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Process and development of ozone-biological activated carbon treatment for micro-polluted raw water

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Abstract. The basic principle and process flow of ozone-biological activated carbon treatment of micro-polluted source water were analyzed, and the application of the method at home and abroad was introduced. Some problems that need to be paid attention to when applying the method were put forward. The results show that ozone-activated carbon water purification technology can effectively remove organic matter and ammonia nitrogen in water. It also has good removal effect on inorganic reducing substances, chroma and turbidity in water. Moreover, the mutagenic activity of effluent can be effectively reduced to ensure the safety of drinking water. Some problems which should be attended are prompted when this technique is in application in the paper. It is a water purification technology worth promoting.

1. Introduction

In today's increasingly serious water pollution, the content of toxic and harmful chemical organic pollutants in raw water is increasing year by year, and the number of categories is increasing year by year, which brings great difficulties to the treatment of tap water. At present, most countries in the world, especially the developing countries, basically adopt the conventional treatment process of "coagulation -- precipitation -- sand filtration -- chlorine disinfection" for the purification of drinking water. A large number of literatures show that although the traditional water treatment process of waterworks can make water clear and eliminate water-borne pathogens[1], many toxic and harmful substances produced by modern industry, especially a large number of organic pollutants, cannot be well removed. It has also been found that certain pollutants are related to the incidence of urban residents and pose a threat to human health. Especially after chlorine disinfection, organic compounds with teratogenic and carcinogenic effects have been widely concerned about drinking water safety.

Therefore, the deep purification technology of drinking water for the purpose of removing micro-polluted organic matter in water has also been deeply studied and widely applied. The new drinking water decontamination technology combining ozone and biological activated carbon, namely the ozone-biological activated carbon water purification process, has attracted much attention and attention due to its high efficiency in removing dissolved organic matter and mutants in water, and its safe and high-quality water[2].

2. Ozone-biological activated carbon water purification process and characteristics

2.1. basic process

In 1969, the Bremen water plant in west Germany discovered that the combination of ozone and biological activated carbon treatment could achieve multiple effects. Common process are shown in Figure 1[3] :

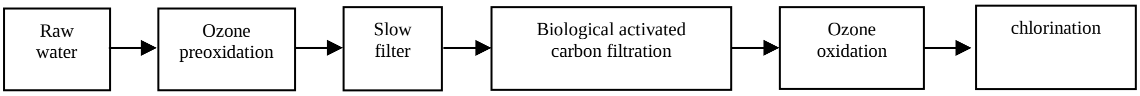

Figure 1. Common process

On the basis of basic process, each water plant can adopt specific process flexibly according to its own conditions. For example, Figure 2 is a process flow chart of a water treatment plant with the addition of ozone-biological activated carbon process[4].

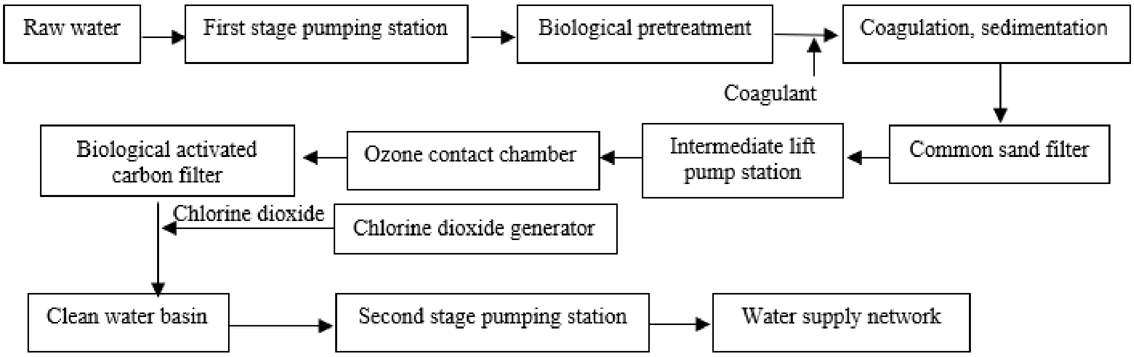

Figure 2. Process diagram of a water treatment plant

2.2. Fundamental

Ozone-biological activated carbon treatment of drinking water combines the chemical oxidation of ozone with the physical and chemical adsorption of activated carbon, biooxidative degradation, and promotes each other, achieving multiple effects [5]. Its practice is to replace the pre-chlorination with pre-ozone oxidation, set up a biological activated carbon filter after the quick filter, and then perform ozone post-oxidation.

