Strategies for the Integrated Management of Black and Odorous Water Bodies in Rural Areas

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Abstract

The rural ecological environment constitutes a critical component of the "three farmers" agenda, with the remediation of black and odorous water bodies being a pivotal element within this domain. This paper elucidates the definition of black and odorous water bodies in rural settings, examines their formation mechanisms and prevailing challenges, and proposes an integrated water body treatment technology encompassing "source control and pollution interception + internal remediation + ecological purification." Additionally, it advocates for enhancing the operational and maintenance models as well as governance systems to provide actionable insights for addressing black and odorous water bodies in rural areas.

Keywords

Black and odorous water, rural areas, treatment technology, operation and maintenance models, governance systems.

1. Introduction

The control and remediation of black and odorous water bodies in rural areas is a critical component of enhancing the rural living environment. This issue is closely tied to the implementation of the rural revitalization strategy and directly impacts the well-being of farmers. In recent years, local governments have actively promoted the treatment of black and odorous water bodies in rural areas, achieving some success in rural wastewater management. However, the improvement of these water bodies remains a significant challenge in enhancing the rural living environment. This paper analyzes the causes and existing problems of black and odorous water bodies in rural areas and proposes comprehensive countermeasures such as "source control and pollution interception + internal remediation + ecological purification" water body treatment technologies. Additionally, it suggests improvements to the operational maintenance model and governance system mechanisms to provide valuable references for managing black and odorous water bodies in rural areas, ultimately contributing to the creation of a beautiful countryside that is suitable for living and working.[1-3]

2. Definition of Black and Odorous Water Bodies

2.1. Sensory Judgment

Black and odorous water bodies are characterized by abnormal water color (such as black or white) or abnormal smell (such as strong, unpleasant odors). If a water body exhibits either "black" or "smelly" characteristics, it is classified as a black and odorous water body.[4]

2.2. Water Quality Monitoring

When sensory judgment does not definitively identify a water body as black and odorous, water quality monitoring can be used to determine its status. Key water quality indicators include transparency, dissolved oxygen (DO), redox potential (ORP), and ammonia nitrogen (NH3-N). The criteria for assessing these water quality indicators are as follows:

Table 1. Classification Standard for the Degree of Pollution in Black and Odorous Water Bodies

Characteristic index (unit)	Slight black odor	Heavy black odor
Transparency(cm)	25~10*	<10*
DO(mg/L)	0.2~2.0	<0.2
ORP(mV)	-200~50	<-200
NH_3-N(mg/L)	8.0~15	>15

Note: * When the water depth is less than 25cm, the value of this indicator is 40% of the water depth

Table 2. Methodology for Determining Water Quality Indices

Numble	Item	Determination method	Remark
1	Transparency	Black and white disk method or type method	In situ assessment
2	DO	Electrochemical method	In situ assessment
3	ORP	Electrode method	In situ assessment
4	NH_3-N	Nesser's reagent spectrophotometry or salicylic acid-hypochlorite spectrophotometry	The water sample should be filtered through a 0.45μm filter membrane

Note: For the analysis method of relevant indicators, refer to the Monitoring and Analysis Method of Drinking Wastewater (4th Edition) (Added Edition).

In principle, detection points should be established along black and odorous water bodies at intervals of 200 to 600 meters, with a minimum of three points per water body. Sampling points are typically positioned 0.5 meters below the water surface; however, if the water depth is less than 0.5 meters, the sampling point should be set at half the water depth. Testing should occur once every one to seven days, with a minimum of three tests conducted.[5]

3. Cause Analysis of Black Odor in Rural Water Bodies

The occurrence of black and odorous water can be attributed to several factors, which are summarized as follows:

(1) Insufficient Hydrodynamic Conditions: Hydrodynamic conditions play a crucial role in water quality. Poor hydrodynamics, characterized by inadequate water flow, can lead to varying degrees of pollution, ultimately resulting in black and odorous water. The deterioration of water quality exacerbates this issue.[6]

(2) Metal Element Pollution: High concentrations of iron and manganese in water bodies can lead to reduction reactions under anaerobic conditions. These reactions produce ferrous sulfide and manganese sulfide, contributing to the black and odorous characteristics of river water.

