Low-Intensity and Micropore Pipes Aeration Powered by Wind-Solar Energy in Treating Urban Black-Odour Rivers

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Abstract. Some effects had been gained in urban inner rivers treatment in recent years. But more medium and small size rivers in city were polluted much heavier because of their small flow, slow velocity and locating deep into the resident areas. The remediation of these rivers needed long and enduring investing and management and thus became the main restrict of the government. This paper according to this status, put forward to a new kind of river aeration model, which combined low-intensity aeration with micropore pipes aeration and powered by wind-solar energy street lamp system. Because of the effectiveness in removing pollutant and low energy consumption, this combined system supported important reference and a new study direction in treating the urban black-odour rivers enduringly.

1. Introduction
Treatment of the urban inner rivers had been done many years, especially in recent years, the government enlarged the scale, increased the investment and deepened the administration to the landscape rivers remediation so the pollution situation of this rivers had gained some degree of change. But there were many another small size rivers. They often located in resident areas, flowed slowly and the water capacity was small. The rubbish pollution and waster water pollution were more seriously. Their self cleaning capacities were weaker so that they were eutrophia, black-odour. They had lost landscape function partly or totally, and had even effected the normal life of the both banks.

It might get a good effect when a kind of short-term and sudden action was taken to these rivers. But it would come to naught before long if it lacked of long-term, feasible treatments. The long-term or years of treatment tracking must be consumed large amount of capital and manpower. It would often rapidly become a heavy financial burden of the government administration so that it was thrown away. So, a kind of economical, effective, endurable method was needed.

This paper introduced a kind of synthesis facilities which used low-intensity and micropore aeration technology powered by wind-solar energy in the day. At night it supplied river banks lighting using partly electric power. It also discussed the feasibility of the facility and whether it can treat the black-odour river enduringly.

2. River aeration technology
The river aeration technology is a kind of method that filled the air or oxygen into the water artificially to enhance the dissolved oxygen (DO) of water body through the aeration equipment. This method could enhance aerobic microbial activity, enlarge various pollutant decomposition abilities, purify the water and strengthen self cleaning capacity. At the same time, this method also could restrain breeding of anaerobic bacteria and algae, reduce the rate of degradation of organic matter by anaerobic
microorganisms, inhibit the production of H2S, FeS and other black-odorants so as to achieve the goal of decontamination and deodorization.

River aeration technology can be divided into two types, air aeration and mechanical aeration, according to aeration means. The air aeration system consists of blower, air transport pipes and aeration pipes. The air or pure oxygen is filled into water through a porous diffuser or air nozzle. Mechanical aeration device is also known as surface aeration device, which uses mechanical equipment to stir sewage to dissolve air in water. The form of air aeration is more widely used in practice.

Aeration technology has been used to control river pollution for more than half a century. In the last century, the United States and European countries had used this technology to increase oxygen, get rid of the pollution and all achieved a curtain of effect. China and South Korea used the technology for both the Asian games and the Olympic Games in the 1980s and 1990s. During the Asian games in 1990, the Qinghe River was aerated for 47 days in Beijing. Foul smell of the river was basically eliminated. The DO content in the aerated area can reach 4-5mg/L, the removal rate of biological oxygen demand (BOD5) reached 74.7-88.2%, the removal rate of chemical oxygen demand (COD) reached 79.9-84.8%, the removal rate of ammonia nitrogen (NH3-N) reached 45%. The water quality basically meets the V-type of national standards. Zhou et al. used experimental methods to prove that river aeration technology has positive and effective effects on the improvement of DO and the elimination of black and odorous substances in water. Wang Wenlin et al. used aeration technology in the garden river of Zhangjiagang and found that DO was improved, turbidity of water was reduced, and concentrations of COD, NH3-N, total nitrogen (TN) and total phosphorus (TP) were decreased significantly.

However, the energy consumption of river aeration technology is always a problem that cannot be ignored. According to statistics, the energy consumption of aeration process in sewage treatment accounts for about 50% to 70% of the total power consumption of the sewage treatment plant. The energy consumption of aeration is also the most important operating cost in the river pollution control, especially the long-term or many years of aeration in the rivers. The energy consumption often becomes a heavy burden of pollution control so that most pollution control projects cannot be carried out years by years and the effect cannot be maintained. Therefore, it is the key and difficult point of river pollution control to carry out long-term and sustainable treatment with high efficiency and low energy consumption. Secondly, the basic theory of aeration is worthy to be researched in order to realize the more accurate aeration, to optimize aeration technology and equipments, and to save power consumption and labor costs greatly. Thus can ensure the effect of pollution treatment.