Preliminary oxidizes and decomposes organic matter and other reducing substances in water to reduce the organic load of the biological activated carbon filter. At the same time, ozone oxidation can break the chain and open the ring, which is difficult to biodegrade in water, and oxidize the macromolecular organic matter into small molecular organic matter. The biodegradability and adsorbability of organic matter in raw water makes it biodegradable[6].Ozone simultaneously oxidizes manganese and iron dissolved in water to form insoluble oxides, which improves the effect of sand filtration and increases the removal rate of manganese and iron. The oxygen generated by the decomposition of ozone can act as an oxygenation in the treated water, so that biological activated carbon filter has sufficient dissolved oxygen (DO), supplements the DO consumption in the water, creates an environment for aerobic growth, and enables aerobic microbial activity. Enhancement, increases the potential of microbial growth, accelerates biooxidation and nitrification, prolongs the service life of activated carbon, accelerates the biodegradation of organic matter, and thus improves its removal of organic matter [7].

Activated carbon treatment after ozone treatment mainly plays several roles:

- Destroy residual ozone in water.
- Removal of compounds or ozone byproducts by adsorption.
- Biodegradation of substances by bacteria on the surface of activated carbon[8].
- As a porous substance, activated carbon can adsorb substances with low concentration in water and difficult to remove by other methods.
- Nitrifying bacteria attached to activated carbon can also reduce the concentration of ammonia nitrogen in water.

In the post-oxidation process, ozone plays major roles in:

- Ozone is more oxidative than liquid chlorine. It destroys the dehydrogenase on bacteria and interferes with their respiration, thus leading to the death of bacteria.
- Oxidizing organic matter, such as pesticides, detergents, phenols, etc.
- Remove DOC[9].
- Oxidative decomposition chelates, such as EDTA and NTA, etc.
- After the reaction between drinking water and ozone, Ames test showed that no mutagenicity substance is produced.

Due to the unstable chemical properties of ozone, it cannot be retained in water for a long time[10]. In order to ensure that the water quality is not polluted during transportation, chlorine is added in the last step. Since organic pollutants have been basically removed through ozone-biological activated carbon, the final water quality is clean.

3. Typical process flow

3.1. Tongxiang city orchard bridge water plant

At present, Kangxitang, which is the main source of drinking water, belongs to Class IV to V water bodies. The main over-standard items are organic matter and ammonia nitrogen. Since conventional treatment process cannot effectively remove pollutants, biological pretreatment process of raw water and advanced treatment process of ozone-biological activated carbon are determined to be added on the basis of the original conventional treatment in the water plant. The process flow of the rebuilt water plant is shown in Figure 3[11].

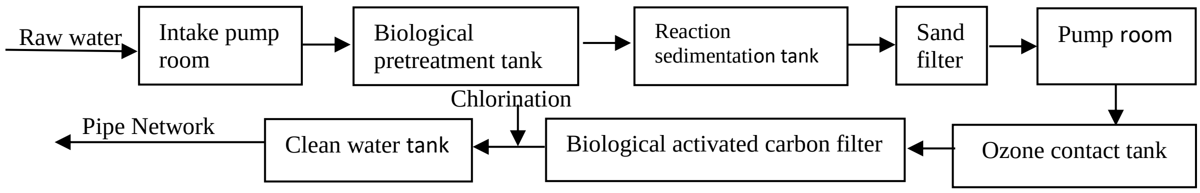

Figure 3. Tongxiang city orchard bridge water plant process flow

3.2. Shanghai Zhoujiadu Water Plant

Zhoujiadu water plant is an old water plant in Shanghai, which has undergone an in-depth treatment and renovation since 1999 and was completed in 2001. After the transformation, the water plant uses huangpu river as raw water with a capacity of 10,000m^3/d. The treatment process is divided into two processes, as shown in figure 4[12].

