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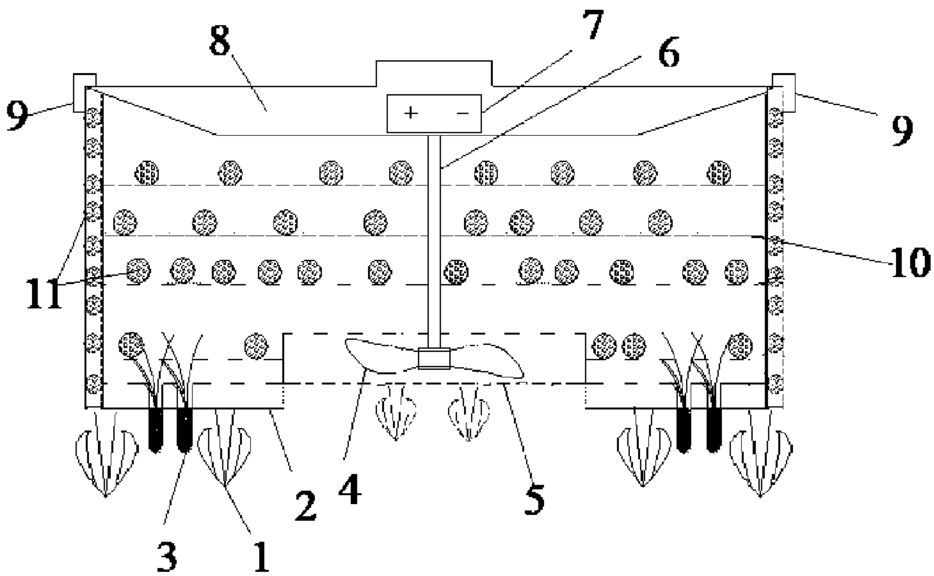
(54) Title: DEVICE AND METHOD FOR IN-SITU REMOVAL OF OVERWINTERING CYANOBACTERIA IN LAKE SEDIMENT



(57) Abrégé/Abstract:
The present invention discloses a device and method for in-situ removal of overwintering Cyanobacteria in lake sediment and belongs to the technical field of water environment research. The device for in-situ removal of overwintering Cyanobacteria in lake

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sediment includes a reactor with an open bottom. The reactor is directly installed on the lake sediment to form a closed internal environment of the reactor; filter screens are arranged in the reactor, adsorption materials are placed on the filter screens, and a water disturbing device is arranged in a lower portion of the filter screen. The water disturbing device includes disturbing blades, and the disturbing blades rotate to drive the water to move. The device for in-situ removal of overwintering Cyanobacteria in lake sediment according to the present invention is used for in-situ removal of the Cyanobacteria, which can effectively control the Cyanobacteria, nitrogen, phosphorus and algal toxins.

ABSTRACT

The present invention discloses a device and method for in-situ removal of overwintering *Cyanobacteria* in lake sediment and belongs to the technical field of water environment research. The device for in-situ removal of overwintering *Cyanobacteria* in lake sediment includes a reactor with an open bottom. The reactor is directly installed on the lake sediment to form a closed internal environment of the reactor; filter screens are arranged in the reactor, adsorption materials are placed on the filter screens, and a water disturbing device is arranged in a lower portion of the filter screen. The water disturbing device includes disturbing blades, and the disturbing blades rotate to drive the water to move. The device for in-situ removal of overwintering *Cyanobacteria* in lake sediment according to the present invention is used for in-situ removal of the *Cyanobacteria*, which can effectively control the *Cyanobacteria*, nitrogen, phosphorus and algal toxins.

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DEVICE AND METHOD FOR IN-SITU REMOVAL OF OVERWINTERING CYANOBACTERIA IN LAKE SEDIMENT

TECHNICAL FIELD

The present invention belongs to the field of water environment research, and particularly relates to a device and method for in-situ removal of overwintering *Cyanobacteria* in lake sediment.

BACKGROUND

Cyanobacteria (such as *Microcystis aeruginosa*, *Anabaena flos-aquae*, *Aphanizomenon flos-aquae*, and *Oscillatoria*) are widely distributed in nature, such as occurring in various water bodies, soil and interior and exterior of some organisms. They can be even found on rock surfaces and in other harsh environments (high temperature, low temperature, salt lakes, deserts and ice fields, etc.). They are large unicellular prokaryotes capable of oxygen-producing photosynthesis, with a long history of evolution, and have certain economic value themselves. However, as human beings are increasingly utilizing environmental resources, industries are developing, and the rural population has become highly concentrated, a large amount of industrial wastewater and domestic sewage containing pollutants are discharged into water without proper treatment. This makes the concentration of oxygen-consuming substances such as ammonia nitrogen, phosphorus and organic pollutants in the water increase, and thereby increasing the load of nutrients in the water, and leading to the large-scale reproduction of *Cyanobacteria*. The outbreak of *Cyanobacteria* blooms leads to the following hazards. First, the exchange between the air and gas in water is blocked, dead *Cyanobacteria* consume dissolved oxygen due to decomposition, and the concentration of dissolved oxygen in the water is rapidly reduced, causing a large number of aquatic animals to die of anoxia asphyxia. Second, sunlight is shielded, which is detrimental to the growth of submerged plants, seriously affecting the survival of aquatic organisms, destroying the ecological balance, and eventually leading to the collapse of the entire water ecosystem. Third, algal toxins are released. The algal toxins which are *Cyanobacteria* endotoxins can be released after cell rupture and show toxicity.

