BIG DATA TECHNOLOGY FRAMEWORK AND DATA UTILIZATION FOR URBAN ENVIRONMENTAL POLLUTION MANAGEMENT

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ABSTRACT

Urban environmental pollution management is of great practical significance to achieving sustainable urban economic development. To improve the efficiency of urban environmental pollution management, we have established a big data technology framework for urban environmental pollution treatment. The relevant pollution data collected are used for targeted pollution treatment. The results show that the average efficiency of environmental pollution control in the whole province of China has increased from 33.67% to 63.67%, an increase of 46%. Among them, the efficiency of environmental pollution control in Guangdong has increased most significantly, with a relative position of 26.47%, which is at the top of the list. Inner Mongolia has the weakest increase in environmental pollution control efficiency, with an appreciation of 6.89% relative to its position, while the other 16 provinces and cities have little change in environmental pollution control efficiency. between 2010 and 2020, the urban pollution and environmental treatment costs that residents need to bear changed significantly, with fluctuations of around 30%.

KEYWORDS

Environmental pollution; pollution management; big data; pollution management efficiency; economic analysis

INDEX

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1. INTRODUCTION

Environmental pollution control is an important initiative to promote the construction of ecological civilization [1, 2]. For ordinary people, a high-quality living environment with blue skies and white clouds is the basic condition for building an ecological civilization of beautiful China and realizing the Chinese dream of rejuvenation of the Chinese nation [3]. In building an ecological civilization society, comprehensive prevention and control of air pollution should be solidly promoted [4, 5]. Further significant reduction of heavily polluted weather and gradual improvement of air quality [6]. Environmental pollution control is a powerful grip to create an upgraded version of China's economy [7, 8]. At present, China's crude development mode of high input, high consumption, high pollution, and low efficiency has not been fundamentally transformed, which is the fundamental cause of serious pollution [9]. In recent decades, China's economy has been developing steadily and rapidly. China has made remarkable achievements in economic construction in the world [10], but along with the economic development, China has paid a huge environmental cost. Along with China's rapid economic growth, China's ecological environment is deteriorating and pollution problems are becoming increasingly serious. The pollution problem has now become a major challenge to China's sustainable economic development [11, 12]. In China, with the advancement of urbanization, more and more people are living in cities. The corresponding urban environmental pollution has become an important part of China's environmental pollution, so it is of epochal significance to do a good job in urban environmental pollution management to build a beautiful China and promote China's modern economic construction.

In China, ecological and environmental problems brought about by urbanization are gradually emerging [13]. Therefore, the issue of urban environmental pollution management has received great attention, and people are eager to solve a series of environmental pollution problems such as water shortage and pollution, and rapid reduction of air quality [14]. People are eager to aspire to and pursue a healthy, green, and sustainable ecological living environment. Faced with the current rapid population growth, excessive consumption of resources, and serious environmental pollution, the sustainable development path is the inevitable way of development nowadays [15-22]. At present, for urban environmental pollution management, there are still problems such as small investment in environmental protection, insufficient urban environmental infrastructure construction, and insufficient policies and laws and regulations for environmental protection [23, 24]. In urban environmental pollution management, the lack of environmental protection investment has led to weak comprehensive urban pollution management capacity. Further, the slow pace of urban environmental infrastructure construction, urban domestic waste, hazardous waste treatment capacity, etc. is not able to keep up with the pace of urban development, thus leading to serious pollution problems over time.

