Research on Correlation Between Industrial Water Consumption and Economic Benefit Based on Frequency Analysis and Principal Component Analysis

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Abstract. Water is a basic natural and strategic economic resource, and is an important material basis for economic and social development. In this paper, the water consumption and industrial added value of key water industries within the county area (Qiantang District is selected as the research object) are investigated and counted. The frequency analysis method and principal component analysis method were used to analyze the industry benchmark value and influencing factors of water efficiency evaluation index (added value of unit water consumption), and put forward the countermeasures to improve industrial water efficiency. It will provide a theoretical basis and reference for the subsequent water resources management of key water use industries.

Keywords: Water consumption; Industrial added value; Principal component analysis.

1 Introduction

At present, Chinese industrial economy is in a critical period of green transformation. Resource and environmental issues are intertwined, and the development space of industrial economy is shrinking. It is of great significance to carry out research on industrial water use efficiency to alleviate industrial water resource shortage and optimize industrial water resource allocation. Chinese total economic and social water consumption is 590.65 billion m^3 in 2023, of which industrial water is 97.02 billion m^3, accounting for 16.4% of the total water. the water consumption rate of industrial water is 22.2%. In order to adhere to the priority of conservation and implement a comprehensive conservation strategy, the Ministry of Industry and Information Technology and other departments issued the Action Plan for Industrial Water Efficiency Improvement in 2022, aiming at realizing the economical and intensive recycling of industrial water resources.

By 2025, the water consumption of 10,000 yuan of industrial added value will be reduced by 16% compared with 2020. The water efficiency of key water use industries will have been further improved. The water withdrawal per ton of steel in the steel industry and the water withdrawal per unit of main products in the paper industry will

Y. Zhang et al. (eds.), *Proceedings of the 2024 10th International Conference on Architectural, Civil and Hydraulic Engineering (ICACHE 2024)*, Advances in Engineering Research 259,
https://doi.org/10.2991/978-94-6463-658-1_48

have decreased by 10%. The water withdrawal per unit of main products in the petrochemical and chemical industry will have decreased by 5%. The water withdrawal per unit of main products in the textile and food industries will have decreased by 15%. Promoting the improvement of industrial water efficiency is an internal requirement to promote the transformation of industrial water use from extensive and inefficient to intensive and economical utilization, an important way to alleviate the contradiction between supply and demand of water resources in China and ensure water security.

Since the end of the 20th century, some scholars have studied water use efficiency, It mainly focuses on efficiency evaluation and analysis of influencing factors [1]. In terms of the analysis of influencing factors of comprehensive water use efficiency, some scholars believe that industrial structure, economic level, import and export demand, technological progress, growth of technical efficiency, per capita education expenditure, regional water resource allocation and development utilization rate, water resource price and government influence have an impact on water resource use efficiency [2]. Chen divided the influencing factors of industrial water use efficiency into regional economic development, the proportion of industry in GDP, scientific and technological funding input, and per capita water resource use [3].

In general, the existing researches mainly focus on the analysis of the influencing factors of the comprehensive utilization efficiency of water resources. From the perspective of the driving factors and efficiency level of industrial water use efficiency, the research on the zoning of industrial water use efficiency is rare. This paper analyzed the changes of regional industrial water use and economic benefits from 2019 to 2023 with different methods in Qiantang District, and studied the influencing factors of industrial water efficiency index. It will provide a theoretical basis for China to establish industrial water efficiency evaluation, carry out industrial water efficiency improvement actions, further improve the intensive use of water resources, optimize the allocation of water resources.

2 Data Sources and Analysis Methods

2.1 Data Source

The water resources data of the whole district are derived from the Hangzhou Water Resources Bulletin (2019-2023) and the water sales data of water groups in the region. The basic economic and social data of the industry are derived from the Qiantang District Statistical Yearbook (2019-2023) and the National Economic Bulletin. This paper selected industrial water enterprises with annual water consumption of more than 10,000 tons in Qiantang District as the research object. The correlation between water consumption and economic benefits of key industries in Qiantang District was analyzed.