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Such toxins are mainly generated by *Microcystis aeruginosa*, *Anabaena flos-aquae*, etc. Fourth, the *Cyanobacteria* blooms may deteriorate the water quality and block the water treatment system. Fifth, the *Cyanobacteria* blooms may affect the landscape and release peculiar smell; and dead *Cyanobacteria* release a large amount of organic matter and emit stench, causing air pollution and water pollution. At the same time, this will stimulate the growth of chemoheterotrophic bacteria, most of which are not beneficial bacteria for aquaculture animals, but pathogenic bacteria, thus further leading to the occurrence of secondary infectious bacterial diseases. Sixth, a few aquatic *Cyanobacteria* such as *Microcystis* may generate algal toxins that can induce human liver cancer. Therefore, the outbreak of *Cyanobacteria* blooms has become a major concern for people in the field of water environment research.

There is a basic consensus in the field of *Cyanobacteria* bloom research. That is, the material basis of *Cyanobacteria* blooms is newly added exogenous nutrient elements (nitrogen and phosphorus pollutants). Nevertheless, there is another major endogenous factor that leads to the continuous outbreak of *Cyanobacteria* blooms, namely overwintering *Cyanobacteria* dormant on the surface of sediment in winter. The growth rate of *Cyanobacteria* increases with the water temperature. When the air temperature reaches 20°C or above and the water temperature is 25-35°C, *Cyanobacteria* cannot break out in a large scale at this normal temperature. Once it enters the high temperature season, *Cyanobacteria* will have a remarkable growth rate, and the *Cyanobacteria* dormant on the surface of sediment in winter will revive and break out. Therefore, for the control of *Cyanobacteria* blooms, we should pay attention not only to the control of exogenous factors, but also to endogenous factors. Therefore, water eutrophication control and *Cyanobacteria* bloom control are like two sides of a coin. Only the control mode taking the two perspectives into consideration is a truly effective way to control *Cyanobacteria* blooms. The control of the emissions of exogenous nutrient elements serves as the basis, while the cleaning of *Cyanobacteria* and exogenous nutrient elements serves as the guarantee.

At present, *Cyanobacteria* bloom treatment methods are broadly divided into four

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categories: chemical methods, physical methods, biological methods and comprehensive treatment methods.

The chemical algae removal methods are to control the reproduction of algae in water by screening and synthesizing chemicals (collectively referred to as algicides). Common algicides include organic bromine algicides, copper salts (copper sulfate, copper chloride), potassium permanganate, etc. Their algae removal mechanism is to kill algae by inhibiting the normal metabolism of algae through metal ions on the one hand, and to remove algae through flocculation of metal ions on the other hand. For example, Chinese patent application publication No. CN109315399A, published on February 12, 2019, discloses a biological algae-lysing preparation with betaine and use thereof. Under the synergistic effect of betaine, vitamin C and a bacterial preparation, *Bacillus subtilis* and *Streptococcus faecalis* are added. This has obvious improvement effect on aquaculture water subjected to *Cyanobacteria* blooms. The water quality index was tested one day after the preparation was put into raw water, and the *Cyanobacteria* removal rate in the raw water was 90%. The biological algae-lysing preparation can effectively remove *Cyanobacteria* in water, degrade pollutants such as *Microcystis*, and effectively improve the water environment. However, the biological algae-lysing preparation has common problems of the chemical algae removal methods. First, such preparation only solves the problem of algae density, but dead *Cyanobacteria* may release deadly algal toxins. At the same time, organic and inorganic pollutants that have been bioabsorbed are released into the water again, resulting in secondary pollution of the water and thus leading to more organic pollution. Only *Cyanobacteria* can be removed, while exogenous nutrient elements cannot be removed. Second, such preparation only has a good treatment effect on the *Cyanobacteria* that have floated up in the water, but has no obvious effect on the *Cyanobacteria* that are dormant in the sediment. Third, the added chemicals inevitably cause chemical pollution to the water.

The biological algae removal methods mainly use microorganisms to lyse *Cyanobacteria*. For example, Chinese patent application publication No.

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CN109897801A, published on June 18, 2019, discloses a compound microorganism for controlling *Cyanobacteria* blooms. The compound microorganism comprises, by weight parts, 10-30 parts of *Bacillus laterosporus* and 10-30 parts of *Bacillus amyloliquefaciens*. The compound microorganism can effectively degrade organic pollutants in water, remove nitrogen and phosphorus, control and reduce *Cyanobacteria* blooms, and have no side effect on environment and human beings. This invention also discloses a method for preparing the compound microorganism and use thereof. However, at present, there are only a few studies on the control of *Cyanobacteria* by microorganisms. The control is greatly affected by environment, with uneven effects and poor replicability. In addition, the microorganisms also have good treatment effects only on *Cyanobacteria* that have floated in the water, but have no obvious effect on *Cyanobacteria* that are dormant in sediment.

