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The Treatment Plan for Long-term Treatment of Black and Odorous Water Bodies by Unmanned Ships

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Abstract

To realize the standardization and long-term effect of black and odorous water treatment, and to improve the intelligence of treatment methods, we use the unmanned ship platform as the basis to integrate the functions of "ozone micro-nano aeration, water surface floating object collection and real-time dynamic monitoring, etc." It is a systematic management plan to achieve black and odorous water treatment. We also use the shore base station as the key to supply unmanned ships and realize unmanned management. Integrating dissolved oxygen, transparency, chemical oxygen demand, and ammonia nitrogen detection sensors to establish a governance model with real-time pollution source detection as the key. And the governance method is fully autonomously adjusted according to the real-time monitoring data to realize the intelligent governance of black and odorous water bodies.

Keywords

Component Black and Odorous Water; Micro-nano Aeration; Garbage Collection; Unmanned Ship; Dynamic Management.

1. Introduction

Affected by production and life, some closed water bodies are hypoxic or anaerobic, the self-cleaning ability of water bodies decreases and anaerobic bacteria multiply and decompose organic matter, resulting in rivers becoming black and odorous. The treatment of black and odorous water bodies is premised on source control and pollution interception. Generally speaking, due to the destruction of water ecosystems, black and odorous water bodies cannot be restored to a state of ecological balance by relying on the self-purification of the water body itself. In addition, under the premise of controlling exogenous pollution, it is necessary to restore the fluidity supplement of the water body, but the black and odorous water body is relatively static, and the external discharge also has a very large ecological risk, how to restore the ecological function of the black and odorous water body has become the key to governance, and the key lies in the dynamic supervision and treatment of water areas.

Currently, the most common treatment methods for black odorous water are either in situ or through external treatment[1].In situ repair mainly uses sediment covering, chemical additives, microbial repair, sediment aeration, etc., external treatment is generally to discharge the water to the relevant treatment equipment and then discharge it back to the water[2]. But these programs are either overly expensive or unable to recycle chemicals, leading to secondary contamination. Moreover, they lack systematicness, cannot restore the activity of water bodies, and cannot maintain the stability of water ecosystems, which will lead to a higher rebound rate of black and odorous water bodies. Of course, some teams have also proposed some systematic treatment schemes, such as the " Unmanned ship repaired by a black and smelly body of water in the river " developed by the team of Dai Youhua

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(2021), which uses the scheme " Microbial agent &Blast aeration & Carbon fiber ecological grass " to comprehensively treat water areas, and has achieved relatively good results[3]. However, we found that these programs lacked long-term effectiveness, and water governance is a long-term process of ecosystem restoration. Given these problems, we propose a three-in-one comprehensive treatment plan of " cleaning, depiction and treatment" (Clean up surface garbage, delineate the distribution of water pollution, and treat black and odorous water bodies), combined with micro-nano ozone bubbles & surface garbage collection & dynamic decision-making for full-time monitoring to achieve long-term treatment of water areas and further improve the intelligence of black and odorous water treatment.

1.1 Introduction to Governance Methods

The fully autonomous unmanned ship treatment scheme of micro and nano ozone bubble & water surface garbage collection & dynamic decision-making for full-time monitoring takes micro and nano ozone aeration as the main means, supplemented by the means of floating objects collection on the surface of the water, repairs both inside and outside to improve the self-purification ability of water bodies, and minimizes the probability of rebound of the black and odorous water body. To improve the long-term effectiveness of governance, we also propose a function that can automatically charge and replace garbage collection bins for unmanned ships. And to improve the effectiveness of water pollution control, we introduce water quality detection sensors combined with water map information to draw a heat map of the distribution of water pollution to ensure that unmanned ships always give priority to the treatment of areas with high pollution levels, to improve the efficiency of unmanned ship governance.