2.2 Analytical Method

2.2.1 Frequency Analysis Method.

Frequency analysis is a way to calculate the frequency of different values of a set of data, or the frequency of data falling into a specified area, and understand its data distribution. Frequency analysis can reflect whether the sample has overall representativeness and whether there is systematic bias in sampling to a certain extent, and thus prove the representativeness and credibility of future analysis of related issues [4].

2.2.2 Principal component analysis.

Principal component analysis is to try to combine the original multiple indicators into a set of unrelated comprehensive indicators, and select fewer comprehensive indicators according to actual needs to reflect the information of the original indicators as much as possible [5].

Suppose that the study of a certain thing involves p indicators, using X_1, X_2, ... X_p means that the P-dimensional random vector formed by these p indicators is X= (X_1, X_2, ... X_p). Let the mean of the random variable be u, the covariance matrix is ε.

A linear transformation of X can form a new composite index, represented by Y, the new composite index can be represented linearly by the original index.

$$\begin{cases} Y_1 = u_{11}X_1 + u_{21}X_2 + \ldots + u_{p1}X_p \\ Y_2 = u_{12}X_1 + u_{22}X_2 + \ldots + u_{p2}X_p \\ \ldots\ldots \\ Y_p = u_{1p}X_1 + u_{2p}X_2 + \ldots + u_{pp}X_p \end{cases}$$

Since the above linear changes can be carried out arbitrarily on the original index, the statistical characteristics of the comprehensive index obtained by different linear transformations are not the same. Synthetic variables Y_1, Y_2, ... Y_p is called the principal component of the original variable respectively, in which the proportion of each variable in the total variance decreases in turn, and the largest principal component dimension reduction analysis is selected in the actual analysis. The advantage of principal component analysis is to construct a few new synthetic variables from the original variables, so that the synthetic variables are linear combinations of the original variables.

3 Study on Industrial Water Efficiency Reference Value

According to the national, provincial and municipal three key monitoring water units list. The key water industry is divided into textile, chemical, food and other industries in Qiantang District. The detailed distribution of various types is shown in Table 1.

Table 1. Industry classification by region.

Industry	Industry classification of national economy	Number
Textile	Textile and garment industry, garment industry, textile industry, chemical fiber manufacturing industry	38
Chemical	Processing of petroleum, coal and other fuels, manufacturing of chemical raw materials and chemical products, rubber and plastic products	48
Food	Agricultural and sideline food processing, food manufacturing, wine, beverage and refined tea manufacturing	13
Others	Other manufacturing	155

The frequency analysis method was used to analyze the added value of unit water consumption (the ratio of industrial added value to industrial water consumption). The reference value under different frequencies was studied. The results are shown in Figure 1-4 and Table 2. The added value of unit water consumption of chemical, textile and food industries are significantly lower than that of other industries in Qiantang District from Table 2.

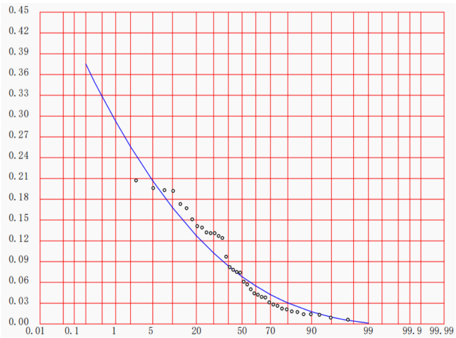

Fig. 1. Frequency diagram of added value per unit water consumption of chemical industry

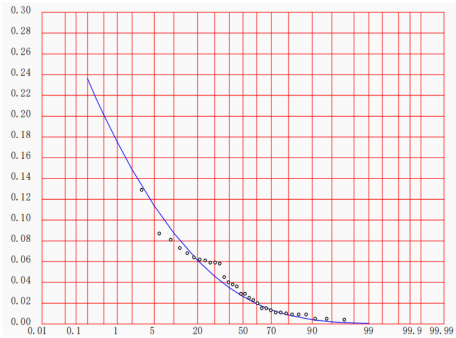

Fig. 2. Frequency diagram of increased value of unit water consumption of textile industry