The physical algae removal methods use artificial and mechanical salvage as the most direct algae removal means. The methods are implemented by interception, dredging, dilution, sewage diversion and other modes. Flocculants are added to flocculate and settle algae to the bottom of the water and recycle the algae. When the sediment dredging treatment method is implemented, nutritive salts in sediment are still massively precipitated into the water, and some *Cyanobacteria* particles also drift into the water. For example, Chinese patent application publication No. CN101602533A, published on February 09, 2011, discloses a method for controlling *Cyanobacteria* blooms. *Cyanobacteria* on the surface of water is sucked and collected by using an acquisition system with a sucker, pumped into a conveying pipe by a suction pump and conveyed to a storage tank. Flocculants are added into the storage tank, so that the *Cyanobacteria* flocculate. The *cyanobacteria* water after flocculating *Cyanobacteria* is sent to a settling separation system for solid-liquid separation to obtain water and *Cyanobacteria* mud with a water content of 80%. The water obtained after solid-liquid separation is sent through the settling separation system to a clear water tank for temporary storage and then discharged to the water through an overflow port. *Cyanobacteria* mud obtained after separation is dried to obtain *Cyanobacteria* mud

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with a water content of less than 70%. The foregoing method can reduce the density of algae cells on the lake surface and remove part of the nutrient load of the lake, but has the following disadvantages. First, only *Cyanobacteria* can be removed while exogenous nutrient elements cannot be removed. Second, the added flocculants may cause secondary pollution to the water. Third, during the mechanical salvage of *Cyanobacteria*, cell rupture may lead to the generation of algal toxins that can induce human liver cancer, and mechanical disturbance accelerates the propagation of the toxins in a bucket, also causing secondary pollution to the water. Fourth, the suction method using a pipe mainly has the disadvantage of adding subsequent treatment, transportation and dehydration, because the sediment sucked out contains more water.

The comprehensive treatment method uses several different processes in one system to treat *Cyanobacteria* in water. For example, a biochemical comprehensive algae removal method and biofilm treatment are combined with other processes for algae removal, and pre-ozonation, biological treatment and an activated carbon adsorption process are combined for algae removal. For example, Chinese patent application publication No. CN102424499A, published on April 25, 2012, discloses a large-scale mobile water purification system for slow-flow or closed water areas such as lakes, reservoirs, ponds and landscape water bodies. Because the water treatment technologies used in this device are mainly physio-chemical techniques, the system is provided with water treatment devices such as a filter unit, an adsorption unit, a micro-current electrolytic ion release unit and an aeration unit. Pollutants in the water are treated through direct contact between each water treatment unit and the water in the water area. Compared with the single treatment technology mentioned above, the solution has the advantages of fast treatment speed and strong treatment capability and being capable of synchronously removing *Cyanobacteria* and nutrients in water. However, the treatment effect is obvious only for the floating *Cyanobacteria* in the water, but the cyanobacteria dormant in the sediment cannot be effectively treated.

Therefore, it is very necessary to develop a purification technology and device that is simple in structure, stable in operation, and can give full play to the cooperative

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function of various units and effectively eliminate *Cyanobacteria*, released algal toxins and nitrogen and phosphorus pollutants in eutrophic water and sediment.

SUMMARY

1. PROBLEMS TO BE SOLVED

In the existing cyanobacteria bloom treatment technology, the process of removing *Cyanobacteria*, algal toxins and exogenous nutrient elements simultaneously is complicated, the treated substances are easily diffused in the removal process to cause secondary pollution to the water and the removal device is complicated, the present invention provides a device and method for in-situ removal of overwintering *Cyanobacteria* in lake sediment. The device and method can effectively remove the *Cyanobacteria*, algal toxins and exogenous nutrient elements in the sediment and can effectively prevent secondary pollution to water in the removal process.

2. TECHNICAL SOLUTIONS

In order to solve the foregoing problems, the technical solutions adopted by the present invention are as follows:

A device for in-situ removal of overwintering *Cyanobacteria* in lake sediment is provided, which including a reactor, wherein the reactor is installed on lake sediment, the bottom of the reactor is open and in direct contact with the sediment to form a closed internal environment of the reactor; filter screens are arranged in the reactor, adsorption materials are placed on the filter screens, and a water disturbing device is arranged on a lower portion in the reactor; the water disturbing device includes disturbing blades, and the disturbing blades rotate to drive the water to move. The whole device and the sediment contact surface jointly form a closed system. The system is naturally divided into three portions from bottom to top: a sediment disturbing portion for disturbing the sediment to make *Cyanobacteria* float up and release nitrogen and phosphorus pollutants, an adsorption filter layer portion for adsorbing *Cyanobacteria*, algal toxins and nitrogen and phosphorus substances, and a denitrification portion for denitrification of nitrogen. The closed system inhibits the

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diffusion of the algal toxins and other nitrogen and phosphorus pollutants released by *Cyanobacteria* in the water in the removal process, thus avoiding secondary pollution to the water. The closed system is favorable for enabling the disturbing blades to drive the water to move, thereby suspending the sediment.

Preferably, the disturbing blades are located on a lower portion of the reactor but are not in contact with the sediment, and a supporting isolation net is installed between the disturbing blades and the sediment contact surface. Because the disturbing blades drive the water to move when working in a closed environment inside the reactor, and the intensity of the water movement is concentrated and large, the generated intensity is sufficient to resuspend the sediment and release *Cyanobacteria* and nutrient elements in the sediment. The disturbing blades do not need to directly act with the sediment. This can minimize the rise of the sediment with water, which affects the adsorption of adsorbing materials. Meanwhile, the supporting isolation net installed between the disturbing blades and the sediment contact surface can effectively prevent the disturbing blades from touching the bottom when working. In addition, the isolation net can have a certain filtering effect on the sediment and further prevent the sediment from floating up with the water.