1.2 Introduction to the Principles of Governance

1.2.1 Introduction to the Principle of Ozone Micro and Nanobubble Treatment.

Compared with ordinary aeration technology, the bubble particle size produced by micro-nano aeration technology is smaller, and the bubbles stay in the water body for a long time, its surface area is large and in full contact with the water body, and it has good dissolved oxygen effect and high oxygen mass transfer efficiency. Micro-nano aeration technology mainly improves the dissolved oxygen content of black and odorous water bodies by transporting ozone micro-nano bubbles, controlling the endogenous source, and restoring the oxygen content of the water body by aeration to water bodies. Ozone has strong oxidation and plays a good role in the inactivation of microorganisms, bacteria, and viruses. It can also oxidize and degrade complex organic pollutant molecules in water, and ozone can be reduced to oxygen after about 30 minutes at room temperature, which can improve the dissolved oxygen content in the water body, accelerate the oxidation process of pollutants in the water body, and thus remove the black odor phenomenon of the water body.

At the same time, it can also inhibit the release of endogenous pollution of sediment in black and odorous water, improve the environment of microorganisms and benthic organisms, and promote the restoration of sediment micro-ecosystems[4]. At present, micro-nano aeration has become a relatively mature scheme for the treatment of black and odorous water bodies, but the existing scheme is mostly segmented and fixed for micro-nano aeration, and the distribution of water pollution has a spatial-temporal difference due to the distribution of pollution sources[5]. Therefore, this scheme is complex to install, less portable, and more resource-consuming. The micro-nano bubbles prepared by us by the pressurized dissolved gas release method can be used as thrust to propel the unmanned ship forward, and the whole section is fixed for aeration, which overcomes the temporal and spatial differences in water pollution to a certain extent.

1.2.2 Introduction to the Principle of Surface Garbage Collection.

The existence of floating objects on the surface of the water will not only cause toxic substances to dissolve in water due to their decomposition but also further damage the water’s ecological environment. At present, the relevant team has studied some unmanned boats for the salvage of floating objects in waters, such as the design of an energy-saving and environmentally friendly surface garbage cleaning vessel researched by Zhang Kaiqi (2020), but only the unmanned ship is applied to floating salvage on the surface, the function is relatively single, and the engineering cost is large. Referring to its scheme, we designed a garbage collection bin adsorbed by an electromagnet that intersects the horizontal plane[6]. When the unmanned ship is driving in the water, the automatic identification system on board locates the position of the garbage prescription and moves forward in this direction, due to its always forward force and water flow, the surface garbage is collected in a surface garbage collection bin. This arrangement does not occupy the installation position of other components, minimizes the use of manpower, reduces capital consumption, and makes it possible to integrate other treatment solutions.

1.2.3 Introduction to the Principle of Dynamic Decision-Making for Full-Time Monitoring.

Dissolved oxygen, transparency, chemical oxygen demand, ammonia nitrogen, and other concentrations are the key factors of the degree of water pollution. According to the spatial and temporal distribution of water pollution in Guangzhou studied by Zhao, Q (2020), it is found that the spatial and temporal distribution of water pollution is uneven. we use four sensors of dissolved oxygen, transparency, chemical oxygen demand, and ammonia nitrogen to achieve the monitoring of the aquatic environment. Although the water quality monitoring unmanned vessel developed by Zhao Tongqiang's (2021) team has verified that the on-board water quality sensor has high accuracy in the field of water quality testing, it will lead to a significant increase in response time due to factors such as sailing speed, water environment, and data fitting[7]. Because the unmanned ship sails close to static water and the sailing speed are slow, the data response time is shortened by 2-3s, and the distribution of water pollution can be updated in real-time.

At the same time, according to the actual needs of this product and the main causes of black and odorous water, to ensure the uniqueness of the priority in the treatment process, we define different priorities for the data obtained by the sensor: dissolved oxygen (DO) > ammonia nitrogen (NH_3-N) > chemical oxygen demand (COD) > transparency. In this way, the unmanned ship gives priority to the treatment of areas with relatively low dissolved oxygen content and does not release ozone in areas with high dissolved oxygen content, to ensure that the dissolved oxygen content of the water area is maintained in a certain normal range, and there will be no large gap in the dissolved oxygen content in different directions for a long time, to maintain the balance of the ecological environment of the water.