3. Low-intensity aeration technology

The low-intensity aeration technology is to reduce the aeration intensity to keep the DO concentration in water at a low level of less than 2mg/L under the premise of meeting the aim of pollutant removal, so as to form an aerobic microbial circulation system. Through the function of biological purification, water pollution is removed and energy is saved. In contrast, medium-intensity aeration refers to the situation where the concentration of DO is maintained at 2-6mg/L and high-intensity aeration refers to that where the concentration of DO is maintained at more than 6mg/L.

Chen Wei’s research[2] gave a comparative conclusion of the three methods gained by laboratory experiments. The experimental devices are 70cm-length and 20cm-diameter tubes independently. The effective water depth is 50cm. The results were obtained after 160 hours aeration experiment. All three aeration modes have good removal effect on COD, with removal rate of more than 60%. Among them, high-intensity aeration has better than low-intensity and medium-intensity aeration. The NH3-N in three devices also showed a fast decreasing trend. After 240 hours, the effect of removal of NH3-N either low-intensity aeration or medium-intensity aeration is basically the same the high-intensity aeration. And all the removal rates of NH3-N are over 90%. All three aeration modes have certain removal effects on TN. After aerated 160 hours, the removal rate of TN by low-intensity aeration reached 56%, which is better than that by medium-intensity aeration or high-intensity aeration. This is
mainly because the DO in water is higher under the medium or high intensity aeration mode, while in the process of low intensity aeration, a hypoxia or anoxic state is formed, Which is beneficial to denitrify for the nitrates produced by ammonia nitrogen, thus greatly reducing the concentration of TN in water. It can be seen that when the experiment is over 10 days old, the decontamination effect of low-intensity aeration is exactly the same as that of medium or high intensity aeration, and even has a better effect on denitrification. The decontamination effect of low-intensity aeration is shown in Fig 1.

![Fig.1 Low-intensity aeration reduces COD, NH3-N and TN](image)

However, the energy consumption of the three aeration modes is quite different. With goal of removal NH3-N over 90%, the running time of the three modes are shown in Tab.1.

| Aeration types      | Reach time (h) | Aeration time (h) | Equivalent aeration (h/Day) |
|---------------------|----------------|-------------------|-----------------------------|
| High-intensity      | 114            | 114               | 5                           |
| Medium-intensity    | 114            | 48                | 2                           |
| Low-intensity       | 352            | 12                | 0.5                         |

The reach time of high-intensity aeration is 114 hours, time of medium-intensity aeration is 114 hours, and time of low-intensity aeration is the longest of 352 hours. But, according to the statistics of aeration time, the aeration time of high-intensity mode is 114 hours, while the aeration time of medium intensity is 48 hours and the aeration time of low intensity is only about 12 hours. That is to say, the high-intensity aeration device works continuously for 5 hours every day, the medium-intensity aeration works continuously for 2 hours every day, and the low-intensity aeration works for 0.5 hours every day, after 15 days, the three models have the same effect on removal of NH3-N pollution in water. It can be seen that the energy consumed by low-intensity aeration is only about 10% of high-intensity aeration and only 25% of medium-intensity aeration. The energy saving effect is significant.

Therefore, it is completely feasible to adopt low-intensity aeration technology in pollution control. It has a better effect especially for TN removal and its energy consumption is greatly reduced. So low-intensity aeration is an ideal way for long-term pollution control in the urban black-odour rivers.

4. **Micropore aeration technology**

Micropore aeration refers to the situation that the diameter of micropore pipe is tiny, generally 0.03 to 0.06 mm, and the average diameter of bubbles is less than 3mm. The diameter of bubbles produced by
the traditional aerator is generally about 20mm. As a result, the area of contact between water and bubbles produced by a micropore tube increases by 6-7 times when entering the same volume of air.

Lu[1] et al. took the raw water from Guangxi University landscape lake, used the air compressor to connect the micropore aerators in the laboratory, and aerate the upper part of the water 2cm away from the bottom mud in a 30cm deep and 35L volume water tank. It is aerated 2 hours every day (9:00am - 11:00am). In the raw water, COD is 37.81-42.20mg/L, NH3-N is 17.03-20.12mg/L, TN is 18.42-23.13mg/L, TP is 1.56-1.98mg/L, DO is 1.53-1.67mg/L, PH is 7.51. The lake is enclosed all around and the main way to replenish is rainfall.

The experiment of aeration for 20 days shows that the change of DO content is shown as Fig. 2. In the third day, it reached 6mg/L or above, and reached the maximum value of 11mg/L around 15 days, which increased 4-5 times during the experiment. The reduction of various pollutants is also significant, as shown as Fig. 3. COD was decreased by 57.5%, ammonia nitrogen by 54% and total nitrogen by 55.5% in the experiment.