Preferably, the bottom of the reactor is provided with a bottom-touching beam, a plurality of plant root grooves protruding towards the sediment are distributed at the bottom of the bottom-touching beam, and submerged plants such as *Vallisneria natans* are planted in the plant root grooves. The bottom-touching beam has a certain lifting effect on the reactor, which can reasonably control the distance between the supporting isolation net and the sediment to prevent the limitations caused by the disturbing blades upon working. The plant root grooves protrude towards the sediment and can be inserted into the sediment, which can strengthen the placement stability of the in-situ removal device on the sediment, prevent the device from moving under the action of water flow, and ensure the sealing property. Submerged plants with a good tolerance and purification ability can effectively adsorb the algal toxins released by *Cyanobacteria* into the closed device, adsorb some nitrogen and phosphorus pollutants,

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and act synergistically with the adsorbing materials.

Preferably, several layers of filter screens with successively smaller pore sizes are arranged in the reactor from bottom to top, and adsorbing materials are placed on each layer of filter screen. The particle sizes of the adsorbing materials on the several layers of filter screens from bottom to top change from large to small with the pore sizes of the filter screens. The filter screen at the bottom layer has a pore size of about 1 cm, and the filter screen at the top layer has a pore size of about 1 mm. Since *Cyanobacteria* are released at the bottom of the reactor and then float upwards, the pore size of the filter screen close to the sediment is large and the pore size gradually decreases upwards. This can ensure that the floating substances can penetrate through a high layer of filter screen as far as possible and ensure that all the filter screens of the whole device absorb the *Cyanobacteria* fully.

Preferably, an inner wall of the reactor is provided with an inner wall filter screen, and the gap between the inner wall filter screen and the inner wall is filled with adsorbing materials. The adsorbing materials are porous ceramsite and/or clay mineral balls. The floating *Cyanobacteria*, nitrogen, phosphorus and algal toxins can be adsorbed and removed more comprehensively.

Preferably, the above filter screens are made of metal organic frameworks (MOFs), such as ZIF-8 and Cu-BTC. The MOFs can effectively absorb gases generated by denitrification. The adsorption principle of the MOFs can be found in the literature: Ruijun Zhang, Dalian University of Technology, 2014, Theoretical Investigation on the Gas Adsorption and Molecular Recognition of Metal-Organic Frameworks.

Preferably, the top of the reactor is provided with a top cover which covers the top of the reactor through a hasp locking device, and the interior of the top cover is provided with a hollow chamber. The disturbing device further includes a motor and a transmission rod, wherein the motor is sealed in the hollow chamber of the top cover, and the motor drives the disturbing blades through the transmission rod to rotate. The top cover can be opened or closed, which facilitates the subsequent use and maintenance of the device. The top cover is locked with the container wall around the

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reactor through the hasp to ensure a closed internal environment. The hollow environment inside the top cover can prevent the water from entering the working environment of the motor.

Preferably, the outer edge of the bottom of the reactor is provided with a fixed anchor which is reverse hook-shaped, and the reactor is fixed on the sediment through the fixed anchor to effectively prevent the device from moving upwards or horizontally.

A method for in-situ removal of overwintering *Cyanobacteria* in lake sediment is provided, which using the above device for in-situ removal of overwintering *Cyanobacteria* in lake sediment, the method comprises the following steps:

1) fixing a reactor on lake sediment to ensure that an isolated and closed internal environment is formed in the reactor;

2) disturbance treatment period: starting a disturbing device, so that disturbing blades drive the water in the reactor to move, the sediment suspends and releases *Cyanobacteria*, nitrogen, phosphorus and algal toxins therein, and the released *Cyanobacteria*, nitrogen, phosphorus and algal toxins float upward and are adsorbed by submerged plants at the bottom of the reactor and adsorbing materials filled in the reactor; meanwhile, denitrification of nitrogen in the water is performed in a denitrification zone formed at the top of the reactor due to hypoxia;

3) standing adsorption period: shutting down the disturbing device and standing; and

4) after the treatment is completed, taking out and cleaning the reactor, and then replacing the adsorbing materials and submerged plants therein, so that the next in-situ removal of overwintering *Cyanobacteria* in sediment can be performed. Specifically, the metal frame is washed with water and then placed in a ventilated place in the sun for exposure, so that adsorbed algae can be eluted and gas can be released. However, the adsorbing material balls and plants are not recycled, and it is preferable to replace both of them. Filter screens are detachable and can be taken out layer by layer to replace the adsorbing material balls and plants, and then the filter screens are installed again.

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Preferably, the disturbance treatment period in step 2) is 10-20 days. During the disturbance treatment period, the disturbing device works intermittently, and the specific mode of the intermittent work is as follows: after working for 12-16 h every day (24 h), the disturbing device stops working and stands for 8-12 h. Preferably, the standing adsorption period in step 3) is 1-3 days.

It should be noted here that the disturbance treatment period and the standing adsorption period constitute a complete treatment period, and the duration of the treatment period depends on the tolerance of the selected submerged plants, such as *Vallisneria natans*, and is generally about 20 days.

