Swarm System of Unmanned Sewage Treatment Vessel in Large Waters

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Abstract. The Swarm System of unmanned sewage treatment vessel in large waters is mainly used to deal with water pollution in large waters. The purpose of the system is to provide assistance to large water areas such as Chaohu Lake whose self-purification capacity is insufficient to solve their own pollution or which have lost their self-purification capacity. The Swarm System is able to carry out water treatment and water quality monitoring to help lakes to restore the ecological environment of water body and self-purification capacity. This system adopts the working mode of local pump in treatment and discharge. The water quality monitoring system, which is combined with BeiDou positioning system and data transmission system, has the ability of presenting the water pollution situation in a three-dimensional way and stronger pertinence in sewage treatment. The mechanism of the system is similar to Unmanned Aerial Vehicle, which is considered as high working efficiency, fast processing speed, low cost and high intelligence.

1. Introduction
The rapid development of economy inevitably brings about environment problems such as the pollution of lakes. Approximately 40 percent of lakes are affected by eutrophication around the world[1]. We take Chaohu Lake in China as an example. It is contaminated by nitrogen, phosphorus nutrients and aerobic organics thus the comprehensive water quality of the whole lake is worse than the surface water standard of class V [2]. The water regeneration cycle is slow and self-purification capacity is insufficient in Chaohu Lake because of its closed hence it needs to be assisted to improve self-purification ability. Among the causes of water pollution, it is significant to point out that the number and coverage of current water quality monitoring systems are seriously inadequate right now[3].

This study focuses on the problem of water pollution in large water area like Chaohu Lake and proposes that the Swarm System of unmanned sewage treatment vessel in large water area should be used to aid the recovery of purification ability of lakes.

Nowadays, the control of lakes is mainly based on biochemical law and controlling pollution sources[4]. Juanjuan Chen has proved that the biological aerated filter and mobile water treatment system are effective in the small area of lakes through experiments[5]. Water quality monitoring vessels have implemented automatic measures such as automatic cruise, automatic obstacle avoidance and automatic sampling analysis[6]. There have been many studies on water quality monitoring and sewage treatment. But these studies can only achieve one of these functions, which may not form a joint system of sewage treatment and water quality information feedback, thus it is difficult for them to achieve better governance results.
We intend to use existing waste water treatment technology, connecting with a variety of intelligent equipment in order to set up a sewage treatment system that isn’t not only constrained by geographical environment but also has a relatively low cost and a high processing capacity. The system concludes a water quality monitoring and management technology, real-time monitoring of water quality and promptly respond, which aid lakes to sort out the problem of pollution within a certain amount of time while restoring the self-purification ability. A literature shows that solar power is very suitable for unmanned surface vehicle [7] and unmanned aerial vehicle (uav) group has size as well as cost advantage. Therefore, this system mainly powered by solar energy. In addition, it can make up for the inadequacy of ability of single through the ability complementary and coordinated action[8]. Moreover, it has been through a lot of simulation experiments and gradually formed a cluster of intelligent method [9].

The innovation points of this project are as follows. First of all, it is based on the network information system while opening up the link of monitoring, controlling, treatment and evaluation. In addition, applying drone bee colony combat thought to lake water treatment in large waters tend to effectively enhance the efficiency of sewage treatment. Furthermore, this project has the possibility to provide auxiliary assist for large closed or semi-closed waters with insufficient or no self-purification capacity. Finally, the unite of multiple systems supplies the system highly intelligent and maneuverable.

2. Swarm Control System
The Swarm System includes Information Communication Command System, Quality Detection Communication System, Energy Management System, Radar Obstacle Avoidance System, etc. Through the Ground Communication Base or BeiDou Positioning System form information communication network between home port and ships as well as the ship to ship. There are four main functions in the home port Information and Communication Command System. First, it is able to collect the results of the automatic detection of the water quality of the lake-borne water. Second, it has the ability to analyze the distribution of the water quality of the lake. Thirdly, it has a tendency to assign the task area to each ship and realize the bee colony work mode.

In addition, the home port Information and Communication Command System coordinates the work of the Shipborne Energy Management System and the Radar Obstacle Avoidance System to ensure the effectiveness and safety of the ship's energy system, as well as the safe movement and work of unmanned sewage vessels. In case of emergency, the Swarm System may give corresponding instructions to make sure the safety of the system and the vessel.
2.1. The composition of the home port
The home port mainly consists of port, Information Processing and Command Center and Sewage Collection and Maintenance Center. It is responsible for the collection, sorting and analysis of data. It also controls vessels in emergency and special situations as well as collecting high concentration sewage daily maintenance and docking of vessels.

