RESEARCH ARTICLE

Cost control of ecological treatment of agricultural wastewater based on secondary net value method

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Received: February 26, 2025; **accepted:** July 13, 2025.

In agricultural production, the unreasonable use of fertilizers, untreated discharge of livestock and poultry breeding wastewater, and rural domestic sewage have led to serious pollution of surface water and groundwater, exacerbating the eutrophication of water bodies. These situations seriously constrain the sustainable development of agriculture and the rural economic environment. Strengthening pollution source control and adopting ecological treatment of agricultural wastewater have become effective ways to control agricultural pollution. However, current agricultural wastewater ecological treatment projects face problems such as large investment scale, long payback period, and multiple risk factors. This research focused on cost control methods for agricultural wastewater ecological treatment based on the secondary net value method. A hierarchical structure framework and a comprehensive control index system for the ecological treatment process of agricultural wastewater were constructed, and the degree of input cost control was judged based on a simple hierarchical structure among the indicators. Further, the recoverable funds in the ecological treatment process of agricultural wastewater were calculated, and a sequence matrix of recyclable funds for the ecological treatment of agricultural wastewater was established to study the cost control process and methods for the ecological treatment of agricultural wastewater by taking a sewage discharge project as the experimental sample. The results showed that the porosity of the proposed method could reach 99% with an average value of 81%, which was significantly higher than that of other algorithms. This research proved that the estimated value of the cost control quantity using the proposed method had a higher fit with the actual value. The proposed method could effectively calculate the cost of agricultural wastewater treatment, and the cost control effect was remarkable. This study provided technical support for solving the cost management in treating agricultural non-point source pollution.

Keywords: secondary net value method; agricultural wastewater; ecological treatment; cost control.

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Introduction

In agricultural production, the rapid growth and unreasonable application of fertilizers, as well as the erosion of farmland floods and rainwater runoff, cause pollutants such as agricultural track water and farmland tailwater to enter rivers, lakes, inland seas, and other water bodies. The sewage collection pipeline network facilities in rural areas are not sound, and there is a lack of sewage treatment facilities. Most domestic sewage, livestock wastewater, agricultural rail water, and farmland tail water are directly discharged into surrounding rivers and lakes without treatment, which causes serious pollution of surface water and groundwater, and exacerbates eutrophication of water bodies. Meanwhile, with the improvement of living standards of rural residents, the domestic water consumption has increased year by year, and the discharge of domestic sewage has also increased. Among the agricultural source pollution, the livestock and poultry breeding industry are more prominent. Large scale livestock farms discharge over 20 billion tons of animal manure and wastewater annually, but over 90% of these farms lack pollution treatment facilities [1]. The chemical oxygen demand, total nitrogen (N), and total phosphorus (P) account for 96%, 38%, and 56% of agricultural source pollutions, respectively. Due to the large population and less land, chemical inputs such as chemical fertilizers, pesticides, and plastic films are widely used in agricultural production to improve the yield, resulting in serious agricultural non-point source pollution. Most of the aquaculture wastewater is directly discharged into rivers and lakes without treatment [2]. The extensive use of fertilizers, pesticides, and plastic films in agricultural production has played an important role in increasing grain yield. However, in some areas, due to insufficient use, a large amount of N and P enter surface water and groundwater through irrigation and rainwater runoff from farmland. The agricultural wastewater produced in the process of agricultural production and life is one of the main causes of agricultural non-point source pollution [3].