In terms of urban environmental pollution management, urban environmental pollution management is closely related to people's lives [25]. Therefore, prevention and treatment of urban environmental pollution management has received wide

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attention. Zhang, X [26] surveyed the environmental concentration and change characteristics of ozone and its precursors in Beijing from May-June 2014-2017 to study heavy ozone pollution. Their study showed the need to adjust control measures according to the changes in ozone precursors and strengthen the coordinated control of urban environmental pollution prevention and control in long-term planning. Fei, F [27] considered municipal biological waste as an organic part of municipal solid waste and a major waste type in low- and middle-income countries. They used the concept of industrial ecology to conduct a complete planning exercise for urban bio-waste disposal systems. Their study showed that conducting urban environmental pollution management has significant economic, environmental, and social benefits. In a study by Guo, J.X [28], they studied showed that in large cities, the coordinated development of pollutants and carbon reduction in the transportation sector can help to achieve urban pollution prevention and carbon reduction. They proposed a bottom-up mathematical model of vehicle development for multiple periods, analyzing the air pollution emission paths and energy restructuring paths, as well as the synergistic benefits of CO2 emission reduction. Further, Zhao, B [29] argued that spatially explicit urban air quality information is important for developing effective air quality control measures. They did this by collecting real-time spatially resolved data on fine particulate matter concentrations. A decision tree model was developed to infer the distribution of PM2.5 concentrations. Tang, W [30] considered water pollution as the main environmental problem among urban environmental pollution. They analyzed various long-term water quality, wastewater treatment plants, and pollutant discharge data to systematically understand the process of water pollution control in China over the past two decades. They suggested that wastewater collection and treatment capacity should be further improved to address the gap between effluent discharge limits of wastewater treatment plants and environmental quality standards for surface water. Xiong, W [31] proposed wastewater recycling as the most effective strategy to reduce the impact of urban water ecosystems. Wang, R [32] in their study pointed out that polluted urban river systems may be an important source of atmospheric methane and nitrous oxide sources. Xiao, Q [33] suggested that environmental investments could reduce the partial pressure of CO2 in small eutrophic urban lakes. Their results show that anthropogenic activities strongly influence the dynamic distribution of lake CO2 and that environmental investments, such as ecological restoration and reduction of nutrient discharges, can significantly reduce CO2 emissions from inland lakes. In all the above studies, we can find that for urban environmental pollution prevention and control, mainly includes several aspects such as air pollution, water pollution, and pollution emission. In conducting urban pollution prevention and control, previous studies tend to focus on one direction to carry out. However, urban environmental pollution treatment is a comprehensive system that needs to be carried out in several aspects such as air pollution, water pollution, and pollution discharge.

Urban environmental pollution management is of great practical significance to achieve sustainable development of the urban economy. In urban environmental pollution management, it involves several aspects such as air pollution, water pollution, and pollution discharge. Therefore, when pollution prevention and control is

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carried out, a large amount of data on the generation of pollutants and the treatment of pollutants will be generated. Therefore, in urban pollution control, we need to analyze a large amount of data to determine the areas that need to be dealt with in urban pollution control. In this research work, we establish a big data technology framework for urban environmental pollution treatment. Through the collected pollution data for pollution prevention and treatment, then improve the efficiency of urban environmental pollution treatment.

2. CONSTRUCTION OF AN EVALUATION PLATFORM FOR URBAN ENVIRONMENTAL POLLUTION MANAGEMENT BASED ON BIG DATA

As urban environmental pollution problems become increasingly serious, a large amount of real environmental pollution data are collected and made public by government agencies [34, 35]. Big data technology is used to automatically extract important pollution causes from these environmental pollution big data and establish a big data-based urban environmental pollution management evaluation platform to better solve a series of problems in urban environmental pollution management in China. In environmental pollution big data, a large amount of environmental pollution data covers the detailed records of environmental pollution generated within the city. Specifically, by using frontier technologies of information science such as big data and artificial intelligence, we can propose to solve the drawbacks of monolithic urban environmental pollution governance and improve the quality and efficiency of urban environmental governance.

2.1. BASIC CONCEPTS OF BIG DATA

Big Data on environmental pollution is different from the traditional data management model in that it brings radical changes in the way data is collected, data pre-processing (stream processing vs. batch processing), and data algorithm approach. At present, we have experienced the evolution of the operational phase, user original phase, and perceptual system phase. This is mainly reflected in the following aspects.

1. Data scale. Due to the booming development of urban informatization, emerging services such as the Internet of Things can collect unprecedented data types as well as data quantities.

