Research on the Technique of Multistage Functional Filtration to Repair Black and Odorous Water

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Abstract: It is of great significance for environmental protection to carry out in-depth research on the treatment of black and odorous water body and form effective water remediation technology. The ecological technology of multistage functional filtration for water restoration can be used as a new and reliable combined filtration process for advanced treatment of black and odorous river, which can effectively intercept pollutants from point sources and purify watershed water. In this paper, a new type of water purification device consisting of cobblestone, quartz sand, activated carbon and PP cotton is developed, which is used to deeply treat black odorous water body and study the filtration and adsorption performance of filter materials on target pollutants. The filtration and adsorption performance of the filter material to the target pollutants, and the influence of the thickness of the filter layer and the particle size of the filter material on the filtration efficiency were studied. The water quality was effectively improved and the purpose of treating the black odor water body was achieved.

Keywords: Multistage filtration, black odor water body, thickness of filter layer, particle size of filter material.

1. Introduction
The Nineteenth National Congress of the Communist Party of China (CPC) put forward that the battle of pollution prevention and control should be fought well before 2020. The Ministry of Ecological Environment divided the battle of pollution prevention and control into seven major battles. The black and odorous water body ranks third in the seven major battles, which was the breakthrough and cornerstone of the national water control. The goal of sponge city construction in our country is to gradually realize that light rain does not accumulate water, heavy rain does not flood, water body is not black and odor, and heat island is alleviated. Black and odorous water body is a prominent problem in urban water environment, and it is also an important and difficult problem in the prevention and control of urban water pollution.

Reviewing China's water treatment projects in the past ten years, due to lack of experience, detailed information on long-term operation systems and in-depth research and development results, there is no
plan based on the site environment, water quality conditions and standard requirements. After the
completion of the project, the rivers are prone to anti-blackness, blockage, overflow, silt deposition and
other phenomena. Therefore, it is of great significance for environmental protection to carry out in-depth
research on the treatment of black and odorous water and form effective water remediation technology.

Multi-media filtration technology improves the removal of suspended solids, dissolved organic
matter and ammonia nitrogen on the basis of traditional deep filtration. Compared with conventional
coagulation filtration process, multi-media filtration has no use of chemical agents and reduces sludge
production. Filter material and the composition of filter material layer are the key factors affecting the
filtration characteristics, which determines the quality of filtered effluent and the basic performance of
filtration equipment. Therefore, the development of filtration technology depends to a large extent on
the research and improvement of the composition of filter material and filter material layer.

In this paper, a multi-stage functional filtration system was developed to deeply treat the black and
odorous water body, and the filtration and adsorption performance of the filter material on the target
pollutants, as well as the influence of the filter layer thickness and the filter material particle size on the
filtration efficiency were studied. The multistage functional filtration system can effectively intercept
the pollution of water point sources and purify the watershed water, so as to effectively control the black
and odorous water body.

2. General situation of Engineering
Based on the comprehensive improvement project of water environment in Qianhai Tieshi area of
Shenzhen, this project covers an area of 174 square kilometers, including 22 sub-projects, including
river regulation, rain-polluted pipe network, sediment disposal, new pipe network and pollution control
facilities, flood control and waterlogging drainage, etc., which provides engineering conditions for
technical research and development of this project.

According to the general idea of "controlling source and intercepting pollution, systematic
management, ecological restoration, construction and management" in Bao'an District of Shenzhen City,
the "seven strategies" for water control and quality improvement are implemented to ensure that the key
battle for water control and quality improvement is won in an all-round way.

![Figure 1. Engineering site.](image)

This paper proposes a four-stage filtration process consisting of cobblestone, quartz sand, activated
carbon and PP cotton as a deep treatment process for black and odorous water. A new type of ecological
water purification device encapsulated with functional filter material by composite geogrid was
developed to intercept the point source pollution of suspended particulate matter and guide the
ecological water purification device to be placed in the polluted waters at intervals to achieve filtration
and purification. Indoor model tests were carried out, including single-stage filtration model tests to
determine the treatment range of pollution sources corresponding to the filter device, and multi-stage
filtration model tests to deal with a variety of pollution sources. The feasibility and applicable conditions
of the multi-stage functional filtration technology for water restoration are proposed to achieve the goal of improving water quality transparency to more than 35 cm.

