one hand, monitoring equipment is susceptible to environmental interference. Some enterprises exploit technical loopholes or manipulate data, resulting in distorted emission data that fails to accurately reflect the pollution situation. On the other hand, there is a laxity in the law enforcement

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process. Due to local protectionism, limited regulatory resources, or insufficient technical capabilities, environmental violations are often inadequately punished, failing to create an effective deterrent. The information sharing and linkage mechanism between monitoring and law enforcement is not sound, leading to doubts about the quality of data used for environmental protection tax collection, and causing a disconnect between actual collection and emission behavior, thereby weakening the policy incentive effect of the tax[8]. To truly exert the guiding and restrictive role of environmental protection taxes on wastewater treatment in the paper industry, it is necessary to strengthen cross-departmental collaboration, improve data authenticity and enforcement rigidity.

4.3 Insufficient Policy Support for Small and Medium-sized Paper Enterprises

Although environmental tax has provided positive incentives for wastewater treatment in the paper industry, small and medium-sized paper mills still face a policy gap. On one hand, small paper mills have a large historical backlog of environmental protection facilities, with lagging wastewater treatment construction and unstable operation. Environmental tax directly increases their compliance costs, but due to the lack of differentiated exemptions, subsidized loans, and other fiscal tools, enterprises find it difficult to cross the investment threshold. On the other hand, there is a lack of technological reserves for clean production and resource utilization, and support such as green innovation subsidies, technical service platforms, and shared pollution control facilities is absent, leaving enterprises with no choice but to pay the pollutant tax rather than actively upgrading processes. If policies cannot be fully complemented in terms of funds, technology, and public services, the leverage effect of environmental protection tax will be diluted by high costs and low capabilities, and the overall wastewater reduction target of the industry will be difficult to achieve.

5. Paths and Policy Suggestions for Optimizing the Incentive Effect of Environmental Tax

5.1 Environmental Tax Facilitates Green Transformation of the Paper Industry

The green and low-carbon transformation of the paper industry needs to be promoted in multiple dimensions. The environmental protection tax can thereby establish a collaborative incentive system for the environment. In terms of the application of green technologies, for enterprises that adopt processes such as all-chlorine-free bleaching and closed-loop water use, the environmental protection tax offers tax exemptions to encourage the development of functional green products like biodegradable packaging paper, and adjusts the tax calculation based on the green added value, motivating enterprises to reduce waste and treat water through technology. In the optimization of the energy structure, for enterprises that promote the clean transformation of coal-fired boilers and increase the application of renewable energy sources like solar power, the environmental protection tax provides preferential treatment based on energy transition investment, and reduces the tax amount according to the reduction in unit product energy consumption, encouraging enterprises to save energy and reduce pollution. In terms of circular economy management, enterprises that improve the waste paper recycling system will receive stepped tax incentives based on factors such as the utilization rate of waste paper recycling and the reduction in pollution through product ecological design. The "producer responsibility extension" incentive will be strengthened. Through the multi-dimensional synergy of the environmental protection tax and the green transformation, the incentive effect on wastewater treatment in the paper industry will be amplified, driving the industry towards green development[9].

5.2 Strengthening Monitoring to Facilitate Tax Collection in the Paper Industry

In the management of environmental tax collection in the paper industry, monitoring data is the key basis, but it faces problems such as fraud and inconsistent quality. To strengthen monitoring and facilitate coordinated tax collection, the following three aspects can be considered: First, increase the research and development of environmental monitoring technologies in the paper industry, encourage academic, industrial and research cooperation to tackle the monitoring of complex media and new pollutants, improve the accuracy and stability of equipment, through standardized research to unify quality control and monitoring methods, making the tax calculation data reliable and comparable, and preventing tax collection disorder caused by inaccurate data at the source; Second, improve the quality control system for monitoring data of paper enterprises, regulatory departments urge enterprises to calibrate and maintain monitoring equipment, strengthen personnel training and assessment, establish a data review and evaluation mechanism, strengthen comparison and sharing among different monitoring institutions,

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ensure that the data entering the tax collection process is true and reliable, providing support for the precise collection of environmental tax[10-11]; Third, optimize the management of monitoring costs, the government provides tax incentives and financial subsidies to support enterprises to rationally allocate monitoring resources, such as stable pollution discharge enterprises adopt a combination of regular spot checks and online monitoring, which not only reduces the monitoring costs of enterprises but also ensures the quality of tax collection data, laying a solid foundation for tax collection coordination with high-quality monitoring data, solving the problem of lenient law enforcement and fraud caused by data issues, and helping the environmental tax effectively motivate wastewater treatment in the paper industry.