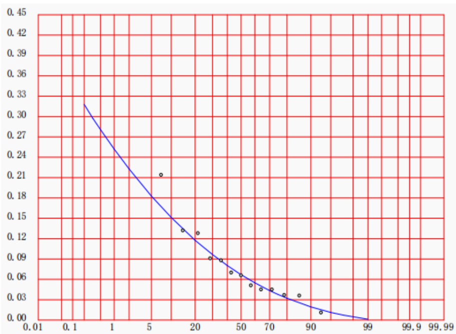

Fig. 3. Frequency diagram of added value per unit water consumption of food industry

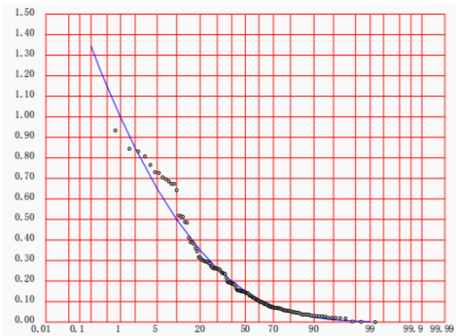

Fig. 4. Frequency diagram of added value per unit water consumption of other industries

Table 2. Water industry unit water consumption added value frequency analysis.

Frequency		**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
Reference value of added value of unit water consumption (ten thousand yuan /m^3)	Textile	0.168	0.127	0.102	0.084	0.068	0.055	0.042	0.030	0.018
	Chemical	0.088	0.061	0.046	0.035	0.026	0.019	0.014	0.008	0.004
	Food	0.151	0.118	0.096	0.08	0.067	0.055	0.043	0.032	0.019
	Others	0.499	0.349	0.261	0.199	0.151	0.111	0.078	0.049	0.023

4 Influencing Factors of Industrial Water Efficiency

From the definition of the added value of unit water consumption, the added value of unit water consumption is the ratio of industrial added value to industrial water consumption. Therefore, the selection of influencing factors must be considered from the aspects of industrial water consumption and industrial added value, Including the proportion of industrial added value in GDP (IG), The proportion of industrial added value of key water industry in total added value (IT), Growth rate of industrial added value (ID), Growth rate of industrial water use (IW), Per capita water resources (PW), The proportion of industrial employees in the total employment of society (PT). The definition of indicators is shown in Table 3.

Table 3. Driver indicators and their definitions.

Index	Unit	Index definition	Representational meaning
IG	%	Regional industrial added value / regional GDP total output value	Industrial development scale
IT	%	Industrial added value of key water industry / total industrial added value	Industrial structure
ID	%	Industrial added value of this year-industrial added value of previous year / Industrial added value of previous year	Industrial development scale
IW	%	Industrial water consumption of this year-industrial water consumption of previous year / Industrial water consumption of previous year	Industrial development scale
PW	m^3/person	Water resources / total population	Water resources conditions
PT	%	Number of industrial employees / total number of employees	Industrial development scale

According to the principle that the cumulative contribution rate of principal components exceeds 85% [6], The principal component factors of each year were extracted, and the data standardization analysis was carried out to obtain the principal component score coefficient matrix, as shown in Table 4. By substituting the data of the driving factors, the numerical matrix of the main factors was obtained, as shown in Table 5.

Table 4. Principal component score coefficient matrix.

Ingredient	**1**	**2**
Zscore (PW)	0.32	-0.043
Zscore (IG)	-0.283	0.077
Zscore (PT)	0.049	-0.484
Zscore (IT)	0.34	-0.119
Zscore (ID)	0.194	0.1
Zscore (IW)	-0.135	0.577

Table 5. Principal component data.

FAC-1	FAC-2
0.63157	-1.32719
-0.21212	0.75294
0.90116	0.79050
-1.32062	-0.21624

Using the above data to establish a regression model, the regression coefficient is 0.873. The load values of each driving factor were calculated on behalf of the primary component score coefficient matrix, as shown in Table 6.