3. Test materials and devices

3.1. Test materials

In the multistage functional filtration test of repairing black and odorous water body, the filter materials were used, including cobble (particle size 10 mm and 20 mm), quartz sand (particle size 0.25 mm and 0.5 mm), activated carbon (coconut shell activated carbon and coal activated carbon) and PP cotton (pore size 1 micron and 5 micron). The physical properties of coconut shell activated carbon and coal activated carbon are shown in Table 1 and Table 2.

| Testing items               | Unit     | Standard specification | Inspection results |
|----------------------------|----------|------------------------|--------------------|
| Moisture                   | %        | ≤10                    | 5.2                |
| Ash                        | %        | ≤10                    | 3.6                |
| strength                   | %        | ≥95                    | 98.91              |
| Iodine adsorption value    | mg/g     | ≥900                   | 1055               |
| Specific surface area      | m²/g     | ≥900                   | 1093               |
| Filling density            | g/l      | 480-580                | 545                |
| PH value                   | /        | 5-10                   | 7.2                |

Table 1. Physical properties of coconut shell activated carbon.

Table 2. Physical properties of coal activated carbon

| Testing items               | Unit     | Standard specification | Inspection results |
|----------------------------|----------|------------------------|--------------------|
| Moisture                   | %        | ≤10                    | 5                  |
| Ash                        | %        | ≤10                    | 7                  |
| strength                   | %        | ≥90                    | 95                 |
| Iodine adsorption value    | mg/g     | ≥450                   | 500                |
| Filling density            | g/l      | ≥550                   | 680                |
| PH value                   | /        | 5-10                   | 7.2                |

3.2. Testing devices

The test device mainly includes: a water distribution tank, a multi-stage filtration device (inner diameter × height =200 mm×505 mm), and a rectangular water purification device. As shown in Figure 2 and Figure 3.

The monitoring and measuring devices mainly include: PH tester, ORP tester, Said disk, AZ8403 dissolved oxygen tester.

Figure 2. Multistage filtration device. Figure 3. Rectangular water purification device.
4. Test process
In this paper, a multi-stage functional filtration and repair water model test was carried out. The four-stage filter materials were 10mm pebbles, 0.25mm quartz sand, coconut shell activated carbon and 1μm PP cotton.

Test process:
1. Collect appropriate amount of sewage water sample.
2. The filter material is assembled from bottom to top in the multi-stage functional filtration repair water model device according to Table 3.

| Filter material                  | Thickness |
|---------------------------------|-----------|
| 10mm pebbles                    | 12cm      |
| 0.25mm quartz sand              | 12cm      |
| coconut shell activated carbon  | 12cm      |
| 1μm PP cotton                   | 2.5cm     |

Figure 4. Repairing water model by multi-stage functional filtration after loading.

3. The black and odorous water body is poured into the high water tank. After the water body flows out of the high water tank, it flows into the lower port of the model device, flows through the four-stage filtration material, and flows out of the upper port of the device into the water collecting tank. Control the standing time of water sample in each stage of filter material. The static time is as follows: the pebble with 10 mm diameter is kept for 7 minutes; the quartz sand with 0.25 mm diameter is kept for 7 minutes; the activated carbon with coconut shell is kept for 12 minutes; and the PP cotton with 1 micron is kept for 4 minutes.

4. After 2 hours of experiment, the filtered water samples were taken out and the transparency of the filtered water samples was compared with that of the raw water samples.

5. After 18 hours, the filtered water samples were taken out and the transparency of the filtered water samples was compared with that of the raw water samples.

6. After the test, the test results were recorded and analyzed to determine the thickness ratio of each filter layer and the size of the filter material in the multi-stage filter material model.

Test result:
Figure 5. Transparency comparison of test raw water, 2 hours and 18 hours.

Fig. 5 of the test results shows that the combination of four-stage filter materials has obvious effect in repairing black and odorous water. The water quality changes from turbid light yellow to clear and transparent after adsorption. The longer the filtration time, the higher the transparency of the filtered water. Therefore, the technology of multi-stage filtration for the restoration of black and odorous water is feasible.

