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Study on the present situation and prevention measures of water pollution in a drainage basin in Eastern Guangdong

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ABSTRACT

The routine water quality monitoring data from 2010 to 2015 were collected, and 24 routine water quality monitoring items were analyzed by single factor standard index method. The results show that the proportion of inferior V-type monitoring sections in the basin has reached 77.78%, which is generally severe pollution, and the main pollution factors are chemical oxygen demand, NH_4^+–N and total phosphorus. After investigation, it was found that the basin was affected by some heavy pollution tributaries, and the upstream to downstream of the main stream showed a trend of gradual pollution, especially when flowing through densely populated urban areas. Through the monitoring of various indicators, according to its concentration, change law and on-site analysis, the main reasons for the occurrence of black and odor in the basin are lagging construction of sewage pipe networks and sewage treatment plants, many heavily polluting enterprises, direct discharge of domestic sewage, random disposal of garbage, and low bottom mud release and management ability. Aiming at the current situation and causes of the black and odorous water bodies in this basin, combined with the research of other scholars, this paper compared the removal effects of various methods on pollutants. Aeration and magnetic flocculation technology can be adopted as emergency treatment measures in the river basin, and the treatment effect of each pollution factor is estimated to reach 80%. At the same time, in the long-term improvement stage of water quality, corresponding rectification measures are proposed, and the comprehensive water environment improvement project system is scientifically planned. The environmental quality is conducive to the sustainable development of urban economy and society, which is of great significance for promoting the coordinated development of economy, society and environmental protection in Eastern Guangdong.

Keywords: Single factor standard index method; Pollution factor; The black smelly water basin; Aeration and magnetic flocculation technology; Sustainable development.

1. Introduction

With the continuous development of China's industry, economy, and society, the population continues to increase, people's living standards continue to improve, and the discharge of domestic sewage is getting higher and higher. However, the backward municipal drainage facilities make it impossible to collect sewage effectively. Part of the sewage is directly discharged into the surrounding or internal rivers of the city, causing annual or seasonal black and odor pollution [1], destroying the urban landscape, affecting the image of the city, endangering the health of residents, and reducing the happiness of residents' lives.

In order to improve the quality of China's water environment and ecological environment, the State Council

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formally promulgated the "Water Pollution Prevention and Control Action Plan" in April 2015, which clearly stated that: "By 2020, water bodies in built-up areas in cities at prefecture level and above, should be controlled within 10%" [2]. Subsequently, the Ministry of Housing and Urban-Rural Development issued the "Guidelines for the Treatment of Urban Black and Smelly Water Bodies", which clearly explained the urban black and gaseous water bodies as: "Urban built-up areas show unpleasant color and (or) uncomfortable smell water collectively" [3].

The specific reason for the formation of black and odorous water is that under anaerobic conditions, microorganisms in the bottom sludge undergo denitrification and iron-manganese respiration. Iron is reduced from Fe^{3+} to Fe^{2+}, and manganese is reduced from Mn^{4+} to Mn^{2+}, forming black precipitates or suspended solids, making the water body appear black [4]. When the oxidation–reduction potential of the sediment further decreases, obligate anaerobic microorganisms become the dominant species, sulfate-reducing bacteria undergo sulfur respiration, and sulfate radicals are reduced to hydrogen sulfide. As the oxidation-reduction potential drops to a lower level, methane will be produced [5]. The corruption of other organic matter in the water body can also produce ammonia and other odorous gases, which can cause the water body to stink [6].

Compared with China, Western developed countries have experienced rapid economic development after the Industrial Revolution, but at the same time the legal system was imperfect and the infrastructure construction lags behind, resulting in serious river black and odor problems [7]. Since the 1930s, many western developed countries began to pay attention to the problem of river black and odor, and actively study technologies for restore river health and improve the ecological environment [8]. Seifert of Germany first proposed the theory of river ecological restoration, that is, the concept of "near-natural river management" combining river management and landscape construction. The renovation project is proposed to ensure the basic functions of river flood control, irrigation, and water conservancy, so as to maintain the natural environment state [9]. Later, developed countries such as Europe, America and Japan have successively proposed sustainable ecological engineering restoration concepts, which mainly included aquatic animal and plant restoration, ecological diversity protection, and coastal residents' pollution prevention and control methods [10,11].

It can be found that foreign scholars focus on studying water pollution control issues from the macro-management level, and have relatively in-depth research in theoretical systems, governance models, policy tools and other fields. However, domestic scholars tend to study and solve specific practical problems in the water pollution control process from the micro level. For example, in terms of system construction and governance technology, their research results often come from the experience summaries after solving many practical problems. Zhang et al. [12] took London's water pollution control as the research object and mentioned the positive effects of measures such as improving the water management system, improving the sewage collection system, and establishing a sustainable drainage system on water pollution control, and analyzed the water environment governance concept of "pollution first, treatment later". Aiming at a black and smelly river located in the urban-rural combined area of Suzhou, Kong et al. [13] proposed "forward investigation and reverse source tracing", sewage disposal and pollution source elimination, and other shore projects, and implemented comprehensive river management with river ecological restoration measures. Hou and Wang [14] reviewed the current outstanding problems of environmental pollution in our country from the perspective of chemical technology, demonstrated the advantages of chemical technology in the treatment of environmental pollution problems, and introduced its practical application in the treatment process. Lin et al. [15] studied Dongting Lake, Guo et al. [16] studied Poyang Lake, and Zhang et al. [17] studied the distribution characteristics and influencing factors of water pollutants in the urban area of Yixing City.