Agricultural pollution is becoming one of the main reasons for the deterioration of rural ecological environment, which seriously restricts the sustainable development of agriculture and rural economic environment. Strengthening the control of agricultural non-point source pollution is a fundamental prerequisite for ensuring the quality of agricultural products, as well as an inherent requirement for improving rural living environment, building ecological civilization, and coordinating the relationship between humans and nature. The problem of agricultural pollution should be solved by means of development and guidance in accordance with the requirements of modern agriculture and sustainable development. While developing agricultural production, efforts should be made to minimize the pollution caused by agricultural production to the environment [4]. Adopting comprehensive harmless treatment technology and ecological treatment of agricultural wastewater are the most effective ways to control agricultural pollution. The research on rural sewage treatment should choose a biochemical ecological combination sewage treatment process based on the characteristics of rural sewage and pay attention to the landscape and ecological benefits of sewage treatment facilities [5]. A study included 17 rural sewage treatment stations with a small investment, low operating costs, convenient maintenance and management, a park landscape effect, and significant ecological benefits demonstrated the requirements of the rural revitalization strategy for improving the living environment to solve the increasingly serious water pollution problem in agricultural and rural areas [6]. The research proposed a comprehensive technical system for ecological treatment and resource utilization of agricultural and rural water pollution. The main removal mechanism of N, P, and organic pollutants in the green foxtail alga wetland was expounded through the absorption capacity and functional microbial community structure characteristics. Fu *et al*. explored the classification and related functional genes of anammox bacteria and the control parameters of partial nitrification anammox process for treatment of low ammonia nitrogen wastewater, which included dissolved oxygen, carbon/N, pH value, sludge age, reactor type, and practical engineering application cases. The results indicated that anammox process had broad application in low ammonia nitrogen wastewater treatment [7]. Another research examined 37 groups of groundwater samples and 10 surface water samples in Eastern Foshan, Guangdong, China from 2005 to 2008 using gas chromatography-mass spectrometry (GC/MS) to determine the distribution characteristics of benzene series including benzene, toluene, ethylbenzene, o-xylene, m-xylene, and o-xylene in groundwater [8]. At present, agricultural wastewater treatment projects on the ecological level are increasing, which have the characteristics of large investment scale, high technical requirements, long recovery cycle, and many risk factors. Many analyses and calculations have been done based on the prediction, estimation, and judgment of the future situation. Environmental changes and uncertainties make the investment decision and operation management of environmental protection projects relatively complex. Anaerobic biological treatment is suitable for the treatment of wastewater of different concentrations and properties. It has the advantages of low sludge production, low energy consumption, and low construction and operation management costs. The biological and ecological combined process is the main development direction of rural domestic sewage treatment technology. The ecological treatment process has the characteristics of low construction cost, low energy consumption, and convenient operation and management, while the biological treatment process can make up for the defects of the ecological treatment process and treat sewage better and more efficiently. Therefore, the biological and ecological combined process is the main direction of the development of rural domestic sewage treatment technology and has broad development prospects. United States of America and Japan have successfully applied rural domestic sewage treatment technologies such as advanced integrated pond technology, trench soil infiltration technology, purification pool technology, *etc*. to rural domestic sewage treatment considering their national conditions. The existing wastewater treatment process generally adopts physicochemical and biochemical methods, and the effluent concentration cannot meet the requirements of the standard. Therefore, it is necessary to conduct advanced treatment for the effluent from the biochemical tank. At present, ecological wastewater treatment methods include membrane separation technology, adsorption, advanced oxidation technology, and biological aerated filter.

The traditional cost control methods are difficult to adapt to the characteristics of ecological treatment processes and lack systematic accounting for recoverable funds, which leads to a significant deviation between cost estimation and actual value, becoming a key bottleneck restriction for the promotion of ecological technologies. This research explored cost control methods for ecological treatment of agricultural wastewater with the aim of protecting the environment and improving treatment efficiency based on the secondary net value method. The study constructed a comprehensive control index system for ecological treatment of agricultural wastewater through the analytic hierarchy process (AHP) and established a recyclable fund sequence matrix by combining the secondary net value method. The cost composition and control threshold were then quantitatively analyzed to solve the cost management problem in agricultural non-point source pollution control and promote the sustainable development of agriculture and rural economic environment.