3. BENEFICIAL EFFECTS

Compared with the prior art, the present invention has the following beneficial effects:

(1) The device and method for in-situ removal of overwintering *Cyanobacteria* in lake sediment according to the present invention are implemented in a totally closed system. The overwintering *Cyanobacteria* are collected and removed, and the algal toxins and nitrogen and phosphorus pollutants are controlled and removed; meanwhile the secondary water pollution caused by the diffusion of the overwintering *Cyanobacteria*, nitrogen, phosphorus and algal toxins in the treatment process are effectively prevented. The device and method have high flexibility and are subjected to little influence by external environmental factors.

(2) According to the device for in-situ removal of overwintering *Cyanobacteria* in lake sediment of the present invention, disturbing blades located on a lower portion of a reactor are utilized to drive the water to move. As the disturbing blades are in a closed environment inside the reactor when working, and the intensity of the water movement is concentrated and large, the generated intensity is sufficient to resuspend the sediment and release *Cyanobacteria* and nutrient elements in the sediment. Therefore, the disturbing blades do not need to directly act with the sediment, which can reduce as far as possible the situation that the sediment floats up with the water and affects the

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adsorption of adsorbing materials. At the same time, the supporting isolation net is installed between the disturbing blades and the sediment contact surface, which can effectively prevent the disturbing blades from touching the bottom when working. In addition, the isolation net can have a certain filtering effect on the sediment and further prevent the sediment from floating up with the water.

(3) The device for in-situ removal of overwintering *Cyanobacteria* in lake sediment according to the present invention reasonably integrates all units of plant treatment, physical treatment and biochemical treatment, and the units cooperate with each other and synchronously inhibit multiple elements, thereby comprehensively and efficiently treating *Cyanobacteria*, nitrogen, phosphorus and algal toxins in sediment.

(4) According to the device for in-situ removal of overwintering *Cyanobacteria* in lake sediment of the present invention, an inner wall of the reactor is provided with filter screens, and the gap between the filter screens and the inner wall of the reactor are filled with adsorbing materials. The floating *Cyanobacteria*, nitrogen, phosphorus and algal toxins can be adsorbed and removed more comprehensively.

(5) The device for in-situ removal of overwintering *Cyanobacteria* according to the present invention is simple in working principle and convenient to maintain, and is a reusable device with high universality and economic efficiency.

(6) The device for in-situ removal of overwintering *Cyanobacteria* in lake sediment according to the present invention is utilized to remove the overwintering *Cyanobacteria* in the lake sediment, which has good removal effect, high flexibility, little influence by external environmental factors and little secondary influence on the water environment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front structural section view of the device for in-situ removal of overwintering *Cyanobacteria* in lake sediment according to the present invention; and

FIG. 2 is a top structural section view of the device for in-situ removal of overwintering *Cyanobacteria* in lake sediment according to the present invention.

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In the figures: 1. fixed anchor, 2. bottom-touching beam, 3. plant root groove, 4. disturbing blade, 5. supporting isolation net, 6. transmission rod, 7. motor, 8. top cover, 9. hasp locking device, 10. filter screen, 11. adsorbing material.

DETAILED DESCRIPTION

The present invention will be further described in detail below with reference to the accompanying drawings.

It should be noted that when an element is called "fixed" to another element, the element can be directly on the another element or the two elements can be directly integrated. When an element is called "connecting" to another element, the element may be directly connected to the another element or the two elements may be directly integrated. In addition, terms such as "upper", "lower", "left", "right" and "middle" referred to in this specification are merely for ease of description, and are not used to limit the scope of implementation. The changes or adjustments in the relative relationship without substantial changes in the technical content are also regarded as the scope of implementation of the present invention.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by those skilled in the technical field of the present invention. The term "and/or" used herein includes any and all combinations of one or more related listed items.

Example 1

As shown in FIGs. 1 and 2, a device for in-situ removal of overwintering *Cyanobacteria* in lake sediment according to the present invention includes a reactor. The reactor is installed on lake sediment, and the bottom installing portion of the reactor on the sediment is open and in direct contact with the sediment to form a closed internal environment of the reactor. Filter screens 10 are arranged in the reactor, adsorption materials 11 are placed on the filter screens 10, and a water disturbing device is arranged on a lower portion in the reactor. The water disturbing device is provided with disturbing blades 4, and the disturbing blades 4 rotate to drive the water closed in the reactor to move. The bottom of the reactor is provided with a bottom-touching beam 2,

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and the bottom-touching beam 2 is in direct contact with the sediment. A plurality of plant root grooves 3 protruding towards the sediment are distributed at the bottom of the bottom-touching beam 2, and submerged plants with a better tolerance and purification ability, such as *Vallisneria natans*, are planted in the plant root grooves 3. An inner wall of the reactor is provided with an inner wall filter screen, and there is a gap between the inner wall filter screen and the inner wall of the reactor. The gap is filled with adsorbing materials 11. The adsorbing materials 11 may be porous ceramsite or clay mineral balls and a mixture of the two. The top of the reactor is provided with a top cover 8 which can be opened or closed. When a closed environment needs to be formed, the top cover 8 covers the reactor and is locked at the top of the reactor by a hasp locking device 9. The hasp locking device 9 may be a hasp lock and of course, it can be replaced with other locking devices, provided that the top cover 8 can be tightly closed at the top of the reactor.