2. Processing tools. At this stage, there are 4 paradigms, based on the new data thinking approach of environmental pollution big data collection for processing various research objects as well as various heterogeneous data. The above 4 paradigms are introduced as shown in Table 1.

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Scientific Paradigm	Methodology
Empirical	Description of natural phenomena
Theoretical	Use of models, generalization
Computational	Simulation of complex phenomena
Data Exploration	Instrument-captured or simulator-generated data; software processing; computer-stored information; scientists analyzing databases

Table 1. Comparison of big data processing paradigms

3. Data types. Traditional data management models have a single type of data while emerging services such as IoT can capture a wide variety of big data types (structured, semi-structured, and unstructured). Of these, the latter two data types account for the largest share.

2.2. TECHNICAL FRAMEWORK

This paper constructs a big data-based urban environmental pollution management evaluation platform including three parts: environmental pollution big data access layer, environmental pollution big data processing layer, and environmental pollution big data application layer, as shown in Figure 1. In the environmental pollution big data access layer, for the problems of diverse sources and different structures of factory emission information system data within the city, Spark distributed is used to pre-process the environmental pollution big data, and the quality and reliability of the environmental pollution big data are ensured by integrating and classifying the environmental pollution big data. In the environmental pollution big data processing layer, the big data-based urban environmental pollution governance evaluation platform constructs a series of environmental pollution big data engines by selecting appropriate environmental pollution big data analysis technologies to conduct efficient and in-depth data mining and fusion analysis of environmental pollution big data. At the application layer of environmental pollution big data, the big data-based urban environmental pollution governance evaluation platform transforms the problem of excessive emissions of factory enterprises into a big data analysis problem by transforming them into a big data analysis problem. The evaluation model of urban environmental pollution management, such as establishing effective pollutant treatment measures and finding low-cost solutions, realizes sustainable development of the urban economy and environment, etc.

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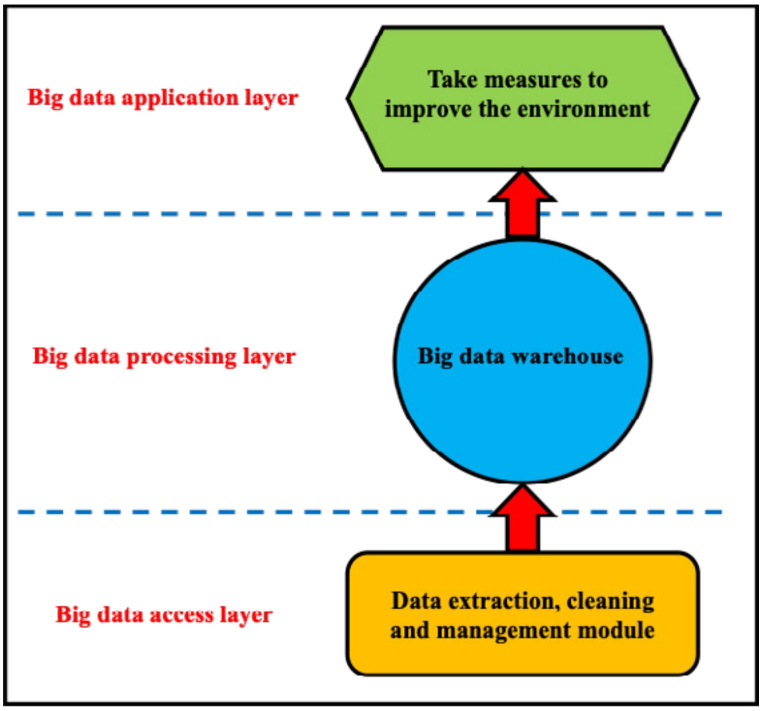

Figure 1. The framework of urban environmental pollution management evaluation platform based on big data.

2.3. RESEARCH PROGRAM

This paper proposes a big data-based urban environmental pollution management evaluation platform that enables a customizable implementation approach based on the environmental governance needs of Chinese cities. We investigated exhaustive projects of environmental governance across China, summarized common problems prevalent in intra-city factory emissions, developed specific research solutions for these problems, and finally validated and analyzed the research content using the environmental pollution big data from the above-mentioned research.