Materials and methods

Agricultural wastewater ecological treatment cost control instructions

The deep treatment of wastewater needed adopting multiple combination processes and leveraging the advantages of various methods to achieve the goal of low cost. The cost control method for ecological treatment of agricultural wastewater took into account the cost structure of the combined process including determining the sequential constraint relationship between single output instructions and receiving instructions in the process of ecological treatment of agricultural wastewater, calculating the issuance time of each action instruction, classifying the ecological wastewater treatment process instructions, and sending the classified instructions to the corresponding unit control module according to the classification results. In the process of ecological treatment of agricultural wastewater, the relationship instruction was a kind of virtual instruction [9], which was mainly used to express the constraint relationship between ecological treatment instructions of wastewater. In the process of decomposing the ecological wastewater treatment process into a single operation instruction, the ecological sewage treatment system needed to analyze the treatment process. The process of operation instruction analysis included analyzing the operation instruction, obtaining the corresponding operation instruction number and parameters, determining the number of operation instructions and the corresponding program function. The parameters in the operation instruction were passed as the final parameters to the determined program, so as to obtain the working status of the agricultural wastewater ecological treatment system and determine it according to the actual working status. The process flow and processing steps used in the cost control of agricultural wastewater ecological treatment provided a basis for the formulation of cost control indicators.

Construction of treatment cost control index based on secondary net value method

The secondary net value method is a cost accounting method based on dynamic adjustment of asset net worth, mainly used to evaluate the difference between the actual value and recoverable amount of a project or asset. This method quantified the cost loss value (I_{MP2}) by comparing the book value (C_{V2}') with the recoverable funds (R_{V2}) and combined it with a threshold to determine whether to trigger book impairment. The core was the construction of a comprehensive control model through a hierarchical indicator system such as technical, economic, and social environmental indicators to achieve cost optimization and risk assessment in the ecological treatment of agricultural wastewater [10]. The comprehensive control index system was a parameter measuring the advanced nature, effectiveness, reliability, applicability, economy, and sociality of agricultural wastewater treatment technology and equipment. The construction of the comprehensive control index system of agricultural wastewater treatment engineering integration technology should follow the principles of science, completeness, combination of qualitative and quantitative, and operational principles. Factors with high sensitivity, strong observability, easy measurement, dominant position, mutual independence, and minimal correlation were selected as controls. All the indexes could reflect the level of engineering technology, the advantages and disadvantages of operation status, and had certain universality. Before selecting indicators, according to the scientific principle, the basic concept of integrated control of agricultural wastewater treatment engineering was defined, and relevant indicators were selected to form the pre-selected index set. According to the principle of strong operability, the indicators with better observability and measurability were selected as control indicators from the perspective of quantity. The close degree of control indicators was then analyzed with the control index system being treated as a fuzzy set, and the most commonly used and simplest method of expert consultation table being used to select one of the five comments of "very important", "more important", "general", "less important", and "unimportant", and then calculating each index [11]. The percentage of the total number of experts consulted was the membership degree of the index to the five comments. According to the principle of selecting the nearest, the index with higher membership degree and better quantitative characteristics were selected. By analyzing the classification results, the pre-selected indicators classified as "unimportant" were removed, and the remaining pre-selected indicators were used as the control indicators of this time. The control index system required a group of indicators with certain logical connections, purpose, and function. Generally, an ideal control index system has three levels of target level, criterion level, and index level. In terms of comprehensive technical control of agricultural wastewater treatment projects, 15 indicators were selected including technical indicators, economic indicators, social environmental indicators, and adaptability indicators. Among them, the cost control method of ecological treatment of agricultural wastewater used the simple and clear hierarchical structure in AHP to judge the superiority of input cost control [12, 13]. The main process included the determination of the index weight using a 1 to 9 scale method to compare the criteria layer under the target layer one by one and construction of the comparison matrix of the criterion layer. The single index of the index layer under the criterion layer was compared for the integrated technology, and the technical comparison matrix was constructed. The consistency test and weight calculation were then performed. Several experts were selected for scoring, and the consistency test was carried out to ensure the reliability and scientificity of the matrix and minimize the influence of personal subjectivity on the control results. The comprehensive average value was obtained by comprehensive comparison of the results, and the average weight of the corresponding index was obtained. The AHP was introduced in this research. According to different control technologies, different factor sets, weight sets, and comment sets were established. Based on the overall ranking results of the technology under the criterion layer, a hierarchical control table was established, and experts were invited to sort according to the ranking results to establish an evaluation matrix. The weight vector (W) and evaluation matrix (R) calculated according to the comparison matrix of control objectives were also established. Based on the AHP, the hierarchical structure framework was constructed, which consisted of target layer O and criterion layer C and was shown below.