In addition, most of the research focuses on the formation mechanism of black and odorous water bodies [18,19], compounds that cause blackening and odor formation [20], development conditions [21], biogeochemical processes [22–24] and methods to control or deal with black and odorous water bodies. Common treatment methods can be divided into physical technology, chemical technology, biotechnology, etc. according to the principle of technical action. According to the current experience of treating black and odorous water bodies in China, the current physical technologies mainly include dredging [25], water diversion and water transfer [26], aeration and reoxygenation [27], pollution interception control, etc., which are currently commonly methods for black and odorous water bodies. Compared with physical treatment technology, chemical treatment technology has a clear directional and fast processing speed. Common treatment technologies include coagulation precipitation [28] and redox [29]. The root cause is the addition of chemical compounds to the water body, while most of these additives are synthetic and expensive. After sewage treatment, new pollutants may be generated, which will deteriorate the water quality again. Therefore, this technology is rarely used in practical engineering, but is often used for some sudden pollution. Compared with physical and chemical technologies, biological treatment technology has the advantages of simple process, low operating cost and stable effect. It can be divided into plant biology method [30], microbial method [31] and biofilm method [32], etc. However, the disadvantage is that certain organisms can only absorb, utilize, degrade and convert certain types of pollutants.

If the focus of the treatment of black and smelly rivers is only the breakthroughs of engineering technology, and there is no systematic analysis of the whole process of water pollution prevention and control, it is very easy to cause the of black and smelly water bodies to rebound, and long-term stable treatment effects will not be achieved. Based on the detection data of pollutants in the research basin, this article will analyze the reasons for the formation of black and odorous water bodies, systematically explore the whole process of water pollution, and promote comprehensive treatment in many aspects, so as to achieve the goal of effective treatment.

2. Research criteria and methods

2.1. Research criteria

With the rapid development of cities and economic construction, pollution has become more and more serious. The water quality of this river basin has deteriorated year by year, especially at the intersection of the two cities, where the water quality of the section has exceeded the standard for a long time, which has severely restricted the sustainable development of the regional economy and society. It has affected the long-term deep feelings between the two cities and become a bottleneck factor in the construction of a harmonious society. Therefore, the pollution treatment of the river basin is imminent.

In order to comprehensively understand the water environment quality of the river basin, this paper collected the routine water quality inspection data of the river basin from 2010 to 2015, and supplemented the monitoring of the current status of hydrology and water quality of the river basin, providing a solid basis for objectively analyzing the temporal and spatial characteristics of the water quality of the river basin.

According to the "Guangdong Province Surface Water Environmental Function Zoning" and the "Guangdong Province Cross-prefectural Level Management Plan for Cross-section Water Quality Compliant with Listed Rivers", the "Surface Water Environmental Quality Standard" (GB3838-2002) Class IV standard is implemented. Therefore, each section in the basin is evaluated using Class IV standards, and the specific indicators are shown in Table 1.

2.2. Research methods

In this paper, refer to the relevant content of "Surface Water Environmental Quality Assessment Method" and "Environmental Impact Assessment Technical Guidelines for Surface Water Environment" (HJ/T 2.3), and use single factor standard index method and other methods for evaluation.

For general water quality indicators, the calculation formula of the single factor standard index method is:

$$S_{i,j} = \frac{c_{i,j}}{c_{s,i}} \tag{1}$$

In Eq. (1), $c_{i,j}$ is the jth actual measured value of the ith water quality index (mg/L), and $c_{s,i}$ is the evaluation standard value of the water quality index (mg/L).

The standard index calculation formula for dissolved oxygen (DO) is:

$$S_{\mathrm{DO},j} = \frac{\left|\mathrm{DO}_f - \mathrm{DO}_j\right|}{\mathrm{DO}_f - \mathrm{DO}_s},\ \mathrm{DO}_j \geq \mathrm{DO}_s \tag{2}$$

$$S_{\mathrm{DO},j} = 10 - 9\frac{\mathrm{DO}_j}{\mathrm{DO}_s},\ \mathrm{DO}_j < \mathrm{DO}_s \tag{3}$$

$$\mathrm{DO}_f = \frac{468}{\left(31.6 + T\right)} \tag{4}$$

In Eqs. (2)–(4), DO_f is the measured saturated DO value (mg/L) under temperature and pressure environment, DO_j is the jth measured DO value (mg/L), DO_s is the evaluation standard value (mg/L).

The standard index formula for pH is as follows:

$$S_{\mathrm{pH},j} = \frac{7.0 - \mathrm{pH}_j}{7.0 - \mathrm{pH}_{\mathrm{su}}},\ \mathrm{pH}_j \leq 7.0 \tag{5}$$

$$S_{\mathrm{pH},j} = \frac{\mathrm{pH}_j - 7.0}{\mathrm{pH}_{\mathrm{sd}} - 7.0},\ \mathrm{pH}_j > 7.0 \tag{6}$$

In Eqs. (5) and (6), pH_j is the jth actual measured value, $\mathrm{pH}_{\mathrm{sd}}$ is the upper limit of the evaluation standard, and $\mathrm{pH}_{\mathrm{su}}$ is the lower limit of the evaluation standard.