It is worth mentioning that the big data's urban environmental pollution management evaluation platform flags the waste emissions of each factory in the city. We extract irregular waste emission events from environmental pollution big data and automatically build a risk assessment model of environmental pollution damage from relevant waste based on the waste composition, emission cycle, and total emission of the factory. Improve laws and regulations to clarify the obligations of the public and enterprises in participating in urban environmental pollution control, and the government to promote green and low-carbon consumption concepts. Eliminate the backward production equipment as well as improve the production process of urban factories, increase pollution control, and complete the task of pollution reduction. To provide a strong solution for urban environmental pollution management.

2.4. ENVIRONMENTAL POLLUTION BIG DATA PROCESSING PROCESS

https://doi.org/10.17993/3ctecno.2023.v12n2e44.204-218

The data sources of environmental pollution big data are widely available, and the application requirements and data types are different, but the most basic processing process is consistent, as shown in Figure 2 Basic processing process of big data. The entire processing process of environmental pollution big data can be defined as the extraction and integration of a wide range of heterogeneous data sources with the assistance of suitable tools, and the results are stored uniformly according to certain standards. The stored environmental pollution big data is analyzed using appropriate data analysis techniques, and the relevant environmental pollution factors are extracted from the environmental pollution big data and the results are fed back to government agencies in an appropriate way so that they can enact policies and take action for pollution control.

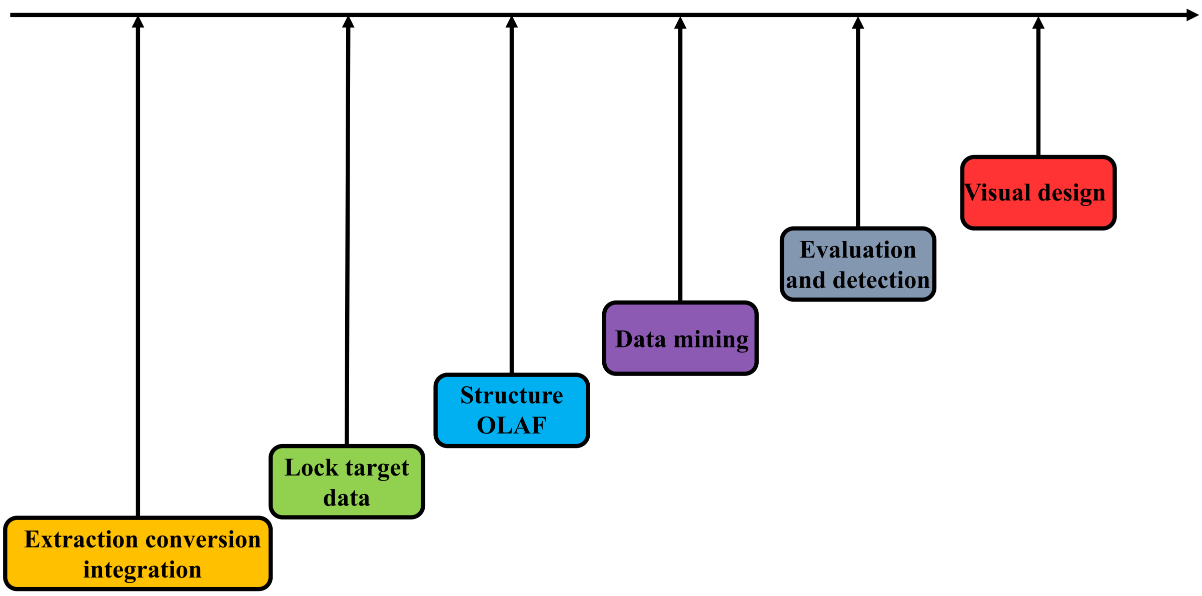

Figure 2. Basic processing flow of big data

3. TECHNICAL EFFICIENCY OF URBAN ENVIRONMENTAL POLLUTION MANAGEMENT

This paper evaluates the technical efficiency of urban environmental pollution control based on data envelopment analysis (DEA). DEA solves the optimal production frontier surface through linear programming and compares the production possibilities of each multi-input and multi-output similar decision-making unit (DMU) with the previous optimal frontier surface to obtain a measure of the relative efficiency of each DMU. The specific evaluation criteria process is as follows.

