Solar-energy mobile water aerators are efficient for restoring eutrophic water

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Abstract. Surface water eutrophication has become a worldwide social issue. Large amounts of secondhand energy, high capital investment are required, and most ecosystem disturbances will arise in the conventional eutrophication restoration measures. However, mobile solar-energy water aerator has the better oxygen transfer rate, hydrodynamic condition and can be used in the large waterbody for its cruising character. Second, the device is low carbon and sustainable for the solar photovoltaic system applications. So the device can be widely used in the eutrophication restoration.

1. Eutrophication and measures
The rapid increase in human activity has substantially accelerated the eutrophication process, which become a worldwide water quality issue. For example, the potential annual value losses in recreational water usage and water-front real estate were approximately $2.2 billion as a result of eutrophication in U.S. freshwaters [1]. A recent study of over 14000 lakes <1 ha size in Great Britain found that 51% are likely to take measures to meet the Water Framework Directive to achieve ‘good status’ by the year 2015 [2]. However, most freshwater lakes in China had faced serious challenge in the eutrophic problems[3], and nearly 2*10⁴ ha aquaculture ponds in China which exports 60% aquatic products to the world have the same trouble[4]. Currently, many countries and districts have taken measures against eutrophication, such as the “Water Framework Directive” in Europe and the “Action Plan for Prevention and Treatment of Water Pollution (i.e., ten key water pollution control plans)” announced in 2015 in China. Except the reduction of discharge, in-site restoration and ectopic treatment are important measures against eutrophication. Sediment dredging, water transfer are major actions to against aquatic eutrophication[5]. However many scientists think sediment dredging measures should be discreetly implemented as it’s big cost and ecological risk of huge volume sludge ,also the lake ecosystem disturbance[6]. Transferring water needs diversion project and a lot of energy consumption, but it can only maintain the ‘good status’ in a short period after one time pour into [7].

2. Aeration and new demands
Artificial aerations which includes the fixed aerator and aeration vessel was considered as the cheapest and best preventive action against eutrophication [8]. Vertical-pump-sprayer, propeller-aspirator-pump, paddle-wheel, and diffused-air-system are the most widely used aerators, all of which must be fixed in
a site, so that energy was focused and cannot be distributed evenly in the water. Thus many installation sites are needed and large quantity of energy dissipation are arising in the fixed aerators. In addition, aeration vessels need high cost and manual operation, making the systems cannot be popularized in the eutrophic restoration. Research interests in mobile aerator have grown in the past 10 years, and several devices were published [9-12]. However their defects of the low mobile capacity, the small working area, the energy-extensive consumption, the dependence of secondary energy and the low overall performance in practice induce the low market application in the aquatic ecosystems rehabilitation. To this end, there is a need to develop novel devices that are able to perform on the larger water area with high efficiency and low-carbon footprint in operation. Emerging solar-energy mobile water aerator (SEMWA) will play a key role in the aquatic ecosystems restoration of low cost application, good performance, and without secondary energy.

3. Device advantages

3.1 Water exchange and Hydrodynamic force

The major difficulty of surface water (lake, reservoir, pond and river) eutrophic restoration is the large area, where the traditional restoration devices are not suitable to put into use. Compared with the small service area (usually less than 0.05 ha) of fixed aerators [13], SEMWA can cruise constantly with the help of time-switch or horizontal location-switch electronic program, and reaches every corner of the water. Hypoxic/anoxic water can be air-lift from the bottom to the surface for oxygenation and photo-chemical treatment, which can control taste and odor problems as well as nuisance algal blooms [14], together its running characteristic water can be maintained fresh as “running water is never stale”. Hence, we only need to spend little cost input than the fixed aerator for the less devices to use.

3.2 Clean energy and sustainability

Solar photovoltaic system is one of the potential low-carbon measures, as its energy payback time is only 1~4.1 years, and system lifetime reaches 30 years [15]. Solar photovoltaic panels and conversion system help SEMWAs obtain the power, which can save 36.8 TWh yr-1 electricity if them were applied in the eutrophic lakes and aquaculture ponds of China sufficiently(lake allocation (photovoltaic area: surface water area) = 2:104; aquaculture pond allocation=4:104). Meanwhile, we can avoid project construction troubles and decrease the current-leakage possibility of traditional electricity power deliver system. Therefore it is one of the best management practices (BMPs) to restore eutrophic water.

4. Function evidences

Aerators had better oxygen transfer rate in the state of mobility, for example, suspended chain moving aeration has lots of practical applications in the BIOLAK process of wastewater treatment plant [16]. In these years, so many aeration vessels have had good applications in the eutrophic lakes and rivers, such as Seine river [17], which the outstanding mobile characters were favored by many customers, “Pioneer One” aeration vessels will play important role in Taiwan fresh water eutrophic restoration [18]. SEMWAs also have been applied to some lakes and ponds (figure 1), which gets many approvals from scientists and customers for their performance of enhancing the water dissolved oxygen effectively, promoting the nutrients circulate and transform, had won the award of “2014 ten most innovative programs in China’s aquaculture industry” and “2015 environmental innovation and entrepreneurship competition in China”[19].
For rivers with narrow shape, SEMWAs have advantages of cruising back and forth while avoiding oxygenation asymmetrical and shipping interference, however the range limit is also needed as they would disappear without control. Alike rivers, eutrophic lakes usually need intensifying aeration in target area through positioning mode. Different power and mobile velocity of SEMWA can be set to satisfy different water area. Additionally, power of traditional aerators usually is below 3kW h-1 due to the energy transfer limits, thus the manufacture cost of the latter is too high.

There are many cases of solar photovoltaic system applications in natural water restoration, for example mechanical water mixer of SolarBee that uses a solar powered pump to create water circulation [20]. Besides, there are also the solar-powered impeller system and the solar powered aeration system [21]. In the water source of Dongguan Songmu mountain reservoir in China, 16 hectares solar energy restoring areas were construct for decreasing the chlorophyll-a concentration and optimizing algae community structure[22]. Extensive applications of solar energy in eutrophic water restoration in the future not only need high electricity transform efficiency of photovoltaic technology, but also depend on reduction of the system cost. In fact, restoration performance will be better when the sunlight is stronger, and energy transform efficiency is the highest when the sunlight is used for the eutrophic restoration directly.

5. Bright future
Although the comprehensive assessments of resource cost savings, device stability and flexibility in the field use still need to be addressed, we envisage that the real-time restoration of eutrophic waters will soon be realized using sustainable methods. From this perspective, SEMWA is one of effective and efficient mobile aerators due to its high efficiency, low carbon, convenience in operation and maintenance, which can enhance the water dissolved oxygen effectively, remit the state of water unfavorable appearance, unpleasant odors and algal blooms as well.

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