2. Methods

The scheme is composed of a hardware platform scheme and a software platform scheme, the hardware scheme is composed of unmanned ship and shore base stations, and the software solution adopts Pixhawk open-source scheme as the software solution platform.

2.1 Introduction to Hardware Scenarios

The overall program is composed of an unmanned ship for water ecological protection and a shore base station, and unmanned ships use the "ozone micro-nano aeration & surface garbage collection" scheme to achieve systematic treatment of water areas "both internal and external repair", supplemented by a dynamic decision-making for fa ull-time monitoring mechanism to achieve the evaluation of water pollution index and the depiction of pollution distribution. At the same time, it uses its automatic driving equipment to achieve automatic driving in the waters, and returns to the shore base station for replenishment after the power is insufficient or the garbage collection device is full; The manipulator of the shore base station is composed of a retractable structure that can not only grab the garbage collection bin to complete the replacement, but also fix the hull and insert the charging device into the unmanned ship for charging.

The unmanned ship for water ecological protection not only needs to integrate a variety of operating equipment but also needs to meet the needs of stable navigation, the unmanned ship is a double hull structure, and the cabin is equipped with an air pump, water pump, and transmission structure. The

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whole is composed of a zone micro-nano aeration power system, garbage collection system, automatic driving system, and power management system. This is shown in Figure 1.

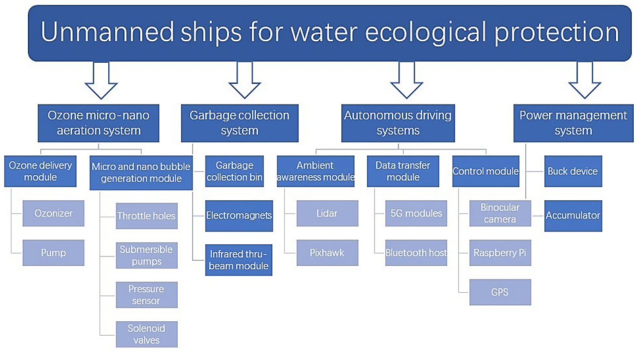

Figure 1. Unmanned ship frame schematic.

Table 1. Unmanned ship parameters.

Parameter	Value
Dimensions (L*W*H)/(mm)	1900*800*800
Draught/m 0.15	0.15
Supporting power/W 2600	2600
Continuous operation time/h	≤4
Working speed /(m·s-1)	≤1.5

The unmanned ship adopts a double-hull structure, and a garbage collection bin is installed in the two hulls. As the unmanned ship advances, the floating objects on the water surface will be collected into the collection bin. On the ship, the installation and disassembly of the collection bin can be realized by turning on and off the electromagnet. The unmanned ship is equipped with automatic driving components such as depth cameras and lidars. The unmanned ship is shown in Figure 2.

At present, spraying aeration is still used in the market for water quality improvement, which requires manpower to fill and purchase drugs, reducing efficiency. Therefore, micro-nano aeration continues to develop and has become a relatively mature scheme for the treatment of black and odorous water. This method has many advantages because of the micro-nano cheongsam produced, such as long residence time in the water, large specific surface area, high oxygen mass transfer efficiency, etc., and is widely used. But the existing schemes are mostly segmented and fixed for micro-nano aeration, and the distribution of water pollution has temporal and spatial differences due to the distribution of pollution sources. This solution is complex to install, less portable, and more resource-consuming

According to the investigation, the production method of micro and nanobubbles is the pressurized dissolved gas release method, dispersed air method, electrolysis method, and other methods[8]. To improve the multiplexing of the function, we use the pressurized dissolved gas release method to take micro and nanobubbles, this method can not only prepare micro and nanobubbles but also as a thrust to promote the unmanned ship forward.