$$F_i(y, x \mid C, S) = \min\left\{\lambda : \lambda_x \in L(y \mid C, S)\right\} \quad (1)$$

$$s \cdot t \cdot L(y \mid C, S) = \left\{ (x_1, x_2, \ldots x_N) : \sum_{k=1}^{K} Z_k y_{km} \geqslant y_m, \sum_{i=1}^{K} z_i x_{in} \leqslant \theta_k x_{kn}, \sum_{k=1}^{K} z_k x_{kn} \leqslant x_n \right\} \quad (2)$$

Where, x is the input; y is the output; z is the weight; N, M and K denote the number of input variables, output variables and DMUs, respectively; F_i is the technical

https://doi.org/10.17993/3ctecno.2023.v12n2e44.204-218

efficiency of the ith DMU; C is the total number of different types of big data; S is the total number of big data samples. In addition, 34 provincial regions in China are selected as DMUs in this paper, and the period for analysis is from 2010 to 2020. To store, manage and analyze environmental pollution big data, we use Spark distributed computing framework for technical implementation. This paper based on Spark distributed computing can reduce the overhead caused by data movement and transparently provide high reliability and high-performance computing for upper-layer applications

4. ANALYSIS AND DISCUSSION

4.1. OVERALL ENVIRONMENTAL POLLUTION CONTROL EFFICIENCY PERFORMANCE

To realize the sustainable development of the urban ecological environment, we introduce big data technology, which should firstly collect the urban ecological environment data according to the urban environmental pollution situation and the governance needs, and build the corresponding standard system structure according to the results obtained from the collection. Finally, pollution treatment should be completed in strict accordance with the corresponding standard indicators. The average efficiency scores of environmental pollution control for the whole province of China, eastern China, central China, and Western China are compiled in Figure 3, which shows that in the early 21st century, the efficiency of environmental pollution control in all regions of China was below 50%. With the proposed policies of energy conservation and emission reduction, carbon peaking, and carbon neutrality in China, the efficiency of environmental pollution management gradually began to improve across China. Between 2010 and 2020, the average efficiency score for environmental pollution control across China's provinces increased from 33.67% to 63.67%, an improvement of 46%. Overall, the efficiency of environmental pollution control across China is increasing, thanks to strong government support for environmental protection. The average efficiency score of environmental pollution control in eastern China increased from 47.02% to 63.67%, an increase of 26.15%. This can indicate that there are large differences in environmental pollution control across China, although local environmental pollution is more serious in central and western China than in eastern China. However, comparing the average efficiency of environmental pollution control in the three regions, the relative environmental cost of economic development is greater in central China and western China, and it is more difficult to balance high economic development with environmental protection. The average efficiency score of environmental pollution control in central China increased from 32.15% to 61.34%, an increase of 47.59%, while the average efficiency score of environmental pollution control in western China increased from 22.28% to 56.72%, an increase of 60.72%. This result further reflects that Central China and Western China are sacrificing the environment to catch up with the economic development of the Eastern region. At the same time, we find that there are large regional differences

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in the efficiency of environmental pollution control and its dynamics among Chinese localities, which generally show a distribution pattern of high in the east and low in the west.