![Fig.2 Effect of micropore aeration on DO in water](image)

![Fig.3 Effect of micropore aeration on COD, NH3-N and TN](image)

At the same time, the energy consumption of micropore aeration technology is obviously lower than that of ordinary aeration method. Xia[4] carried out comparative experiments in the breeding pond. It was found that the micropore aeration device not only increased the oxygen faster but also saved more electricity energy than ordinary aeration device (water-wheel aerator). Their electric consumption is 1406 kWh and 460 kWh respectively driven by the same 2.2kw Roots blowers (zwg-10/2.2). The power was saving 67.3%. Generally, traditional aerator can increase oxygen 1.1-1.9 kg per 1kWh electric energy. While the micropore aerator can increase oxygen 3.4-4.9 kg per 1kWh electric energy in fresh water, it is 2.6 times that of traditional aerator.
It can be seen that the micropore aeration technology has good function of purifying water quality and low energy consumption during reoxygenation and pollution control of urban rivers, which is also an ideal choice for the long-term pollution control.

5. **Aeration and landscape lamp system controlled by wind-solar complementary energy**

In order to save the long-term operation cost of aeration reoxygenation project further, the renewable hotspot energy, such as wind and solar energy resources, can be used as the power. So it was considered that the landscape lamps complementary with solar and wind on both sides of the river provided the power of aeration devices during the day, and their partial energy was powered themselves at night. In this way, the one-time investment of urban municipal government not only plays the role of brightening the river but also realizes the long-term pollution control. Kill two birds with one stone.

5.1. **Power matching problem**

Currently, the power of wind turbines of street lamp system is mostly 300-1500 W, the power of each solar panel is about 100-200W, and that of LED lights is 50-80W. The aerated blower can be selected according to the actual condition of the river and the arrangement of the aeration pipe, and the power can be between 200W and 2000W.

If the composite system adopts a wind turbine of 400W, two pieces of solar panel of 100W and a 60W LED energy-saving lamp and if sunshine time is 8 hours per day, wind time is 6 hours all day and all night (the wind speed is greater than the minimum starting speed of the turbine), and the lighting time is 10 hours per night, the aeration time of each day can be at least half an hour even without battery storage when the power of the blower is less than 600W. If the battery storage is considered, the power of the blower is about 2kW, and the aeration can be more than 1.5 hours every day. If the turbine power increased to 500W, the panels are connected in series with 4 pieces and other parameters remain unchanged, the aeration time can reach 5-6 hours per day. 365 days a year without interruption, the effect of pollution control and deodorization can be imagined. When the water quality reaches a certain standard level and each parameter reaches the standard, the aeration device can be controlled to stop working to reduce waste.

In practical projects, the number of aeration devices can be adjusted according to the layouts of lamps located at one side or both sides, the width of the river and the flow rate of water. It can be considered that two or more lamps power one aeration device.

5.2. **The layout of aerator pipes**

The aeration pipe can be put on the top of the bottom mud, or put into the mud with certain depth to improve the residence time of DO in water and increase the utilization of oxygen. This is the main configuration of micropore aerators currently. The specific layout length and type should be reasonably designed according to different river conditions. It is not only suitable for the blower power but also can increase the area of reoxygenation as much as possible.

It can also adopt a Suspended Chain Aerating Device. Each set of equipment consists of a buoy, transport pipes, aerating micropore tubes (which can be configured with single or multiple connections), and a weight balancer. It is connected into chains with pipes group by group. The chains float on the water through the buoyant force of the buoy. The aerating micropore tubes are suspended in water without other fixed devices only by weight balancer. This aeration method can expand the aeration area by using several aeration pipes result to saving the beginning investment. It is suitable for the geotechnical structure of the river bed and there is no need for navigation. The aerator can be directly pulled out of the water when it needs to be maintenance.

6. **Conclusion and prospect**

Low-intensity and micropore aeration technology is feasible and effective in pollution control of river. A good decontamination effect can be achieved soon after a certain time management (ten or dozens
of days). The content of chemical oxygen demand, ammonia nitrogen, total nitrogen and total phosphorus in water can all be reduced by 40-50%. The black-odour rivers will improve significantly. In addition, the energy consumption of this method is much lower than that of normal aeration technology. The electricity consumption is only 10-30% of that of the normal way. The energy saving effect is significant. Coupled with it is powered by the wind-light complementary energy lamp system without the consumption of conventional energy, the long-term operation cost of the system is further reduced and the capital investment of this project is also saved greatly. Thus the long-term and persistence of the project can be guaranteed more possibly. Due to the small power required, the low-intensity and micropore aeration technology is easier to match the power of the wind-light complementary street lamp system. Its one-time investment has also fallen. It is a clever combination of two important urban construction goals for river pollution control and urban lighting. It is a kind of compound system which is benefit for comprehensive city administration and it is much worth to be studied and popularized.

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