5.3 Green Finance Supports Environmental Protection Tax Incentives for Paper Industry

The green transformation of the paper industry requires substantial investment in funds and technologies, and the effectiveness of the environmental protection tax incentive mechanism also depends on the improvement of enterprises' pollution control capabilities. Securing national industrial policies and green financial support can provide multi-dimensional assistance: enterprises should closely follow policies such as energy conservation and emission reduction, and apply for special funds, discounted loans, etc. For example, applying for the "Industrial Green Development" special project to build a clean production demonstration project, obtaining financial support to carry out green technology research and development, and improving the level of pollution control, so that the environmental protection tax can be more effectively incentivized through the reasonable allocation of enterprises' pollution control costs[12]; utilizing market-based mechanisms such as pollution rights trading, enterprises can activate environmental capacity resources to obtain renovation funds. Green financial innovation products (green loans, bonds, etc.) can broaden financing channels, reduce the financial pressure of enterprises for pollution control, and motivate enterprises to respond to the environmental protection tax guidance and increase investment in wastewater treatment; relevant departments should guide industrial capital and venture capital to participate in the research and development of green pulp and paper production technology. Through joint ventures and industrial alliances to integrate resources, the foundation for enterprises' green innovation funds can be strengthened, and the ability of enterprises to cope with environmental protection tax constraints and incentives can be enhanced. With an external financial support system, the incentive effect of the environmental protection tax on wastewater treatment in the paper industry can be strengthened, promoting the green development of the industry.

5.4 International Experience Empowers Environmental Protection Tax Incentives for Paper Industry's Water Pollution Reduction

Many countries around the world have promoted green transformation in the paper industry through the combination of environmental taxes and industrial policies. Through forestry policies and tax incentives, Brazil encourages enterprises to increase forest output, build factories scientifically, reduce reliance on imported wood pulp, and grants tax exemptions to enterprises that adopt water-saving and clean production methods, forming a virtuous mechanism of "green investment - tax incentives - continuous emission reduction". Nordic countries such as Sweden and Finland implemented dynamic adjustment mechanisms of environmental taxes linked to pollutant emission concentrations and water resource efficiency earlier, providing rewards to enterprises with high wastewater reuse rates, and using part of the tax revenue to support technological upgrades and green infrastructure of enterprises, forming a "taxation - refund - promotion" closed-loop incentive. Japan relies on the "Water Pollution Prevention Act" to strictly enforce emission standards and provides technical support and monitoring norms for small and medium-sized enterprises through industry associations.

International experience shows that environmental protection taxes should become an important policy lever for the green transformation of industries. China can draw on the "differentiated taxation based on emissions" principle, establish a tax rate mechanism dynamically linked to indicators such as emission concentration and reuse rate, and use part of the tax revenue to support technological upgrades and green innovation of small and medium-sized enterprises, through "policy - technology - funds" synergy, to enhance the guiding role of environmental protection taxes in wastewater treatment, achieving environmental and economic win-win results.

6. Conclusion

Environmental protection taxes have driven profound changes in wastewater treatment in the paper industry: Large enterprises achieve emission reduction and efficiency improvement through

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technological upgrades, industry resources are concentrated towards dominant enterprises, and total emission reduction and process iteration have achieved remarkable results. However, problems such as the survival predicament of small and medium-sized enterprises, the mismatch between policies and green practices, and shortcomings in tax collection and management coordination still restrict the full release of the incentive effect of environmental protection taxes. In the future, efforts should be made in multiple dimensions such as optimizing policy design (such as differentiated incentives, connecting green innovation), strengthening monitoring and law enforcement coordination, and improving the green financial support system to break the vicious cycle of "high treatment costs - insufficient technology investment - large compliance pressure". Only by integrating environmental protection taxes with industrial policies, technological innovation, and market mechanisms can the industry shift from "passive pollution control" to "active transformation", providing support for achieving the "carbon neutrality" goal and high-quality development, and promoting the industry to move towards a sustainable future in the balance between ecological constraints and economic development. In the future, with the popularization of green technologies, digitalization of environmental protection tax collection, and deepening of green financial coordination, environmental protection taxes will precisely incentivize the paper industry. They will help large enterprises deepen "technological emission reduction - resource value increase", help small and medium-sized enterprises break the "high cost - low technology" predicament, promote the industry to move from "passive emission reduction" to "active green value increase", and promote sustainable development of the industry.

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