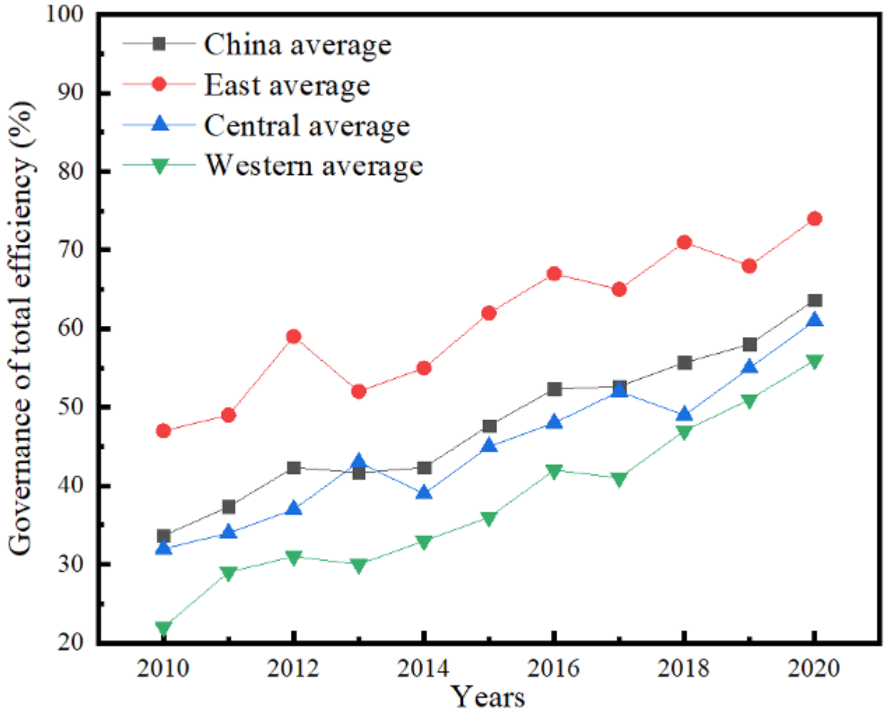

Figure 3. Changes in the average efficiency scores of environmental pollution control in China as a whole and in the three major regions

4.2. PERFORMANCE OF ENVIRONMENTAL POLLUTION CONTROL EFFICIENCY BY PROVINCES AND CITIES

Urban pollution environmental data can accurately reflect the current stage of urban environmental problems. In turn, it can fully reflect the quantity, quality, distribution, and other relevant information of various elements in the process of urban environmental pollution management. In the process of urban ecological environmental protection, urban pollution data can fully reflect the changing characteristics of the environment. To facilitate the comparison of environmental pollution control efficiency in various regions of China, regional differences in environmental pollution control efficiency in eastern China, central China, and western China are explored in depth. We extracted the environmental pollution control efficiency of 17 provinces and municipalities in China for observation and studied the changes in environmental pollution control efficiency in ten years (2010 to 2020), and the results are shown in Figure 4. From Figure 4, it can be seen that the city with the most obvious increase in the efficiency of environmental pollution control within ten years is Guangdong, which is at the top of the list with an upward relative position value of 26.47%. This indicates that the Guangdong government has been able to achieve a common and harmonious development between two hard indicators for economic development and environmental protection. In addition, the city with the

https://doi.org/10.17993/3ctecno.2023.v12n2e44.204-218

weakest increase in environmental pollution control efficiency is Inner Mongolia, with an increase of 6.89% relative to its position, and little change in environmental pollution control efficiency compared to the other 16 provinces and cities. The above results fully indicate that central and western China provinces and cities have seriously neglected environmental protection while developing their local economies, resulting in a serious decline in the relative position of environmental pollution control efficiency. Eastern provinces and cities in China have achieved a relatively harmonious co-development between environmental protection and economic development, and have been performing relatively well or have achieved a significant increase in the relative ranking of environmental pollution control efficiency.