$$A = \left(a_{ij}\right)_{k \times k} \tag{1}$$

As for the control objectives, a cost evaluation team composed of senior managers and experts in the field was established. All indicators were compared and the relative criticality was obtained based on the experience and the characteristics of evaluation objectives [14]. The standard corresponding to the control matrix O of the target layer, $C_1, C_2, \cdots, C_k$ was shown below.

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1k} \\ a_{21} & a_{22} & \cdots & a_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ a_{k1} & a_{k2} & \cdots & a_{kk} \end{pmatrix} \tag{2}$$

According to the solution of the optimal comprehensive matrix of the group control matrix, the optimal comprehensive control matrix C was obtained, and the product of each row of elements in the control matrix was calculated as follows.

$$M_i = \prod_{j=1}^{k} a_{ij} \tag{3}$$

$$\overline{w_i} = \sqrt[k]{\prod_{j=1}^{k} a_{ij}} \tag{4}$$

By using the square root of equation (4) and normalizing the implementation M_i, the results of $\overline{w_i}$ were obtained as follows.

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{k} \overline{w_i}} \tag{5}$$

The maximum eigenvalue was then calculated below.

$$\lambda_{\max} = \sum_{i=1}^{k} \frac{\left(AW\right)_i}{k w_i} \tag{6}$$

where $\left(AW\right)_i$ was the i element of the vector AW. The consistency index CI was used to test the consistency of the control matrix A, and the membership vector B was normalized to obtain B*, which was calculated with the comment set V. The comprehensive control result G was

Table 1. Cost control system for ecological treatment of agricultural wastewater.

Quasi horizon	Weight	Index layer	Weight
Technical index	0.1	Stability of technology	0.41
		The difficulty of operation management	0.58
		Effluent standard rate of pollutants	0.60
Economic indicators	0.27	Economic index of agricultural wastewater	0.27
		Cost recovery rate of annual wastewater treatment capacity	1.00
		Annual cost handling capacity	1.00
Social environmental indicators	0.23	Integrated technology social environment indicators	0.23
		Waste water recovery and utilization rate	1.00
Adaptability index	0.38	Coordination between the economic development level of the district and the city	0.25
		Coordination degree with regional natural climate conditions	0.32
		The degree of coordination with regional production mode	0.30

obtained as $G = B * \cdot V_T$. The score of integrated technology was then determined using standardized index layer to calculate the criterion level score and the comprehensive control score of the target layer [15]. The score of criterion layer A_l was equal to the score of its index layer multiplied by its corresponding weight. W_{Bj} was the weight of index layer. B_j was the score of indicator layer. The total score E was equal to the standard layer multiplied by its corresponding weight, thus forming the cost control system of agricultural wastewater ecological treatment.

Cost control method for ecological treatment of agricultural wastewater

The order matrix of recoverable funds $d_{ij}\left(i=1,2,\ldots,y;j=1,2,\ldots,n\right)$ was established to describe the evaluation of the i control index to the j index. The standard structural entropy model was determined as follows.

$$x\left(I\right) = -\delta P_n\left(I\right)\ln P_n\left(I\right) \quad (7)$$

where P_n was the normalization. The index ranking function $P_n\left(I\right)$ and the index adjustment coefficient δ were equal to the sum of the control thresholds $\frac{g-I}{g-1}$ of the structural $\frac{1}{\ln\left(g-1\right)}$ entropy model, respectively.

$$\frac{x\left(I\right)}{\left(\frac{g-I}{g-1}\right)-1} = \beta\left(I\right) \quad (8)$$

The structural entropy model was then obtained as follows.