As shown in FIG. 1, the disturbing device further includes a motor 7 and a transmission rod 6. The motor 7 drives the disturbing blades 4 through the transmission rod 6 to rotate, and the interior of the top cover 8 is provided with a hollow chamber for placing and sealing the motor 7. The outer edge of the bottom of the reactor is provided with a fixed anchor 1 which is reverse hook-shaped, and the reactor is fixed on the sediment by the fixed anchor 1. The disturbing blades 4 are located on a lower portion of the reactor but are not in contact with the sediment, and a supporting isolation net 5 is installed between the disturbing blades 4 and the sediment at the bottom of the reactor.

As shown in FIG. 1, several layers of filter screens 10 with successively smaller pore sizes are arranged in the reactor from bottom to top, and each layer of filter screen 10 is detachable. Adsorbing materials 11 are placed on each layer of filter screen 10 to form several adsorbing material 11 layers. The particle sizes of the adsorbing materials 11 of the adsorbing material 11 layers become smaller in the reactor from bottom to top. The filter screen at the bottom layer has a pore size of 1 cm, and the filter screen at the top layer has a pore size of 1 mm.

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The above filter screens (including the inner wall filter screen) may be ordinary steel wire filter screens or be made of special materials, such as MOFs, provided that the filter screens are able to place adsorbing materials.

A method for in-situ removal of overwintering *Cyanobacteria* in lake sediment by using the device for in-situ removal of overwintering *Cyanobacteria* in lake sediment and the principle thereof are implemented as follows.

(1) Fix a reactor on lake sediment and closely cover the reactor with a top cover 8 to ensure that an isolated and closed internal environment is formed in the reactor.

(2) Disturbance treatment period: Start a motor 7 of a disturbing device, so that the motor 7 drives disturbing blades 4 to rotate, and the disturbing blades 4 drive water in the reactor to move. Because the disturbing blades are in the closed environment in the reactor and the intensity of the water movement is concentrated and large, the generated intensity is sufficient to resuspend the sediment. The sediment suspends and releases *Cyanobacteria*, nitrogen, phosphorus and algal toxins therein. The released *Cyanobacteria*, nitrogen, phosphorus and algal toxins are dispersed in the water and float up accordingly and are adsorbed by submerged plants at the bottom of the reactor and adsorbing materials 11 filled in the reactor. In addition, denitrification of nitrogen in the water is performed in a denitrification zone formed at the top of the reactor due to hypoxia.

(3) Standing adsorption period: Shut down the disturbing device, and stand, so that the dispersed *Cyanobacteria*, nitrogen, phosphorus and algal toxins can be fully adsorbed and removed.

(4) After the treatment is completed, take out and clean the reactor, and then replace the adsorbing materials 11 and submerged plants therein, so that the next in-situ removal of overwintering *Cyanobacteria* in sediment can be performed. Specifically, the metal frame is washed with water and then placed in a ventilated place in the sun for exposure, so that adsorbed algae can be eluted and gas can be released. However, the adsorbing material 11 balls and plants are not recycled, and it is preferable to replace

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both of them. Filter screens are detachable and can be taken out layer by layer to replace the adsorbing material 11 balls and plants, and then the filter screens are installed again.

Example 2

This example is basically the same as Example 1, except that the submerged plant selected in this example is *Myriophyllum verticillatum*, and the disturbance treatment period is 10 days; disturbing blades 4 stop after working 12 h every day and stand for 12 h; and the standing adsorption period is 1 day. In addition, the filter screen in this example is made of ZIF-8.

In this example, Gehu Lake sediment in March was treated, and the removal of *Cyanobacteria*, nitrogen, phosphorus and algal toxins was detected. The concentrations of pollutants in the water when the disturbed sediment was not subjected to other treatments before treatment and after treatment are shown in Table 1.

Table 1 Tested indicators of water before and after treatment

	Cyanobacteria (chlorophyll in water (μg/g))	Nitrogen (mg/kg)	Phosphorus (mg/kg)	Algal toxin (μg/kg)
Before treatment	1.16	132.77	63.15	275.6
After treatment	0.18	31.47	19.33	13.9
Removal rate	84.5%	76.3%	69.4%	95.0%

Example 3

This example is basically the same as Example 1, except that the submerged plant selected in this example is *Potamogeton crispus*, and the disturbance treatment period is 16 days; disturbing blades 4 stop after working 14 h every day and stand for 10 h; and the standing adsorption period is 2 days. In addition, the filter screen in this example is made of Cu-BTC.

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In this example, Gehu Lake sediment in March was treated, and the removal of *Cyanobacteria*, nitrogen, phosphorus and algal toxins was detected. The concentrations of pollutants in the water when the disturbed sediment was not subjected to other treatments before treatment and after treatment are shown in Table 2.

Table 2 Tested indicators of water before and after treatment

	Cyanobacteria (chlorophyll in water (μg/g))	Nitrogen (mg/kg)	Phosphorus (mg/kg)	Algal toxin (μg/kg)
Before treatment	1.16	132.77	63.15	275.6
After treatment	0.16	29.56	17.23	21
Removal rate	86.2%	77.7%	72.7%	92.4%

Example 4

This example is basically the same as Example 1, except that the submerged plant selected in this example is *Vallisneria natans*, and the disturbance treatment period is 20 days; disturbing blades 4 stop after working 16 h every day and stand for 8 h; and the standing adsorption period is 3 days. In addition, the filter screen in this example is an ordinary steel wire mesh.