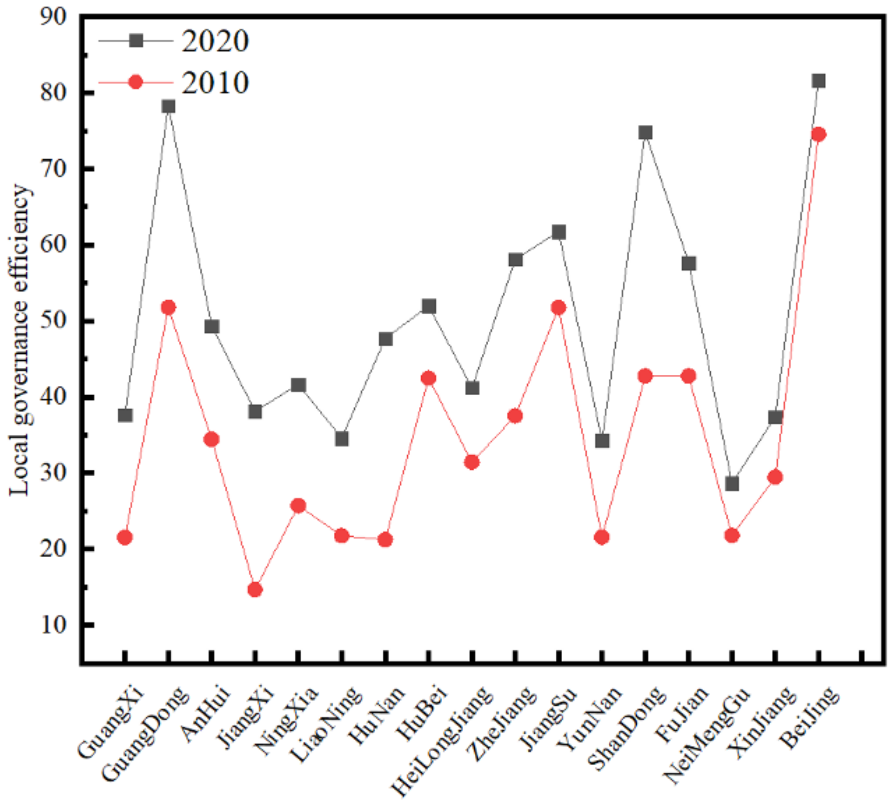

Figure 4. Change in the average efficiency score of environmental pollution control in a region of China

4.3. ECONOMIC ANALYSIS OF URBAN POLLUTION ENVIRONMENTAL MANAGEMENT

To comprehensively improve urban pollution environmental management, first of all, it is necessary to focus on the classification of urban pollutants and the economics of the recycling process. In the process of building the urban environmental data-based management system, this part should be the focus. By transferring information such as the type of urban pollutants collected by the government and relevant departments to the big data framework, and using this as the basis, we can realize the analysis of the economics of urban pollutants classification and recycling more scientifically. Next, the data obtained is analyzed in terms of social group participation

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rates using market research, and the proposed measures are revised several times by integrating the results of the market research. The analyzed economic data is transmitted to the information. Urban residents, as emitters, should be financially responsible for the management of the domestic pollution they cause. Therefore, we have compared the economic analysis of sewage treatment and domestic waste treatment, which are common in urban pollution. Figure 5 shows the change in urban pollution treatment costs for urban residents between 2010 and 2020. We can see that for urban sewage treatment, the cost is significantly higher than the cost of urban domestic waste treatment. In 2010, residents need to bear the cost of urban sewage treatment of 283.56 yuan and the cost of garbage treatment of 132.59 yuan. In comparison, the cost of sewage treatment is 2.14 times higher than the cost of garbage treatment. The overall trend seems to be that there is a trend toward lowering the cost of municipal sewage treatment. In 2019, the lowest cost of sewage treatment that urban residents need to bear is only 208.6 yuan, which is 26.44% lower than the highest 283.56 yuan in 2010. This indicates that in the process of urban pollution and environmental management, sewage treatment is becoming more and more efficient, and the cost that residents need to bear gradually decreases. Similarly, in terms of urban waste disposal costs, the highest cost required to be spent in 2011 was 176.2 yuan. In 2016, the lowest cost of municipal waste treatment was required to be borne, requiring 128.9 yuan, a decrease of 26.84% year-on-year. The change in the cost of urban sewage treatment and urban domestic waste treatment can be seen through the change in the cost of urban pollution environment treatment that residents need to bear between 2010 and 2020, with fluctuations of about 30%.