The formula for calculating the over-standard rate (Re) is:

$$R_e = \frac{n_e}{n} \times 100\% \tag{7}$$

In Eq. (7), n_e: the number of exceedances of a certain item, n: the total number of monitoring of a certain item.

3. Overview and problem analysis of the river basin

3.1. Water quality analysis and evaluation

Routine water quality monitoring items include water temperature, pH, DO, permanganate index, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), NH_4^+–N, total phosphorus (TP), total nitrogen (TN), Cu, Zn, fluoride, Se, As, Hg, Cd, Cr^{6+}, Pb, Cyanide, volatile phenol, petroleum, LAS, sulfide, fecal coliform, etc. According to the

Table 1
Environmental quality standard limits for surface water

Project \ Classify		Unit: mg/L				
		Class I	Class II	Class III	Class IV	Class V
COD	≤	15	15	20	30	40
BOD_5	≤	3	3	4	6	10
NH_4^+–N	≤	0.15	0.5	1.0	1.5	2.0
TP	≤	0.02	0.1	0.2	0.3	0.4
TN	≤	0.2	0.5	1.0	1.5	2.0

monitoring data of the handover section from 2010 to 2015, the single factor standard index method was used to analyze the over-standard situation of its 24 routine water quality monitoring items, and the top five major over-standard indicators in the order of standard index values are listed in Table 2.

As can be seen from Table 2, the annual mean of water quality showed that the main factors exceeding the standard of the intersection section were TP, TN, NH_4^+–N, DO and BOD_5, and the other indicators reached or were better than class IV. Among them, DO exceeded the standard index most seriously from 2010 to 2012, and the standard index value reached more than 4. After 2013, the standard index began to improve, and the standard index dropped to 1.00 in 2015. TP index had been a more serious factor exceeding the standard.

From the perspective of time trend, the change trend of water quality at the handover section is not obvious, but fluctuates greatly. The fluctuation of water quality is mainly affected by factors such as dry and high seasons and flow, and it has shown a trend of improvement in the past five years. Among them, the DO index has shown a trend of improvement year by year during the wet season, normal water season and dry season, and the water standard has changed from a poorer Category V to a Category IV water standard, which was significantly improved (Fig. 1). The lowest value appeared in the dry season of January 2011, and the organic matter index COD_{Cr} indicator was classified as Class V except for the normal water period in 2010 and the low water period in 2014 and 2015. The rest periods basically reached the Class IV water standard, and the maximum concentration appeared during April in the normal period of 2010 (Fig. 2). The concentration of BOD_5 index in the high-water season from 2010 to 2015 was lower than that in the normal water season and the low water season. The concentration of BOD_5 index in each water period was higher than that in the IV water standard, which was in line with or worse than that in the V water standard, and the maximum concentration appeared in 2011 (Fig. 3). The nutrient salt indexes of N and P (TN, TP and NH_4^+–N) fluctuated greatly, and there was no significant difference in the water quality of the concentration values in different water periods, presenting alternating fluctuations and falling into the standard of poor V water throughout the year. The maximum value of TN concentration appeared in April of the horizontal period in 2010 (Fig. 4), and the maximum value of NH_4^+–N appeared in March of the horizontal period in 2010. The maximum TP appeared in March of the normal period of 2010 (Fig. 5).

It can be seen from the above that the whole basin was seriously polluted during the study period. The proportion of monitored sections inferior to Category V reached 77.78%, and the main pollution factors were NH_4^+–N, TP and COD_{Cr}, and the maximum exceeding multiples were 1.84, 3.86 and 1.83 times respectively. Most of the exceeding rates reached 100%. The overall water quality status is inferior to Category V, which belongs to severe pollution. The investigation found that the basin is affected by some heavily polluted tributaries. The main stream is gradually polluted from upstream to downstream, and the water body changes from upstream Category III to downstream junctions to become inferior V. The deterioration of water quality is particularly obvious when flowing through densely populated urban areas, and the water quality of heavily polluted tributaries is worse than Category V.

3.2. Analysis of heavy metals in bottom mud

During the inspection period, the study conducted a river surface sediment inspection at the river basin junction, which was implemented simultaneously with the

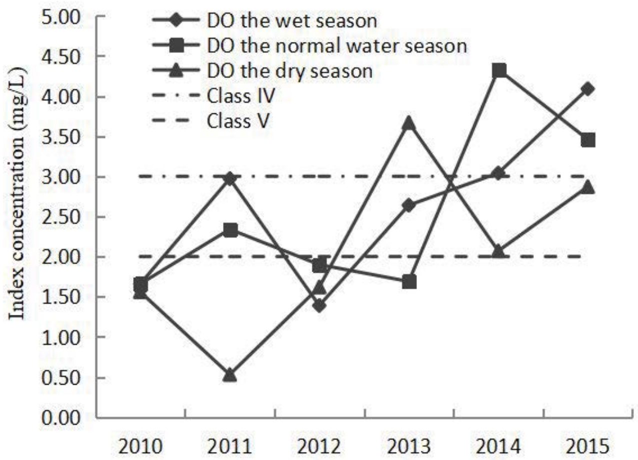

Fig. 1. Change trend of DO time at the junction section.