Table 6. The load value of the main component factor of the added value of unit water consumption.

Index	Principal component	Specific gravity (%)
IT	0.215	25.7
PW	0.203	24.2
IG	-0.179	21.4
ID	0.123	14.7
IW	-0.085	10.2
PT	0.031	3.7

According to the load change of each index of driving factors in the principal component, when the load value is negative, the effect of the index on the principal component is negative load. As can be found from Table 6, IT, PW, ID and PT are positive. According to the proportion of contribution value, IT > PW > ID > PT, among which the contribution value of IT is the largest. Therefore, the higher the proportion of the added value of the key water industry, the higher the added value of the regional unit water consumption.

5 Countermeasures and Suggestions for Industrial Water Efficiency Improvement

5.1 Expanding the Application of Reuse Water

In terms of scientific and technological innovation, according to the relevant national and provincial promotion technology catalogues, the departments of trade should promote feasible reuse technology, and strictly treat and disinfect the reuse water in accordance with the standards for meet the water application requirements and quality requirements of industry and related high-tech fields. In terms of capital policy, starting from the operation cost of enterprises, enterprises are encouraged to carry out the collection and utilization of rainwater and mine water, reducing the consumption of conventional water resources, and promoting vigorously their own wastewater treatment to reduce the economic cost of repeated water use.

5.2 Encouraging the Use of Unconventional Water Sources

The government should strengthen the management of the development and utilization of unconventional water sources, incorporate unconventional water sources into the unified allocation of water resources, and expand the scale and proportion of utilization year by year. Encouraging industrial parks to build centralized sewage treatment facilities and recycled water utilization systems. Strengthening the construction of pipe network. Water users should use rainwater efficiently and reduce the amount of new water taken.

5.3 Improving the System of Water-Saving Policies and Regulations

The government policy should highlight the priority of water saving in the development, utilization, protection, allocation and scheduling of water resources, and establish the allocation and trading system of water rights indicators [7]. Exploring the reform of water prices, adopting a variety of price management methods. And improving the water quota standard system, revise and improve the industrial water quota standard system in the region.

5.4 Optimizing the Industrial Structure and Distribution

According to the regional water resources conditions and industry characteristics, the government should scientifically adjust the industrial structure layout, optimize the allocation of water resources. The production capacity replacement policy of chemical, textile and other industries should be strictly implemented, and new projects should be replaced with equal or reduced production capacity [8]. New construction, reconstruction and expansion of high-water consumption projects should be strictly controlled, and high-water consumption processes, technologies and equipment should be phased out on schedule. We will promote the withdrawal of backward production capacity and strengthen the improvement and upgrading of industrial parks.

5.5 Accelerating the Transformation and Research of Water-Saving Technologies

Enterprises with backward water efficiency should be classified into steps and implemented within a time limit for water-saving transformation, and high-water consumption industries should be actively promoted to carry out water-saving transformation. Industrial enterprises and parks should be encouraged to take the initiative to carry out or entrust third-party service institutions to carry out water-saving assessment of production processes and equipment. The potential of water saving should be deeply tapped, and the integrated optimization of water use system should be promoted to realize serial water use, differentiated water use, multi-use of one water and cascade utilization [9].

6 Conclusion

This paper analyzed the benchmark value of added value of unit water consumption of key industries and explored the relationship between different driving factors and industrial water efficiency. The regional industrial scale and industrial structure have significant effects on the level of water use efficiency. In terms of the change of factor driving effect, the key industries have the highest influence factor on The proportion of industrial added value of key water industry in total added value(IT), and the economic benefits of textile, chemical and food industries in the region are lower than the overall benefits of other industries. Therefore, this paper puts forward some countermeasures and suggestions, such as perfecting policies and regulations, optimizing industrial structure, strengthening technological transformation and tackling key problems, which are of great reference significance for Qiantang District and related areas to formulate scientific and reasonable industrial water-saving policies and optimize industrial structure.

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