The device as shown in Figure 2, when the device is working, the ozone generator is supplied by the solenoid valve connected to the device, and the water is filtered through the filter net from the inlet of the submersible pump, mixed with the air containing ozone controlled by the solenoid valve from the inlet, and is sucked into the inside of the submersible pump, and the pressure rises under the stirring action of the pump impeller. When the water containing a large amount of supersaturated gas after pressurization by the pump flows through the throttle hole of the pump outlet, the flow rate is accelerated, according to the venturi effect, the pressure at the throttle is rapidly reduced, the gas dissolved in the water is rapidly released, and the "mist-like" micro-nano bubbles formed at the outlet are sprayed into the water to achieve aeration and push the hull forward[9]. At the same time, to ensure the efficiency of micro-nano preparation, we have added a pressure sensor to the throttle hole for sensing pressure, to feedback to the control circuit to control the intake volume with a solenoid valve.

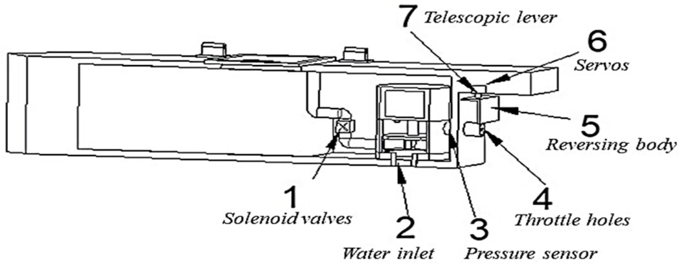

Figure 2. Micro-nano aeration device schematic.

For the design of the shore base station, the entire device is composed of an infrared radio module, a manipulator, and a proximity sensor. When the unmanned ship lands, the proximity sensor of the unmanned ship receives a signal and controls the electromagnetic the iron loses its magnetism, and at the same time the base station's infrared radiation device is blocked and the proximity sensor is turned on, it indicates that the unmanned ship has arrived at the base station's working area. In the double hull of the marksmanship Considering that the base station is only used as a replacement platform for the collection bin and still cannot achieve long-term treatment of the water environment, the bionic manipulator we use, compared with the traditional manipulator, uses a telescopic design and installs a charging interface, the grasping feet of the manipulator fix the unmanned ship and the base station relatively. The electric push rod is stretched out, and the charging port is inserted into the charging port of the unmanned ship to realize charging.

2.2 Introduction to Hardware Scenarios

The software solution is composed of a decision-making part and a control part, and the decision-making part is responsible for making decision-making judgments on the environmental information obtained by modules such as environmental perception, and then transmits it to the control part to control the movement of unmanned ships. The scheme uses Viet (One method that makes use of boustrophedon motions is the BA* method described in Viet et al) to complete the SLAM composition of the water area[10]. The yolov3 algorithm to realize the identification of water surface garbage, and the water quality sensor to complete the marking of areas with high water pollution, and comprehensively forms a format model of the water area[11]. USV uses garbage on the surface of the water as the starting point of the search and the highest pollution as the search end pendpointchieve a great greater e of the water. It uses the Raspberry Pi & Pixhawk scheme, uses the ROS operating system, refers to Lenes, Jan Henrik's USV design scheme, and uses the Relevant methods for Complete Coverage Path Planning (CCPP) developed by the A* algorithm to ensure that the water is aerated as correctly as possible[12].

The Raspberry Pi runs on Ubuntu20.04+ROS Noetic, which supports programming in the Python language. Developers can use the MAV Link protocol and ROS topic mechanism to achieve telemetry, programmatic access to status and parameter information, and direct control of unmanned boat motion. Its operating logic is shown in Figure 3, and it is equipped with a high-speed USB3.0 USB 3.0ace that can be connected to an external 5G module. This facilitates the control of extranet access

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and transmits water quality data to the ground platform in real tireal-timeilitate the formulation of governance plans.