$$\beta\left(I\right) = \frac{\ln\left(g-I\right)}{\ln\left(g-1\right)} = \ln\left(P_n\left(I\right)\right) \quad (9)$$

where $\beta\left(I\right)$, I, and g were the corresponding membership function values and transformation parameters of d_{ij}. Sum I to g was set to be equal to $g+1$ and $a+2$, respectively, then the equation was obtained as below.

$$P_n\left(I\right) = \frac{\left(a+2\right)-\left(a+1\right)}{\left(a+2\right)-a} = \frac{1}{a+1} \quad (10)$$

where a was the number of sorting for a given primary indicator. The more obvious the correlation between each indicator and the cost control of ecological treatment of agricultural wastewater, the higher the ranking of each indicator, and vice versa [16].

$$\beta\left(a\right) = -\ln\left(\frac{B_j}{W_{Bj}+1}\right) \quad (11)$$

where W_{Bj} was the weight of the index layer. B_j

was the score of the indicator layer. The weight coefficients in the control system were determined, and the cost control objectives were matched to realize the design of cost control method for ecological treatment of agricultural wastewater (Table 1). The cost control process of ecological treatment of agricultural wastewater was shown in Figure 1.

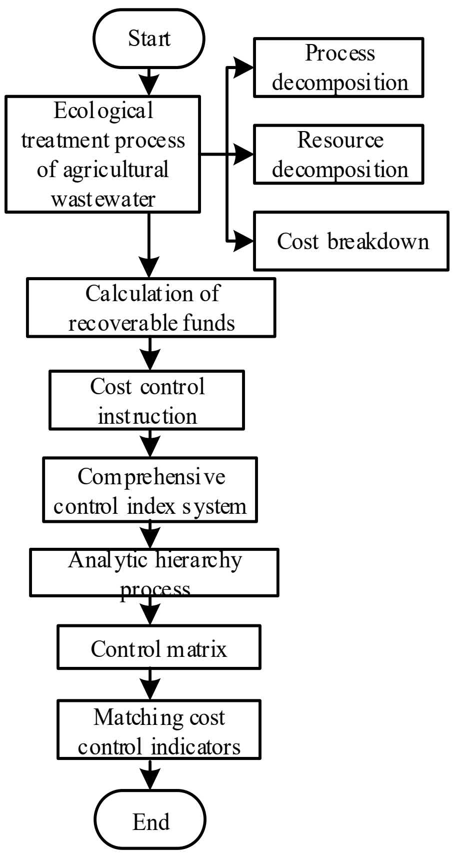

Figure 1. Cost control process of ecological treatment of agricultural wastewater.

Validation of proposed system

To verify the application effect of the cost control method of agricultural wastewater ecological treatment based on secondary net value method, an experimental platform was built to simulate the operation process of the system. According to the actual needs of wastewater treatment process and the principle of total cost control, the annual report of a sewage discharge project that combined biological agent and lime process to produce high calcium external drainage was taken as the data source. During the sewage treatment process, the consumption of tap water was 9,483 tons, the annual power energy consumption was ¥3.196 million, and the AC power consumption was 5.96 million kwh, the cost was ¥3.13 million, the costs of various reagents, materials, and sewage acid treatment lime milk was ¥20 million, and the target cost was ¥35.18 million. According to the actual cost control situation, the stability of treatment cost under the integration of multiple treatment processes was considered, and the control degree of treatment cost between the proposed system and the conventional systems was compared [5-7].

Results and discussion

Phased cost control performance of different control methods

The phased cost control performance of different methods in three decomposition stages of process, resource, and cost demonstrated that the proposed system showed a large increase in the process decomposition compared to the method developed by Brown [5], while it was lower than those methods reported by Chen and Fu *et al*. [6, 7] with less overall recovery of funds (Figure 2). However, the increase of cost control in the three stages of the proposed method was the smallest one, which indicated that the performance of proposed system in stage cost control was the best, and the overall performance was better than the other control methods.