Table 2
Major projects exceeding the standard of the handover section from 2010 to 2015

Time	Over-standard items/standard index				
	1	2	3	4	5
2010	DO/4.95	TN/3.53	NH_4^+–N/2.32	TP/2.26	BOD_5/1.74
2011	DO/4.12	TN/3.21	NH_4^+–N/2.15	TP/2.28	BOD_5/2.02
2012	DO/4.90	TN/2.64	NH_4^+–N/2.08	TP/2.39	BOD_5/1.25
2013	DO/2.30	TN/2.31	NH_4^+–N/2.19	TP/2.31	BOD_5/1.46
2014	DO/1.82	TN/1.59	NH_4^+–N/1.62	TP/1.59	BOD_5/1.42
2015	DO/1.00	TN/2.31	NH_4^+–N/1.91	TP/2.31	BOD_5/1.60

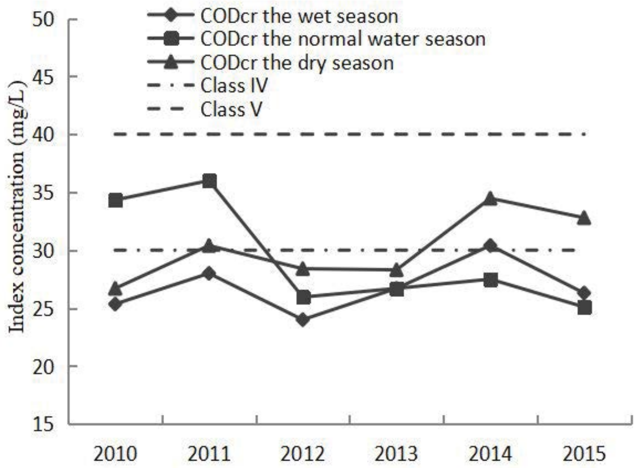

Fig. 2. Trend diagram of COD_{Cr} time variation at the junction section.

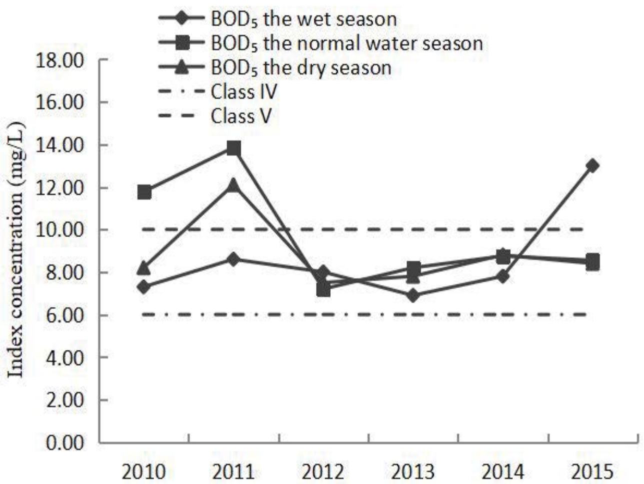

Fig. 3. Time variation trend diagram of BOD_5 at the junction section.

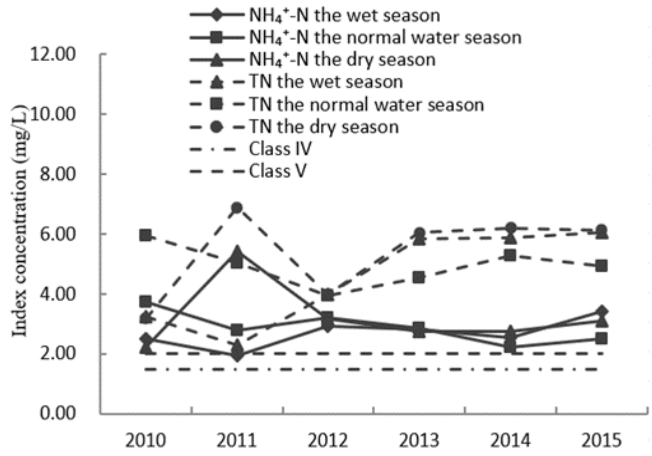

Fig. 4. TN, NH_4^+–N time variation trend at the junction section.

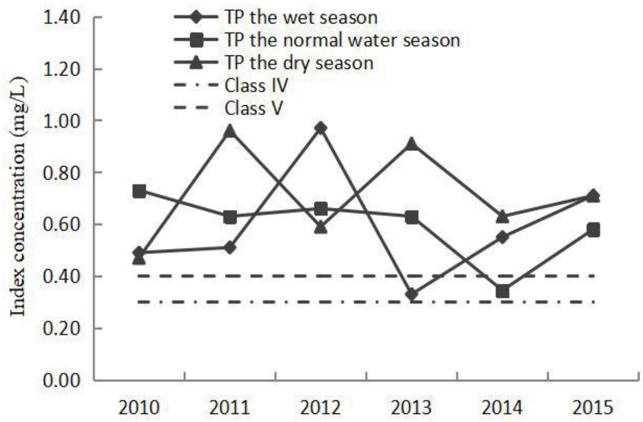

Fig. 5. Tendency diagram of TP time at the junction section.

hydrological and water quality survey. The inspection and analysis results are shown in Table 3.

It can be seen from the above table that the contents of various heavy metal pollutants in the bottom sludge of the transfer section are within the control standard range of the neutral and alkaline soil, most of which are within the control standard value range of acid soil, and only two indicators Cd and Cr exceed the acid soil control standard. It can be seen that there are fewer heavy metal pollutants in the water pollutant discharge in this watershed, and the source of domestic pollution should be the main source. After being dredged, the sediment can be used for nearby agricultural purposes under non-acidic conditions.