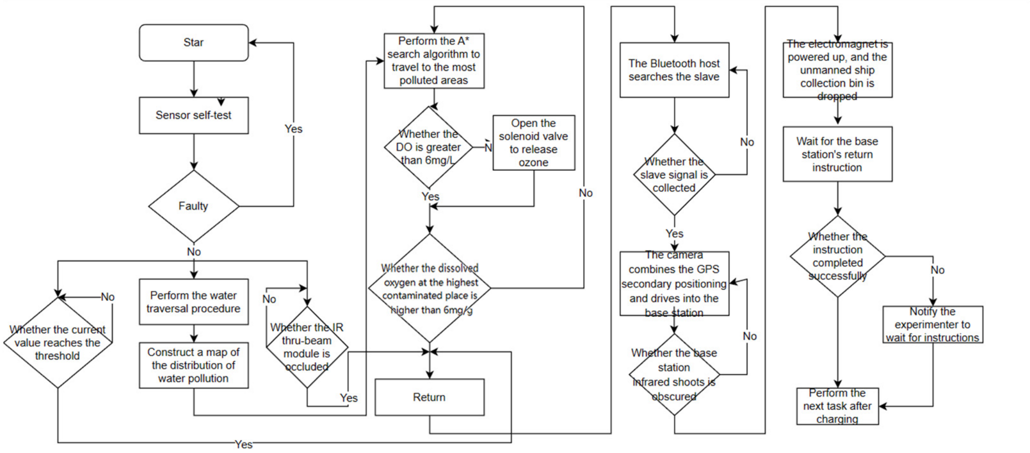

Figure 3. The process by which the program runs.

3. Results

3.1 Experimental Prerequisites

Due to the cost of the project and other reasons, it is impossible to completely isolate the influence of the surrounding environment, and multiple sets of parallel control tests cannot be carried out at the same time, so the experimental area is first subjected to 12 days of non-treatment observation, and then the water area is treated for 12 days using the scheme shown in the paper, and finally, the water area is observed for 12 days after the end of the treatment, to fully observe the treatment effect of the scheme described in the paper on the black and odorous water body.

3.2 Experimental Conditions

Before the experiment, it is necessary to check the operation stability of each unmanned ship system to avoid non-accidental factors and reduce errors After a 12-day observation of the water selected by the experiment, the water area was treated experimentally, and the unmanned ship and the shore base station were released into the water for a 12-day field test. The volume of water in the experimental area is about 6000m3, the depth of river water is 30cm-150cm, and the fluidity of the water body is poor. Because less garbage distribution was observed on the water surface, 200 plastic bottles were artificially released in the experimental area to fully observe the experimental effect.

3.3 Experimental Results

Table 2. Changes in water quality parameters before treatment.

	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12
Transparency/cm	7.8	7.8	7.7	8.0	8.1	7.9	8.0
DO mg/L	0.17	0.11	0.12	0.15	0.11	0.17	0.13
NH_3-N mg/L	21.3	22.1	21.5	21.8	21.4	21.8	21.5
COD mg/L	151.7	150.8	153.5	152.8	151.3	151.7	152.3
Number of garbage/100m^2	53	55	55	58	59	57	58

In the whole experimental stage, the determination of various performances, data collection to the same point of 30cm under water, every two days to collect water samples for inspection, before the treatment of water quality data as shown in Table 2, the treatment period water quality data as shown in Table 3, after treatment of water quality data as shown in Table 4, unmanned ship performance

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results as shown in Table 5. The table visually shows the changes in water quality at each stage of treatment, and the contents of DO, Transparency, NH_3-N demand, and COD are relatively stable before and after treatment and are significantly reduced during treatment, indicating the feasibility of unmanned ships in the field of water treatment.

Table 3. Changes in water quality parameters during treatment.

	Day 12	Day 14	Day 16	Day 18	Day 20	Day 22	Day 24
Transparency/cm	8.0	10.3	12.2	15.3	17.5	22.3	25.6
DO mg/L	0.13	0.93	1.66	2.83	3.41	3.82	4.21
NH_3-N mg/L	21.5	17.3	15.2	12.3	10.3	8.6	7.8
COD mg/L	152.3	220.6	280.7	130.6	112.5	78.3	58.6
Number of garbage/100m^2	258	146	83	62	43	29	22

Table 4. Changes in water quality parameters after treatment.