In this example, Gehu Lake sediment in March was treated, and the removal of *Cyanobacteria*, nitrogen, phosphorus and algal toxins was detected. The concentrations of pollutants in the water when the disturbed sediment was not subjected to other treatments before treatment and after treatment are shown in Table 3.

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Table 3 Tested indicators of water before and after treatment

	Cyanobacteria (chlorophyll in water (μg/g))	Nitrogen (mg/kg)	Phosphorus (mg/kg)	Algal toxin (μg/kg)
Before treatment	1.16	132.77	63.15	275.6
After treatment	0.24	22.72	23.49	14.5
Removal rate	75.9%	82.9%	62.8%	94.7%

The foregoing examples are merely used to illustrate the technical idea of the present invention, and cannot be used to limit the protection scope of the present invention. Any changes made on the basis of the technical solutions according to the technical idea proposed by the present invention fall within the protection scope of the present invention. Technologies not covered by the present invention can be implemented by the prior art.

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What is claimed is:

1. A device for in-situ removal of overwintering *Cyanobacteria* in lake sediment, comprising a reactor, wherein the reactor having a bottom is installed on the lake sediment, the bottom of the reactor is open and in direct contact with the lake sediment to form a closed internal environment of the reactor; filter screens are arranged in the reactor, adsorption materials are placed on the filter screens, and a water disturbing device is arranged on a lower portion in the reactor; the water disturbing device comprising disturbing blades, wherein the disturbing blades rotate to drive water in the reactor to move; and wherein the disturbing blades are not in contact with the lake sediment, and a supporting isolation net is installed below the disturbing blades but above a contact surface of the lake sediment.

2. The device according to claim 1, wherein the bottom of the reactor is provided with a bottom-touching beam, and the reactor is installed on the lake sediment through the bottom-touching beam; a plurality of plant root grooves protruding towards the lake sediment are distributed at a bottom of the bottom-touching beam, and submerged plants are planted in the plant root grooves.

3. The device according to claim 1, wherein the filter screens comprise several layers of detachable filter screens arranged in the reactor from bottom to top, and pore sizes of the several layers of the detachable filter screens become smaller from bottom to top; the adsorption materials are placed on each layer of the detachable filter screens to form several layers of the adsorption materials; and particle sizes of the adsorption materials of the several layers of the adsorption materials become smaller in the reactor from bottom to top.

4. The device according to claim 3, wherein an inner wall of the reactor is provided with an inner wall filter screen, and a gap between the inner wall filter screen and the inner wall of the reactor is filled with the adsorption materials; and the adsorption materials are porous ceramsite and/or clay mineral balls.

5. The device according to any one of claims 1 to 4, wherein a top of the reactor is provided with a top cover which covers the top of the reactor through a hasp locking device, and an interior of the top cover is provided with a hollow chamber; the water disturbing device further comprises a motor and a transmission rod, wherein the motor is sealed in the hollow chamber of the top cover, and the motor drives the disturbing blades through the transmission rod to rotate.

6. The device according to claim 5, wherein an outer edge of the bottom of the reactor is provided with a fixed anchor which is reverse hook-shaped, and the reactor is installed on the lake sediment

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through the fixed anchor.

7. A method for in-situ removal of the overwintering *Cyanobacteria* in the lake sediment, wherein the method comprises:

1) installing the reactor of the device as defined in any one of claims 2 to 6 on the lake sediment to ensure that the closed internal environment of the reactor is formed in the reactor;

2) disturbance treatment period: starting the water disturbing device, so that the disturbing blades rotate to drive the water in the reactor to move, and the water drives the lake sediment to suspend;

3) standing adsorption period: shutting down the disturbing device and standing; and

4) after the in-situ removal is completed, removing and cleaning the reactor, and then replacing the adsorption materials and the submerged plants for a next round of the in-situ removal of the overwintering *Cyanobacteria* in the lake sediment.

8. The method according to claim 7, wherein the disturbance treatment period in said step 2) is 10-20 days; and during the disturbance treatment period, the disturbing device works intermittently following a schedule of after working for 12-16 h every day, the disturbing device stops working and stands for 8-12 h.