4. Causes analysis of water environment problems

The study found that the water pollution prevention and control situation in this river basin is severe. The river section is in a state of heavy pollution. The water quality of the main stream and most of its tributaries is worse than class V. The main pollution factors are chemical oxygen demand, ammonia nitrogen and total phosphorus, oxygen consumption organic matter and nitrogen and phosphorus. The problem of nutrient pollution is prominent.

4.1. Construction progress of sewage pipe network and sewage treatment plant is lagging behind

The sewage pipe network is still the main shortcoming of pollution control measures. According to the investigation, the first local sewage treatment plant has a total scale of 100,000 ton/d, and the length of the supporting main pipe is only 1.4 km, and the supporting pipe network is seriously insufficient. At present, the water plant only concentrates on the treatment of domestic sewage collected in the urban area. The regional distribution is uneven, and the sewage treatment rate needs to be improved. According to the concentration calculation, it is estimated that the domestic sewage collection rate in the urban area is only about 60%, which is already the highest in the whole basin. The domestic sewage that is not collected effectively has

Table 3
Analysis results of river surface sediment detection in the basin

						(mg/kg)	
Project		Cu	Cd	Cr	Pb	Hg	As
Detection value		129	5.08	791	139	2.79	28.9
Agricultural sludge control standard	Acidic	250	5	600	300	5	75
	Neutral alkaline	500	20	1,000	1,000	15	75

a high concentration and directly enters the river basin, which has a greater impact on the downstream assessment section. The most critical problem in the basin is that the sewerage pipe network cannot achieve effective collection.

The construction progress of the sewage treatment plant needs to be accelerated. The amount of domestic sewage in the study basin is about 150,000 ton/d, and the amount of industrial wastewater is about 100,000 ton/d. The only domestic sewage treatment facility built and operating is the first sewage treatment plant (100,000 ton/d), which is far from meeting the sewage treatment requirements in the basin.

4.2. There are many heavy polluting enterprises, which are scattered and have limited control ability

According to the environmental statistics database, there are 166 major pollution sources in the basin, with daily discharge of 26,787.48 tons of wastewater, 3.32 tons of chemical oxygen demand, and 0.16 tons of ammonia nitrogen. The analysis shows that among the distributed enterprises, the heavy-polluting industries account for a relatively large proportion. The chemical oxygen demand and ammonia nitrogen emissions in the basin rank first in the industrial output value of machine-made paper and paperboard, cotton chemical fiber textile, printing and dyeing finishing, feather (velet) processing, and leather tanning processing industries. It shows that there are many heavy-polluting industries with high emissions and low output. In addition, the enterprises are small in scale, scattered, and limited in governance capabilities, causing serious structural and pattern pollution.

4.3. River sediment pollution restricts water quality improvement

According to the results of on-site sampling and analysis, the sediment near the junction section in the basin has been seriously polluted, and the pollutants have accumulated in the sediment. Under appropriate conditions, the pollutants in the sediment will be released into the water body, causing endogenous pollution in the water body and affecting the subsequent water quality improvement process.

4.4. Lack of sewage treatment facilities in rural areas, and the rural sewage in the region is basically discharged without treatment

Part of the domestic waste collected by villages and towns in the basin is transported to a simple landfill for centralized treatment, and part of the waste is dug nearby for landfill. Trash accumulation has been found along roads, rivers and in the rivers. And aquaculture wastewater and domestic sewage are directly discharged into the nearby rivers without treatment. Non-point source pollution was caused by the use of chemical fertilizers and pesticides.

4.5. Environmental management capability needs to be improved

According to the investigation, the average chemical oxygen demand and ammonia nitrogen concentration in the drainage of seasoning, fermented products manufacturing, vegetable and fruit processing, cosmetics manufacturing and other industries in the basin far exceed the discharge standards. In particular, undocumented production and environmental violations such as illegal discharge, leakage and excessive discharge have been repeatedly banned. Administrative capacity according to law, environmental supervision and punishment, and punishment for environmental violations need to be improved urgently.

5. Comprehensive rectification suggestions

The treatment of black and odorous water bodies is a systematic project, and the causes, current situation and influencing factors of black and odorous water bodies are different. According to the rectification measures in other parts of the country and the actual situation in eastern Guangdong, from the perspective of water environment treatment in river basins, the following treatment measures are proposed from the two stages of emergency treatment and long-term water quality improvement, aiming to provide a macro perspective and theoretical basis for the control of black and odorous river channels and the prevention and control of water pollution in river basins.

5.1. Program recommendations for emergency governance phase

The main pollutants in the basin are COD, NH_4^+–N and TP. Studies have shown that magnetic adsorbents have a good effect on phosphate removal, and the maximum removal rate of phosphates can reach 98.14%, which can be used as an emergency treatment method for water bodies for rapid recovery and clarification of water bodies [33]. Harsha et al. studied a novel bentonite–alum adsorbent system to treat phosphates in black and odorous water. The results showed that the removal rate of phosphates by the system was 92.2% under the optimal adsorption conditions [34].

According to Huang [33] research on Caojiagou in Harbin, the main control factors of Caojiagou are COD, NH_4^+–N, PO_4^{3-}–P, DO, T and Fe. The coagulation and aeration experiment results on Caojiagou raw water showed that the maximum removal rates of COD and nitrate by magnetic flocculation reached 89.77% and 98.14%, respectively. The maximum removal rate of COD by the aeration oxygenation method can reach 65%; the addition of activated sludge during aeration can further increase the removal rate of COD and ammonia nitrogen; under the combination of aeration and magnetic flocculation, the removal rates of COD, NH_4^+–N, PO_4^{3-}–P, TP and Fe can reach 99.42%, 80.87%, 100%, 99.22% and 85.35%, respectively. The specific comparison before and after removal is shown in Fig. 6.