(3) Organic Pollution: The root cause of black and odorous water is biochemical in nature. Under anaerobic conditions, the oxygen consumption rate of organic matter exceeds the reoxygenation rate, leading to anoxic conditions. Anaerobic microorganisms decompose organic matter, producing foul-smelling pollutants such as hydrogen sulfide, methane, and ammonia. Over time, this results in visible black and odorous water.[7]

Agricultural non-point source pollution has become increasingly severe due to the increased use of fertilizers. During heavy rains, surface soil fertilizers can wash into rivers, causing eutrophication and contributing to black and odorous water. Long-term pollution leads to the

accumulation of contaminants in bottom sediments, reducing water environmental capacity and causing secondary pollution through resuspension of these sediments.

4. Challenges in the Regulation of Black and Odorous Water Bodies in Rural Areas

(1) Inadequate Capital Investment. The remediation of black and odorous water bodies in rural areas necessitates substantial capital investment, encompassing equipment procurement, technology research and development, and human resources. However, due to insufficient funding, many regions struggle to allocate adequate resources, hindering the smooth implementation of renovation projects.

(2) Low Technical Proficiency. Although significant progress has been made in the remediation technology for black and odorous water bodies in rural areas, the technical proficiency remains lower compared to urban areas. Many regions lack professional technical personnel and advanced equipment, leading to suboptimal remediation outcomes.

(3) Insufficient Management. Inadequate management is a prevalent issue in the remediation of black and odorous water bodies in rural areas. The absence of effective management mechanisms and supervision measures in numerous regions results in recurring illegal pollution discharge activities that cannot be promptly halted or addressed.

(4) Unclear Accountability. The comprehensive treatment project for black and odorous water bodies involves multiple departments, including housing construction, development and reform, agriculture and rural affairs, ecological environment, water management, and township governments. This multi-departmental involvement leads to unclear accountability. The lack of information sharing channels and mechanisms among departments hinders steady coordination of governance projects. Moreover, after treatment, the water management mechanism remains ambiguous, increasing the risk of secondary black and odor issues.

(5) Lack of Mature Reference Models. Most black and smelly water bodies in rural areas are closed waters with poor self-purification capacity and marked seasonal changes. During wet seasons or summers with abundant rainfall, these water bodies may contain water, while they are mostly dry in winter and spring. There is no clear criterion for determining whether they should be classified as black and smelly water bodies, resulting in numerous unaccounted cases. Due to varying geographical locations, different causes of black and odor, and diverse governance requirements, it is inappropriate to adopt a uniform governance model. As the treatment of black and odor water bodies in rural areas is still in its infancy, there is a lack of mature reference models.[8]

5. Treatment Technology for Black and Odorous Water Bodies in Rural Areas

With the government's increasing emphasis on controlling black and odorous water bodies in rural areas, various action plans and guidelines have been continuously issued, leading to comprehensive implementation of control measures. These technologies can be categorized into three main types: source control and pollution interception, internal remediation, and ecological purification. Source control and internal pollution management form the foundation, while ecological restoration ensures sustained improvement in water quality.[9]

5.1. Source Control and Pollution Interception

Source control and pollution interception in rural areas primarily focus on non-point source control of livestock and poultry breeding. Key technologies include fecal and urine separation, rainwater and wastewater diversion, solid manure composting, and agricultural land reuse

after wastewater treatment. Non-point source control is particularly effective for managing pollutants such as snowmelt, livestock and poultry sewage, and surface solid waste.