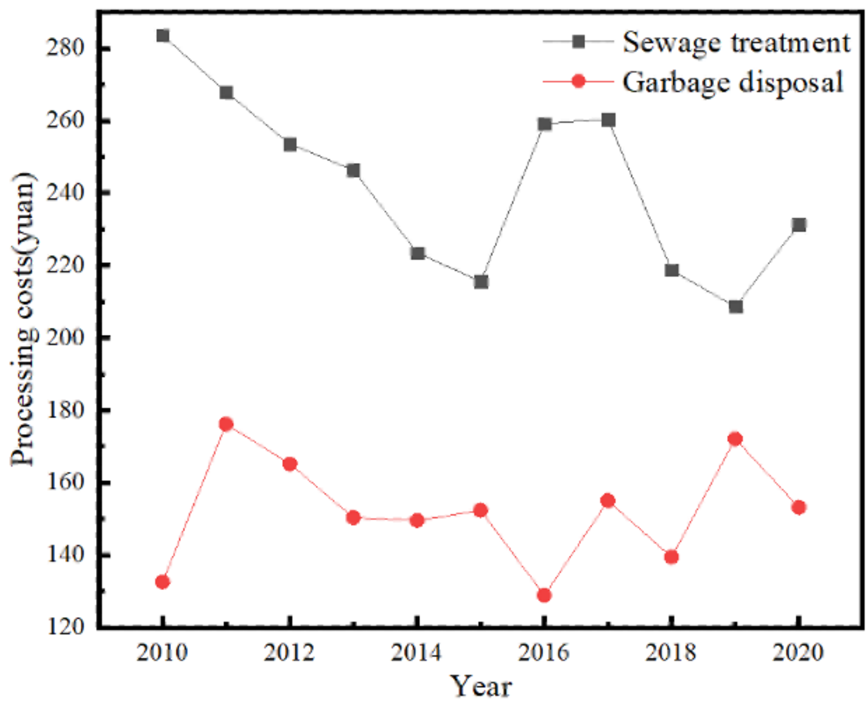

Figure 5. Change in urban pollution treatment costs for urban residents from 2010 to 2020

5. CONCLUSION

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We address air pollution, water pollution, and other pollution sources that need to be dealt with for urban environmental pollution management. We establish a big data technology framework for urban environmental pollution treatment, collect relevant pollution data, and further use the collected data for pollution prevention and treatment. The results are expressed as follows.

1. Between 2010 and 2020, thanks to the government's strong support for environmental protection, the average efficiency score of environmental pollution control in China's provinces rose from 33.67% to 63.67%, an efficiency increase of 46%, and the efficiency of environmental pollution control across China has been rising. At the same time, we find that there are large regional differences in the efficiency of environmental pollution control and its dynamics across Chinese localities generally showing a distribution pattern of high in the east and low in the west.

2. The environmental pollution control efficiency of 17 provinces and municipalities in China from 2010 to 2020, Guangdong's environmental pollution control efficiency increased the most significantly, with a relative position of 26.47%, which is at the top of the list. Inner Mongolia has the weakest increase in environmental pollution control efficiency, with an increase of 6.89% in relative position, and little change in environmental pollution control efficiency when compared with other 16 provinces and cities.

3. In 2010, residents had to bear the city's sewage disposal cost of $283.56 and garbage disposal cost of $132.59. In comparison, the cost of sewage treatment is 2.14 times higher than the cost of garbage treatment. The overall trend seems to be that there is a trend toward lowering the cost of municipal wastewater treatment. In 2019, urban residents need to bear the lowest cost of sewage treatment, which costs only 208.6 yuan, 26.44% lower than the highest 283.56 yuan in 2010. This indicates that the process of urban pollution environment management, and sewage treatment efficiency is getting higher and higher, and the cost that residents need to bear gradually decreases. between 2010 and 2020, the cost of urban pollution environment treatment that residents need to bear changed significantly, fluctuating at about 30%.

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