It can be seen from the figure that under the combination of aeration and magnetic flocculation technology, the reduction of each indicator has reached 80%, which can quickly restore the water body to a better sensory effect and quickly achieve the purpose of water purification. The main pollution factors in the basin are COD, NH_4^+–N, and TP, which are similar to those in Caojiagou. Therefore, aeration and magnetic flocculation technology can be used for emergency treatment measures in this basin, and the treatment effect of each pollution factor is estimated to reach 80%.

5.2. Long-term water quality improvement phase program proposal

After emergency treatment measures, the degree of blackness and odor of the water body will be alleviated. However, in order to prevent the water quality from turning black and smelly, comprehensive treatment should be taken from multiple perspectives such as source emission reduction, process interruption and management from a long-term perspective and combining the on-site situation to achieve the goal of clear and odorless water body.

5.2.1. Accelerate the pace of the construction of urban sewage treatment plants, with emphasis on supporting the construction of sewage collection pipe network

In view of the uneven distribution of local sewage treatment plants and the low sewage treatment rate, the construction of the second sewage treatment plant should be accelerated in light of the local conditions. The sewage collection pipe network in the old urban area and heavily polluted rivers should be actively promoted to implement rain pollution in the river basin, speed up the improvement of rain and sewage diversion in the drainage system of the old county, expand the sewage collection area, and increase the concentration of the inflow of the sewage treatment plant. For the road network and all construction projects in the new district of the county, it's necessary to strictly implement the rain and sewage of the pipeline network diversion, adopt measures such as clean-up and diversion and interception along the river to greatly increase the sewage collection rate, and send to the pollution treatment plant through pipelines, box culverts and other facilities.

5.2.2. Adjust and optimize the industrial structure and optimize the spatial layout

In accordance with the "Guidance Catalogue for Eliminating Outdated Production Process Equipment and Products in the Industrial Sector", "Industrial Structure Adjustment Guidance Catalog" and relevant industry pollutant discharge standards, combined with water quality improvement requirements and industrial development, the basin leader should formulate and implement annual backward production capacity out of plan, and vigorously promote the elimination and withdrawal of outdated production capacity in heavy-polluting industries such as electroplating, papermaking, and leather and so on out of backward production capacity. The governance should effectively control key sources and other enterprises with water pollution, encourage enterprises to introduce high-tech and pollution-free technological processes, make full use of resources, save water, and build clean production projects with low pollution emissions. The person in charge must gradually adjust and optimize the industrial structure and optimize the spatial layout.

5.2.3. Steadily promote the comprehensive improvement of the rural environment

Townships and towns in the basin should establish a three-level sanitation team at county (district), town and village levels, formulate environmental sanitation management measures, comprehensively clean up the domestic garbage accumulated on both sides of the roads and rivers in the jurisdiction, and prevent the behavior of piling up and placing indiscriminate. Regularly salvage the town's ditches garbage can alleviate the secondary pollution caused by domestic garbage to the water environment. At the same time, the relevant government must strictly implement the regulations on the delimitation of restricted areas for livestock and poultry, clean up the prohibited areas, large-scale livestock and poultry farms, strictly limit the scale of family free-range breeding, and regularly organize the development of livestock and poultry breeding industry pollution prevention and control special inspections, strictly prevent the rebound of pollution from livestock and poultry breeding, and establish a sound long-term prevention and control mechanism. In addition, the governmental should also encourage the use of organic fertilizers such as human feces, reduce the use of chemical fertilizers, pesticides,

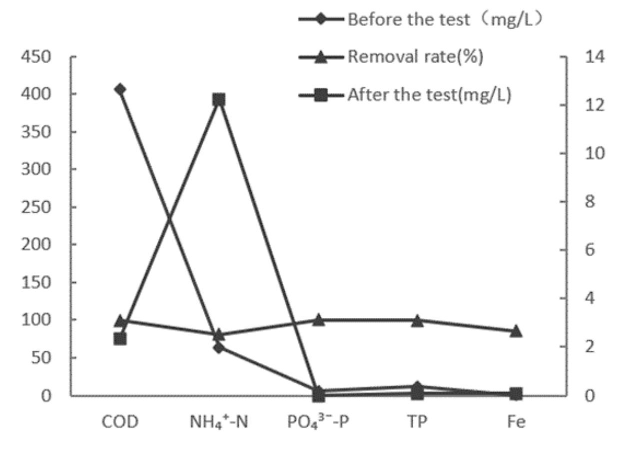

Fig. 6. Removal rate of each indicator (Data comes from Huang's research [33]).

and hormone-like substances, promote cleaner agricultural production, realize the recycling of agricultural production and living materials, and promote the transformation of extensive agriculture to ecological agriculture.

5.2.4. Promote the construction of water resources allocation projects to ensure the ecological base flow

The basin is a rain-source river with small flow during the dry season and very limited environmental capacity. On the basis of vigorously promoting source control and emission reduction, the construction of water conservancy projects has been increased, and a large number of water conservancy and water engineering facilities have been constructed and renovated to gradually form surface water and groundwater. A good pattern of joint dispatching, optimized allocation, and efficient utilization of groundwater, local water and transit water will improve the deployment and security capabilities of regional water resources, and give full play to the role of controlled water conservancy projects in improving water quality.