The effect of application

To verify the practical application effect of proposed method, the analysis degree of total recoverable funds by different methods was compared, and the control degree was evaluated accordingly. The results showed that the Confucius degree reached 99% with an average value of 81% in the proposed method, while the average values of other methods were 78% and 73%, respectively (Figure 3). These results were

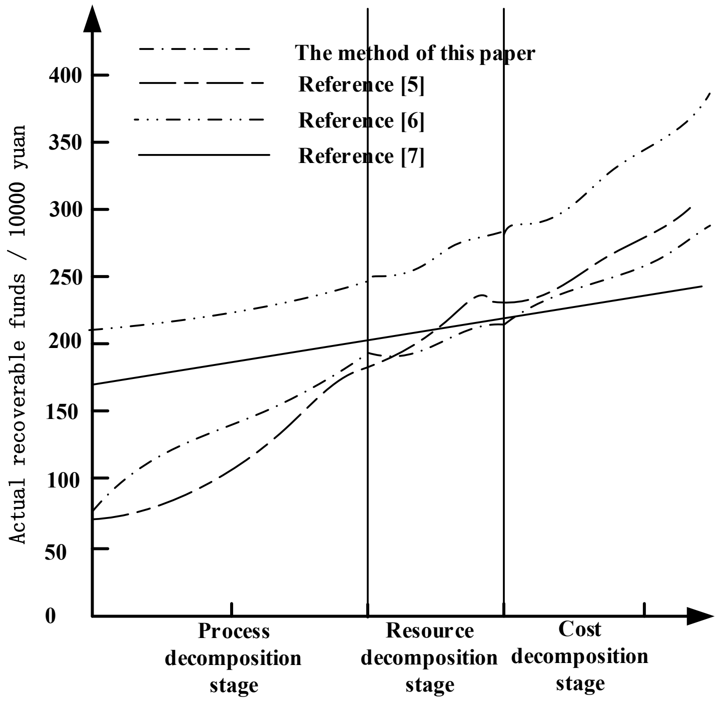

Figure 2. Phased cost control performance of different methods.