5. Analysis of influencing factors of filter material

5.1. Thickness factor of filter layer
In the filtration stage of multi-stage functional filtration for repairing black and odorous water body, some suspended substances with smaller particle size enter the depth of the filter layer through the upper filter material. The thicker the filter layer is, the deeper the suspended substances in the water can be transported to the next filter layer. The more suspended substances are intercepted, the greater the ability of the filter material to intercept pollutants, thus increasing the sewage interception capacity of the filter. The thickness of the filter layer is also one of the key factors affecting the filtering effect. Generally speaking, when other filtration conditions are the same, the thicker the filter layer, the better the filtering effect. Increasing the thickness of the filter layer can improve the filtering effect and increase the amount of sewage interception, but this is not the bigger the better. If the thickness of the filter layer is too large, the lower filter material can not fully play its role of pollution interception in the whole filtration cycle, which reduces the utilization rate of the filter material, reduces the amount of pollution per unit volume of the filter material, and also increases the head loss of the filter layer. Therefore, it is necessary to design a reasonable thickness of filter material.

Based on the model test of multi-stage functional filtration for water restoration, when the thickness of PP cotton, coconut shell activated carbon, quartz sand and pebbles reaches a certain value, the effect of increasing the thickness of filter layer on the removal of filtered water is not very obvious. Meanwhile, considering the nature of sewage, the filtration cycle should not be too long. Based on the above factors, the thickness of PP cotton, coconut shell activated carbon, quartz sand and pebbles are all 0.5m.

5.2. Particle size factor of filter material
In the filtration stage of multi-stage functional filtration for repairing black and odorous water body, the suspended matter intercepted is continuously filled in the pore between the filter materials. In theory, for the same material, the larger the particle size of the filter material, the larger the space that the filter material can intercept suspended matter, and the larger the pollution interception amount of the filter layer. On the other hand, the pores between the filter materials are large, and the fine suspended particles remaining in the sewage are easy to pass through the filter layer, which will eventually affect the quality of the filtered effluent, and the filtered water can not meet the expected requirements. Therefore, choosing the appropriate particle size of filter material can improve the filtration effect to a certain extent.

The pebble filter material grade is used as the primary filtration of the four-stage filter material, and its particle size has a great influence on the filtration performance of the fourth-stage filter. Determining the size of pebbles is a necessary prerequisite for the study of four-stage filtration test. In the filtration stage, for the suspended particles with small particle size in sewage, the whole filter layer of pebbles plays a role of pollution interception at the same time. If the size of the selected pebble is too small, the
large suspended particles will not be able to enter the depth of the filter layer and only accumulate on
the surface of the filter layer, thus forming the surface filtration, which is not conducive to the filtration.
Therefore, increasing the particle size of pebble filter material is helpful to improve the filtration
performance. In this experiment, because pebble filtration belongs to the stage of primary filtration, even
if a small amount of suspended solids are passed through the filter layer, they can be intercepted by
quartz sand in secondary filtration, coconut shell activated carbon in three-stage filtration or PP cotton
in four-stage filtration, which will not have a great impact on the whole filtration. So pebbles with
particle size of 20mm are selected.

The homogeneous quartz sand filter with smaller particle size has smaller porosity and can intercept
suspended matter with smaller particle size. The smaller the particle size of the filter material selected
for the filter, the longer the filtration period, the better the quality of the filtered effluent. Even if there
is a small particle size suspended matter passing through the filter layer, it can be intercepted by coconut
shell activated carbon or PP cotton in the filter column, which will not have a great impact on the whole
filtration. So the quartz sand filter with particle size of 0.25 mm is selected.

Coconut shell activated carbon is made of high quality coconut shell as raw material, through a series
of production processes. Coconut shell activated carbon is black in appearance and granular in shape. It
has the advantages of developed pore, good adsorption performance, high strength, easy regeneration
and economic durability. But because of the origin of coconut shell and other issues, the price is higher
than conventional wood activated carbon.

The results show that both PP cotton filtration mechanism and quartz sand filtration mechanism
involve two processes: migration and adsorption. Because quartz sand filtration has the phenomenon of
surface filtration to a certain extent, while PP cotton is a deep filtration effect, so the amount of PP
cotton interception is larger. PP cotton as the four-stage filter of the four-stage filter is the last
"protection", so choose 1 micron of PP cotton with particle size.

6. Conclusion

1) The effect of four-stage filter material combined with filter column in repairing black odorous water
body is obvious, and the water quality changes from turbid light yellow to transparent clear color.
2) The longer the filtration time, the higher the transparency of the filtered water.
3) The thickness of the filter layer has a great influence on the filtration effect, and the optimum
thickness should be selected in combination with the water quality conditions.
4) To a certain extent, the filter effect can be improved by choosing the appropriate size of filter
material.

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