5.2.5. Strict law enforcement and supervision, strengthen management

We should implement the reform of the vertical management system of environmental supervision agencies below the provincial level. At the same time, the government should comprehensively implement the networked management of environmental supervision, optimize the allocation of supervision forces, and promote the extension of environmental supervision services to rural areas. The government should implement systems such as pollutant discharge declaration, pollutant discharge permit, total pollutant control, time limit treatment, target responsibility system, quantitative assessment, etc., strengthen the supervision of pollution sources, and eliminate illegal pollutants. In addition, it is necessary to strictly manage the environmental impact assessment of construction projects, strengthen risk assessment, adhere to the environmental assessment and acceptance, and eliminate environmental risks from the source.

6. Conclusion

In this paper, the water quality and its changes in a basin in eastern Guangdong are monitored. Based on the monitoring data, the single-factor standard index method is used to analyze various indicators to determine the main pollution factors that cause the black and odor of water body in the basin. Combined with the research of other scholars, the pollutant removal effect of each method was compared, and the combination was selected. This study appropriate black and odorous water treatment technology, combined with local social and economic conditions, puts forward suggestions for a comprehensive improvement plan for the watershed. The research reached the following conclusions.

- This paper collected the routine water quality testing data of a section of the basin from 2010 to 2015. The results showed that during the study period, the whole basin showed a serious pollution trend, with 77.78% of the inferior V-type sections detected, and the overall pollution was severe. The investigation found that the basin was affected by some heavily polluted tributaries, and the upstream to downstream of the main stream showed a trend of gradual pollution, especially when flowing through densely populated urban areas.
- Through the monitoring of various indicators, according to its concentration, change law and on-site analysis, the main reasons for the occurrence of black and odor in the basin are lagging construction of sewage pipe networks and sewage treatment plants, many heavily polluting enterprises, direct discharge of domestic sewage, random disposal of garbage, and low bottom mud release and management ability. Therefore, it is recommended to adopt corresponding measures such as dredging, sewage interception and storage pipes, improvement of management ability and environmental protection awareness, so as to eliminate pollutant discharge and reduce pollutant input from the root.
- The main control factors for black and odor determined by the single-factor standard index method are COD, NH_4^+–N and TP. Combined with the research of other scholars, the pollutant removal effect of each method is compared. Aeration and magnetic flocculation technology can be adopted as emergency treatment measures in this basin, and the treatment effect of each pollution factor is estimated to reach 80%.
- According to the two stages of emergency treatment and long-term improvement of water quality, a comprehensive remediation plan for the watershed is proposed. At the same time, the watershed passes through two cities, and the water pollution at its handover section is serious. The people's governments of the two cities should actively negotiate and determine the responsibilities of each group to ensure that the water quality meets the standard and achieves the purpose of clear and odorless water body.

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References

[1] M.H. Zhang, L. Wang, Research on treatment of black–odor water of Loushan River in Qingdao City, Yangtze River, 51 (2020) 54–61.
[2] The State Council Water Pollution Prevention and Control Action Plan [EB/OL], 2015. Available at: http://www.gov.cn/zhengce/content/2015-04/16/content_9613.htm
[3] Ministry of Housing and Urban-Rural Development Guidelines for the Treatment of Urban Black and Smelly Water Bodies [EB/OL], 2015. Available at: http://www.mohurd.gov.cn/wjfb/201509/t20150911_224828.html
[4] J.W. Liu, Analysis on the Characteristics of Black and Odorous Pollution and Study on the System Control Scheme in Shitou River Basin [D], Harbin Institute of Technology, China, 2020.
[5] Y.J. Wang, Y.T. Xiao, C.W. Zeng, Study on the repaired method of black-odor river and its application, J. Water Resour. Res., 4 (2015) 464–469.