5.2. Internal Remediation

Internal remediation technologies mainly involve cleaning and dredging of biological residues and floating matter. Seasonal internal pollutants like aquatic plants, coastal vegetation, and fallen leaves should be removed before they dry and decay. Floating objects on the water surface, including leaves, plastic bags, and other domestic waste, require ongoing cleaning and maintenance. Dredging methods include mechanical and hydraulic dredging, with considerations for storage and purification of the original black and odorous water. Prior to dredging, a thorough survey of sediment pollution should be conducted to determine the scope and depth of dredging. The dredging season should be selected based on local climate and rainfall patterns, ensuring minimal impact on aquatic life. Post-dredging water quality must meet the "no black odor" standard.[10]

5.3. Ecological Purification

Ecological purification employs techniques such as constructed wetlands, ecological floating islands, and aquatic plant cultivation, utilizing soil-microbial-plant ecosystems to effectively remove organic matter, nitrogen, phosphorus, and other pollutants from water. For optimal water purification, landscape enhancement, and climate adaptability, locally sourced plants with strong purification effects should be prioritized, with attention to their spatial layout within water bodies. Harvesting of plants should occur during appropriate seasons. Ecological purification should only be applied after effective control of external and internal pollutants, ensuring no conflict with other water body functions. While ecological purification may not significantly improve severely polluted rivers, it is widely applicable for long-term urban water quality maintenance, continuous pollutant removal, and environmental and landscape enhancement through ecosystem restoration.[11]

5.3.1. Constructed Wetlands

Constructed wetlands leverage the synergistic physical, chemical, and biological processes of soil, artificial media, plants, and microorganisms to treat sewage and sludge. In rural areas, constructed wetlands offer significant advantages: they use purely biological methods for water purification, avoiding secondary pollution; they enhance the rural environment with aesthetically pleasing aquatic plants and flowers; and they provide sustainable economic benefits by selecting high-value aquatic plants that generate income alongside wastewater treatment.

5.3.2. Ecological Floating Islands

Ecological floating islands utilize ecological engineering principles to degrade COD, nitrogen, and phosphorus levels in water. They significantly improve water transparency and quality indices. Plant roots form dense networks in the water, absorbing suspended particles and gradually developing biofilms that metabolize pollutants into inorganic substances, which are then converted into plant nutrients via photosynthesis. Harvesting floating island plants and fish/shrimp reduces nutrient levels in the water. Additionally, floating islands inhibit algal photosynthesis by blocking sunlight, reducing phytoplankton growth and promoting settlement, thus preventing algal blooms and enhancing water clarity. Floating islands also provide habitats for birds, fish, and aquatic insects, offering multiple benefits such as water purification, landscape beautification, habitat creation, and environmental education.

6. Countermeasures for the Rectification of Black and Odorous Water Bodies in Rural Areas

6.1. Enhance Technical Governance Capabilities

Based on continuously updating the inventory of black and odorous water bodies in rural areas, organize water treatment experts to classify and develop targeted technical guidelines for remediation according to pollution types. These guidelines should consider local hydrogeological conditions and socio-economic development, prioritizing solutions that directly impact daily rural life, such as household rivers, ponds, and ditches.

6.2. Optimize Operation and Maintenance Models

Deepen policies like "promoting treatment through incentives" and "substituting subsidies with rewards," increasing capital investment in rural black and odorous water body remediation. Improve financing mechanisms to attract social capital for project construction and operation. Pilot projects will be launched in regions with heavy remediation tasks, enhancing social participation and market operations. Funding sources will be diversified, accelerating the formation of replicable and scalable early-stage remediation and late-stage operation and maintenance models.[12]

6.3. Strengthen Governance Systems and Mechanisms

Reinforce a vertical management system where provincial authorities provide guidance, municipal governments oversee implementation, county governments organize efforts, and township governments execute specific tasks. Emphasize the primary role of county governments in management responsibilities, clarifying the roles of relevant departments such as agriculture, water resources, ecology, housing, and development reform. Establish clear divisions of responsibility for initial governance, late-stage operation and maintenance, supervision, and support, along with communication, coordination, information sharing, and collaborative promotion mechanisms at city, county (district), and township levels.

7. Conclusion

In rectifying black and odorous water bodies, it is essential to integrate local realities and adopt a comprehensive approach combining "source control and pollution interception + internal remediation + ecological restoration." Continuous improvement of management and operation models, multi-channel funding, inter-departmental coordination, and joint efforts are necessary to steadily enhance rural environmental quality and contribute to rural revitalization.

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