	Day 24	Day 26	Day 28	Day 30	Day 32	Day 34	Day 36
Transparency/cm	25.6	24.8	25.2	24.2	23.3	21.2	19.6
DO mg/L	4.21	4.11	3.86	3.88	3.76	3.61	3.37
NH_3-N mg/L	7.8	8.7	8.8	9.3	9.9	10.2	11.6
COD mg/L	58.6	72.3	77.6	83.3	89.3	92.3	95.1
Number of garbage/100m^2	22	27	26	29	30	33	33

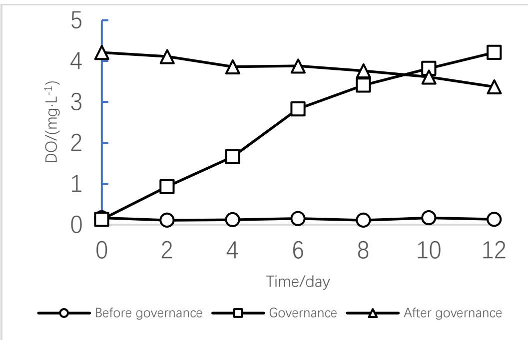

Figure 4. Changes in DO in different governance periods

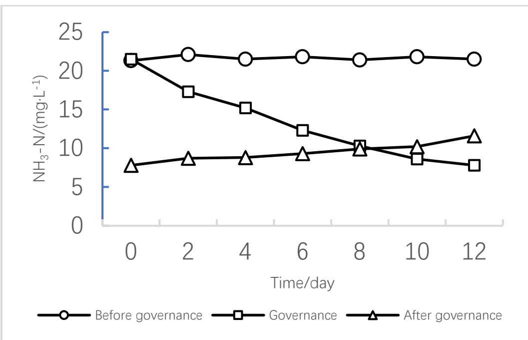

Figure 5. NH_3-N in different treatment periods.

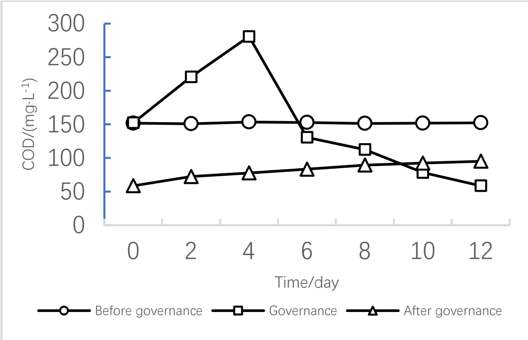

Figure 6. Changes in COD during different governance periods.

Table 5. Unmanned ship performance results.

Parameter	The setting value	Assay data
Boat speed (while operating)/(m/s)	1	1
Single consecutive job time/min	240	200
Auto Charge Single Success Rate/%	≥80	50
Replacement garbage collection single success rate/%	≥80	65

Figure 7. First view recognition.

4. Conclusion

From the analysis results, it can be seen that due to the small training set of the deep learning recognition scheme, recognition errors are prone to occur, resulting in errors in the identification of floating objects on the water surface and the recognition of charging interfaces, which can be effectively improved in the later development.

From the analysis of experimental data, it can be seen that the degree of black odor in the waters is still slowly deepening before treatment. After the treatment of black and odorous water bodies by unmanned water ecological vessels, the original severe black and odorous water bodies get rid of black odor, which can show that the treatment plan has obvious positive significance for the treatment of black and odorous water bodies in the waters. At the same time, after the unmanned ship stopped treatment, although the water quality parameters of the water have a slow recovery trend, there is still a rebound phenomenon, which shows that the water needs to be continuously treated.

Given the research status of unmanned ships in the treatment of black and odorous water, there are still some problems in the application of this scheme, which need to be noted: First of all, the strategy of using hull movement to collect floating objects on the surface is cumbersome, and the garbage is easily washed away by hydrodynamic forces when the unmanned ship approaches, which adds difficulties to practical work to a certain extent. Secondly, micro-nano aeration alone has the problem of mismatch between energy consumption and removal efficiency, which is also part of the factors causing the rebound of black and odorous water, and it is necessary to develop technologies that combine energy conservation and purification with a high degree.

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