[6] J. Zhang, D.L. Wei, Y.M. Ying, H.H. Li, Study advances of low strength organic wastewater treatment at anaerobic conditions, Environ. Sci. Manage., (2006) 84–87.
[7] Y.M. Yu, Study on the Effect Analysis and the Evaluation System Optimization of Black-Odorous Water Body Renovation in Chongqing, Congqing Jiaotong University, China, 2019.
[8] H. Wang, Study on Biological-Ecological Technology of Water Restoration, Dalin University of Technology, 2013.
[9] A. Seifert, Naturnaeherer wasserbau, Deutsche Wasser Wirtsehaft, 1983.
[10] L.N. Zhang, H. Wang, G.W. Li, Y. Xiong, Management technology and development trend for urban black and odorous water body, Environ. Prot., 45 (2017) 62–65.
[11] B. Claus, R. Lennart, Effects of who-ecosystem manipulations on ecosystem internal processes, Trends Ecol. Evol., 9 (1994) 218–223.
[12] J. Zhang, X.X. Ding, J. Zhu, J.S. Gao, London water pollution control strategy, Environ. Dev., 31 (2019) 62–67.
[13] S. Kong, S.J. Zhu, F.J. Qin, Discussion on experience of a river rehabilitation in Suzhou, Water Wastewater Eng., 47 (2021) 67–71.
[14] Y. Hou, C.Y. Wang, Application of chemical technology in ecological environment pollution control, Environ. Dev., 31 (2019) 192–196.
[15] R.P. Lin, Z.K. Ni, S.K. Guo, J.J. Gong, S.R. Wang, The trend and downside risk of water quality evolution in Dongting Lake in recent 25 years, China Environ. Sci., 38 (2018) 4636–4643.
[16] Q.P. Guo, T. Zhang, J. Zhang, Researches on the spatial and temporal distribution of primary water pollutants during dry season in Poyang Lake, Jiangxi Hydraul. Sci. Technol., 42 (2016) 103–107.
[17] Q.H. Zhang, X.C. Wang, Q. Wang, W.N. Yang, Characteristic of spatial-temporal distribution of urban water pollutants of Yixing city located in the west shore of Taihu Lake, Chin. J. Environ. Eng., 10 (2016) 373–380.
[18] S. Even, J.-M. Mouchel, P. Servais, N. Flipo, M. Poulin, S. Blanc, M. Chabanel, C. Paffoni, Modelling the impacts of combined sewer overflows on the river seine water quality, Sci. Total Environ., 375 (2007) 140–151.
[19] Z.W. Liang, M. Siegert, W.W. Fang, Y. Sun, F. Jiang, H. Lu, G.H. Chen, S.Q. Wang, Blackening and odorization of urban rivers: a bio-geochemical process, FEMS Microbiol. Ecol., 94 (2018), doi: 10.1093/femsec/fix180.
[20] M. Rzepecki, Dynamics of phosphorus in lacustrine sediments: the process of uptake/release of dissolved phosphorus by sediments in different habitats and lakes, Pol. J. Ecol., 60 (2012) 717–740.
[21] C.Y. Yu, L. Liu, Analysis on the present situation of rural water pollution and its treatment measures, J. North China Univ. Water Resour. Electric Power (Nat. Sci. Ed.), 40 (2019) 48–51.
[22] R.B. Zoleker, R.S. Todmal, V.S. Bhagat, S.A. Bhailume, M.S. Korade, S. Das, Hydro-chemical characterization and geospatial analysis of groundwater for drinking and agricultural usage in Nashik district in Maharashtra, India, Environ. Dev. Sustainability, 23 (2020) 4433–4452.
[23] S. Antony, V.V. Dev, S. Kaliraj, M.S. Ambili, K. Anoop Krishnan, Seasonal variability of groundwater quality in coastal aquifers of Kavaratti Island, Lakshadweep Archipelago, India, Groundwater Sustainable Dev., 11 (2020) 100377, doi: 10.1016/j.gsd.2020.100377.
[24] E. Metzger, D. Langlet, E. Viollier, N. Koron, B. Riedel, M. Stachowitsch, J. Faganeli, M. Tharaud, E. Geslin, F. Jorissen, Artificially induced migration of redox layers in a coastal sediment from the Northern Adriatic, Biogeosciences, 11 (2014) 2211–2224.
[25] J.A. Babinchak, J.T. Graikoski, S. Dudley, M.F. Nitkowski, Effect of dredge spoil deposition on fecal coliform counts in sediments at a disposal site, Appl. Environ. Microbiol., 34 (1977) 38–41.
[26] C.F. Tong, L.L. Yue, J.L. He, Y.Y. Shao, Y.X. Yan, F.Y. Liu, Water quality simulation and water diversion effect analysis of external Qinhuai River in Nanjin, Water Resour. Prot., 28 (2011) 49–54.
[27] D.G. Gu, H. Xu, Y. He, F. Zhao, M.S. Huang, Remediation of urban river water by Pontederia Cordata combined with artificial aeration: organic matter and nutrients removal and root-adhered bacterial communities, Int. J. Phytorem., 17 (2015) 1105–1114.
[28] V.V. Dev, G. Baburaj, S. Antony, V. Arun, K.A. Krishnan, Zwitterion-chitosan bed for the simultaneous immobilization of Zn(II), Cd(II), Pb(II) and Cu(II) from multi-metal aqueous systems, J. Cleaner Prod., 255 (2020) 120309, doi: 10.1016/j.jclepro.2020.120309.
[29] K. Nakata, A. Fujishima, TiO_2 photocatalysis: design and applications, J. Photochem. Photobiol., C, 13 (2012) 169–189.
[30] K.D. Shao, J.J. Duan, L.H. Xue, L.X. Xue, B.B. Zhou, D.F. Xu, Purification effect of five kinds of hydrophytes on total nitrogen and nitrate in simulated vegetable field runoff water, J. Environ. Eng. Technol., 10 (2020) 406–413.
[31] H. Zheng, Y.T. Gao, M.Y. Xie, R.F. Chen, Y. Ma, Research on application of microbial technology on black and malodorous pond in rural area, Environ. Eng., 39 (2021) 61–65.
[32] Y.Q. Sheng, Y.X. Qu, C.F. Ding, Q.Y. Sun, R.J.G. Mortimer, A combined application of different engineering and biological techniques to remediate a heavily polluted river, Ecol. Eng., 57 (2013) 1–7.
[33] C. Huang, Forecasting, Assessment and Remedy Technologies Formal Odorous Black River Caojia in Harbin, Haibin Institute of Technology, China, 2017.
[34] H. Mahadevan, V.V. Dev, K.A. Krishnan, A. Abraham, O.C. Ershana, Optimization of retention of phosphate species onto a novel bentonite-alum adsorbent system, Environ. Technol. Innovation, 9 (2018) 1–15.