9. The method according to claim 8, wherein the standing adsorption period in said step 3) is 1-3 days.

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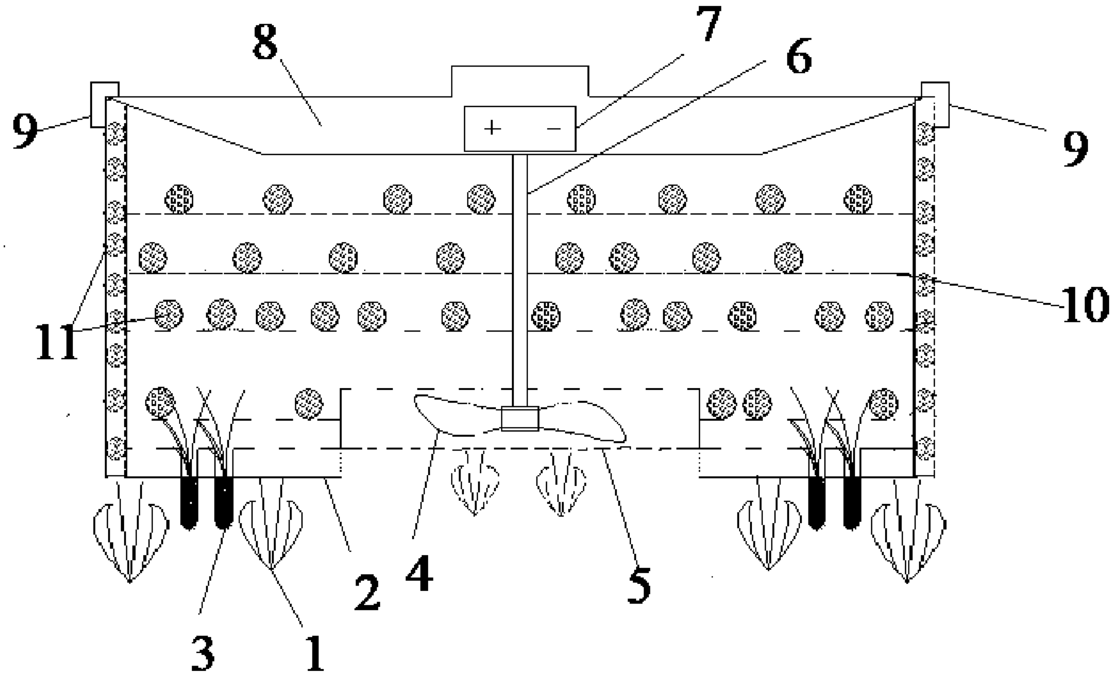

FIG. 1

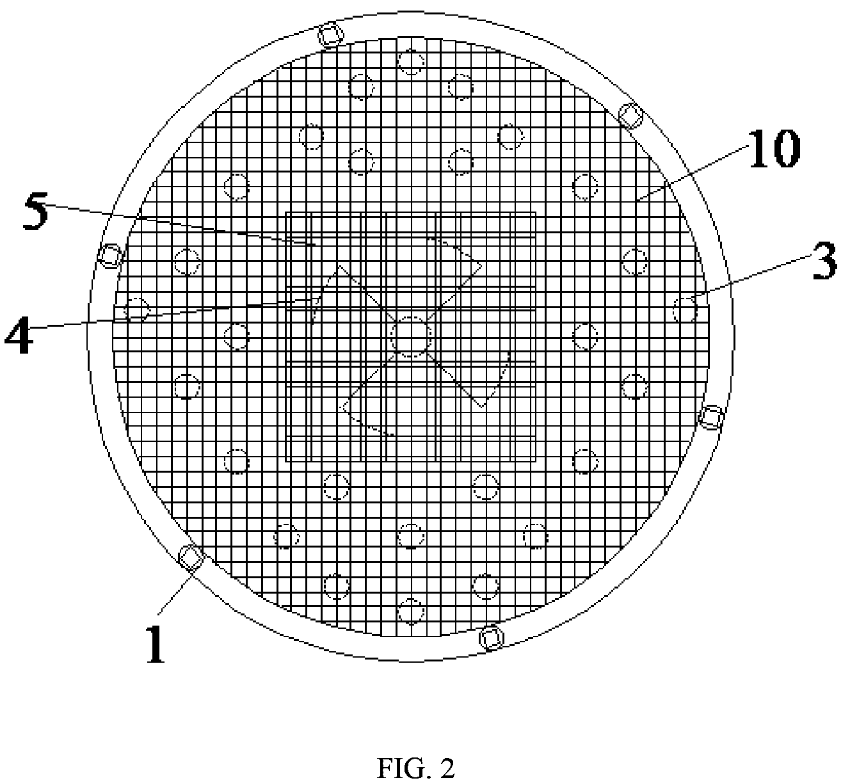

FIG. 2

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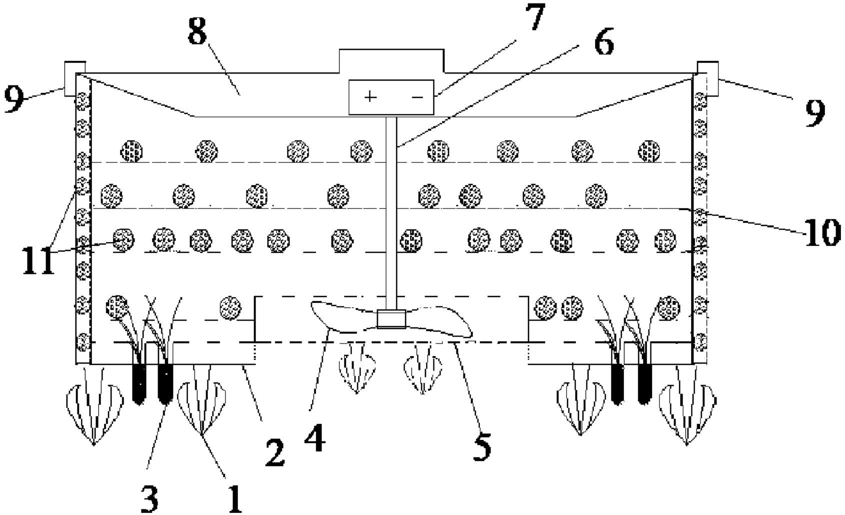
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