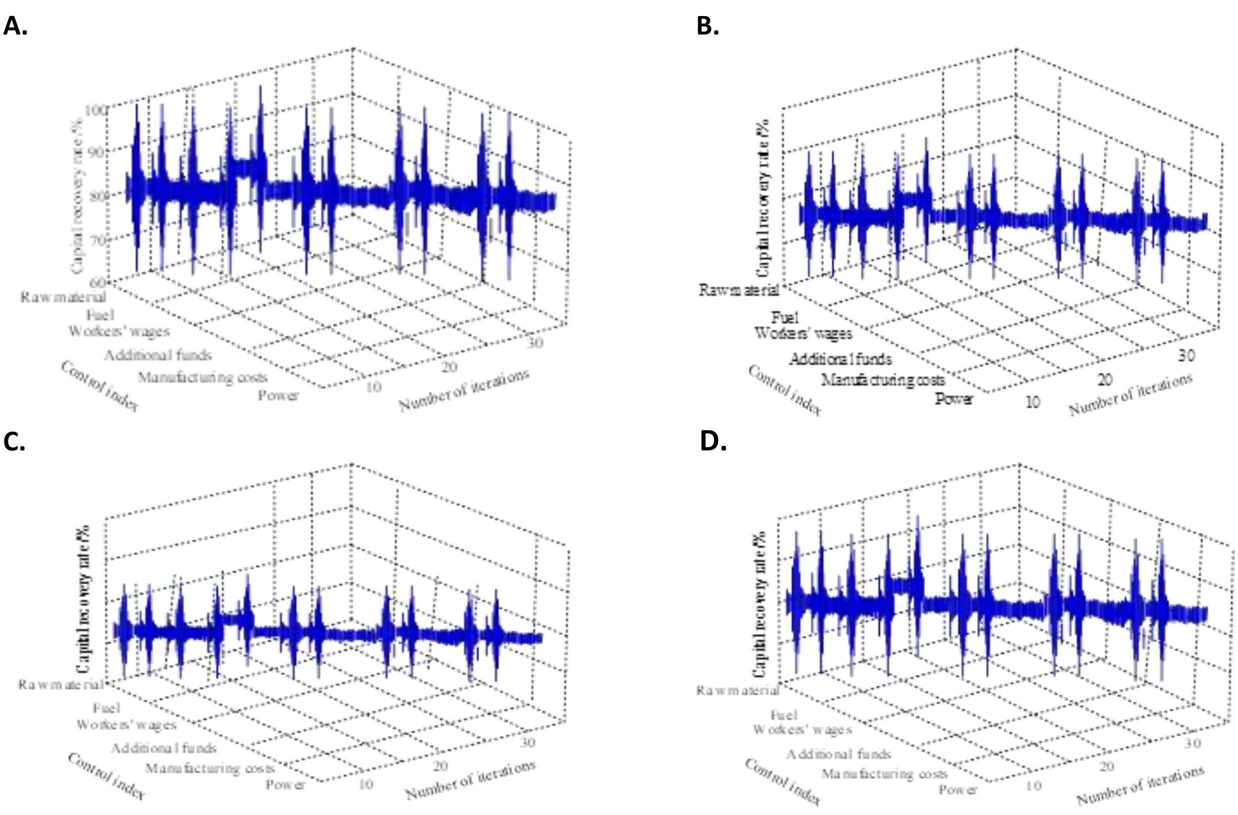

Figure 3. General description of valuation analysis results of bill preparation. **A.** proposed method. **B.** method reported by Brown [5]. **C.** method reported by Chen [6]. **D.** method reported by Fu *et al*. [7].

due to the introduction of the secondary net value method into the cost control of ecological treatment of agricultural wastewater. Under the accounting mode of the secondary net value method, the specific input cost value was adjusted to the specific book value to effectively calculate the actual treatment costs.

Validation of the feasibility

According to the fitting effect between the estimated value of cost control and the actual value, the validity of the feasibility analysis results of different methods was judged, and the method proposed in this study was further verified by comparing the cost control efficiency. The comparison test results showed that the proposed method established a comprehensive control index system to accurately calculate the recoverable funds, and the fitting degree with the actual value was higher than that of the other methods (Figure 4). The results indicated that the proposed method had strong cost control performance and could provide beneficial value for related research in this field.

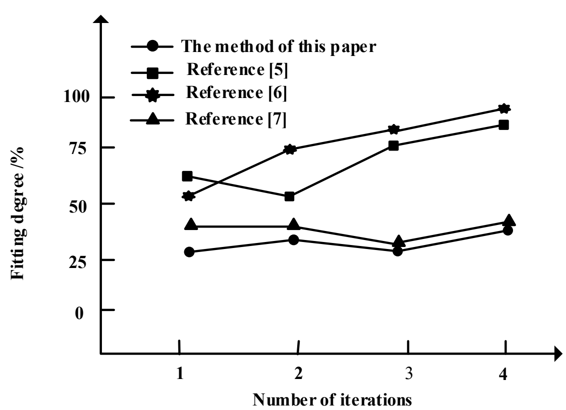

Figure 4. Cost control feasibility comparison results of different methods.

This research proposed a secondary net value method and investigated its application in the cost control of agricultural wastewater ecological treatment, which was of great significance to scientifically and accurately define the "recoverable funds in the treatment process". A comprehensive control index system for the ecological treatment process of agricultural wastewater was constructed. The experimental results showed that the proposed method could adjust the specific input cost value to the specific value of the input cost under the accounting mode of the secondary net value method, which could effectively calculate the actual processing cost and ensure the stage cost control performance and overall control performance. To build an ecological civilization and coordinate the relationship between humans and nature, future research should pay attention to the issue of agricultural source pollution and solve it through development and guidance in accordance with the requirements of modern agriculture and sustainable development. While developing agricultural production, efforts should be made to minimize the pollution caused by agricultural production to the environment. The comprehensive adoption of harmless treatment technology for agricultural wastewater and the construction of demonstration projects for the resource utilization of agricultural wastewater would be the most effective ways to control agricultural non-point source pollution.

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