The home port Sewage Collection Center is used for the collection of backwash sewage from each sewage treatment vessel, daily maintenance and repair of the vessel. The sewage from the high concentration sewage tank of the backwash system is transported to the sewage collection center of the home port. The sewage is able to be preliminarily treated in the collection center in order to prevent the deterioration of water. When it reaches a certain capacity, it may be batch delivered to the bank based sewage treatment plant for treatment and discharged after achieving the standard.

The home port Information Processing and Command Center brings together all water quality monitoring device test results as well as Beidou positioning data in the ship, feeding back to the water pollution situation of distribution. When the command center finds any abnormal situation or emergency, it has the ability of commanding sewage treatment ships as soon as possible.

2.2. Composition of sewage treatment vessel
The unmanned sewage treatment vessel consists of Energy System, Sewage Treatment System, Backwash System, Water Quality Testing and Communication System, Communication Control and Command System, Radar Obstacle Avoidance System and BeiDou Positioning System. Among them, the sewage treatment system employs the process of combined compound biological filter, which mainly consists of grille, compound filter and regulating tank. The compound filter adopts the layered module structure with a total of 6 layers. Hollow plastic basket is used to hold the filter material. There is a gap between the layer and the layer thus the filter material surface biofilm is able to fully contact with the air. Meanwhile, the modular structure has the ability of facilitating the disassemble of each layer which is conducive to the heavy pollution section targeted cleaning. The filter material is
composed of three fillers, including ceramsite, volcanic rock and gas block. Therefore, the removal rate of COD, ammonia nitrogen, total nitrogen and total phosphorus is really high[10].

Figure 2. Process diagram of combined biological filter.

3. The control method

First, according to the size of the working area and the treatment capacity of the sewage treatment ship, the staff put a certain number of sewage treatment ships into the working area originally. Then the sewage treatment ship uses the water quality monitoring system to sample and test the working area before transmitting the results to the command center[11]. At the same time, the onboard satellite positioning system may convey the position information of the ship to the command center in real time.

Second, the main controller of the command center receives water quality monitoring and position data of each sewage treatment ship then data processor begins to analyze them to judge pollution situation. According to that, the water pollution situation partition diagram may be formed and displayed in the interaction boundary. At the same time, the information of water pollution distribution and required sewage treatment capacity is sent to each sewage treatment ship through the communication system[12].

Third, after receiving the water pollution zoning information and the sewage treatment capacity information required by each area, the onboard communication system of each sewage treatment ship tends to send them to the onboard controller which may start the sewage treatment ship accordingly[13]. When the total sewage treatment capacity of the sewage treatment vessel in a certain working area meet the sewage treatment capacity required in the area, other sewage treatment vessels have a tendency to go to other working areas while sending the response signal again until all sewage treatment vessels arrive at the working area.

Forth, during the normal operation of the system, the division of labor method for multiple vessels working together in the same area is that a vessel with only water quality monitoring function which is distributed in the working area as the monitoring vessel. Several vessels with sewage treatment and water quality monitoring functions simultaneously as the working vessel. The monitoring vessel is responsible for real-time monitoring of water quality and providing support when necessary. Ships are required to sewage treatment and treatment effect monitoring.

Fifth, when treatment capacity of work boat with treatment function in the work area reaches the upper limit, the onboard controller may stop the mechanism, only turn on the water quality monitoring method and upload the detection data through the shipboard communication system.

Sixth, after data analysis, if water quality fails to reach expected goal, the monitoring ship is able to turn its sewage treatment capacity into a working ship to continue sewage treatment then the working ship becomes a new monitoring ship to continue working. If the working ship is unable to complete the remaining sewage treatment tasks, the command center is going to send extra working ships to assist until the water quality monitoring is achieved the expected goal. Since then, the command center transmits the return instruction to the onboard communication system before controlling the vessel return in the working area through the onboard controller. When the water quality in the working area attains the goal, the ship with the highest residual sewage treatment capacity stays in the working area as a monitoring station for real-time monitoring of water quality. The data processor of the command center conducts real-time analysis to obtain real-time dynamic information of water quality.
4. Economic analysis

All ships in the Swarm System are manufactured in a standardized manner, which are divided into ships of several sizes according to sewage treatment capacity. Compared with the traditional sewage treatment plant, the treatment cost is low due to the fact that this project adopts local pumping and discharge for sewage treatment. Moreover, this system is able to be used in other water areas therefore it has a wide range of applications. The Swarm System itself also has characteristics of cheap and high efficiency. The government's governance of Chaohu Lake has invested tens of billions with no substantive progress. Although the construction of swarm system cost is expensive initially, the consumer is reasonable because it may bring huge economic benefits in later period.

5. Summary

Compared with the existing technology, this project provides a complete unmanned sewage treatment control system. The control method of the ships is fully functional, adaptable and practicable. It provides a solution for all-weather sewage treatment. It is also able to realize the cluster operation of multiple ships and improve the response efficiency of sewage treatment ship through two control modes. Moreover, it has the value of popularization and application.

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