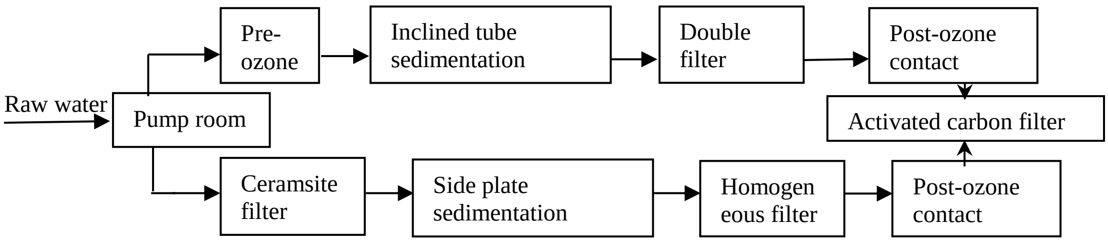

Figure 4. Zhoujiadu water plant process flow

3.3. Sinopec qianguo petrochemical branch water plant

The original drinking water source of the plant is shallow groundwater, which has been depleted due to the continuous exploitation of shallow groundwater, and the pollution has become increasingly serious. In 1994, the plant decided to treat Songhua River water as a source of drinking water. It decided to adopt t13e advanced water treatment process of "ozone oxidation and biological activated carbon adsorption"[13].

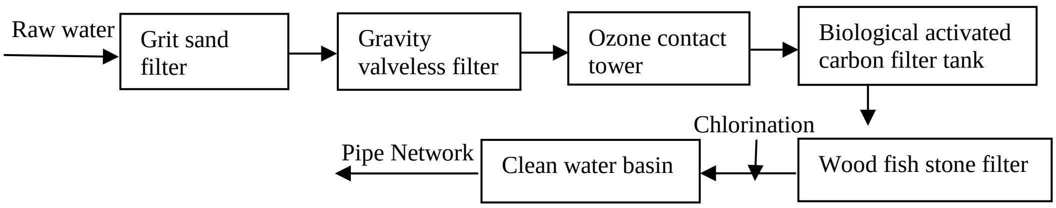

Figure 5. qianguo petrochemical branch water plant process flow

4. Problems to be further studied and solved

- The ozone-biological activated carbon method has higher investment and operation costs. According to the operation experience of changzhou no.2 water plant, the unit water investment of ozone-biological activated carbon is about 200 yuan /m^3/d, and the operation fee is less than 0.2 yuan/m^3. The investment of increasing ozone-activated carbon design (including adding pressurized pump station) in shenzhen water plant is 250-270/m^3/d, and the operation cost is 0.2-0.3 yuan/m^3.
- The problem of calculating the optimal ozone dosage in the system by analytical method needs further study.
- The operation effect of biological activated carbon is affected by various conditions, such as water temperature, pH value and bacteria species, and the effect is unstable. Especially during the suspension of the membrane, the treatment effect is not good because the biofilm is not formed. It is the focus of this process to seek suitable growth conditions for activated carbon and screening of dominant strains.
- It is impossible for the added ozone to completely oxidize the organic matter in the micro-polluted water source into an inorganic substance, but various intermediate products, that is, by-products of ozone treatment, are generated. Most of the by-products of ozone are hydrophilic substances. Foreign research reports have recently pointed out that some by-products are carcinogenic or potentially carcinogenic.
- It is necessary to improve the system model to clarify the relationship among water quality, residence time of ozone and biological activated carbon device, filtration rate, ozone dosage and ozone concentration.

5. Process development

Along with the research and development of ozone biological activated carbon system, new process combinations have also been continuously developed. For example, ozone exhaust is reused to increase the absorption rate of ozone in sewage and the effect of coagulation, reaction and precipitation of sewage. In recent years, European countries such as France have continuously improved their ozone biological activated carbon systems in order to further improve water quality. They built a reservoir near the water intake and let the raw water stay there for 2-3 days. Biological flocculation and biochemical oxidation were used to remove ammonia nitrogen, and heavy metals were removed through precipitation. Then ozone was added in three times before and after the reservoir and in front of the activated carbon filter. After the improvement, the amount of added ozone in the system is less and the effluent quality is better.

6. Conclusion

To sum up, ozone-biological activated carbon water purification technology can effectively remove organic matter and ammonia nitrogen in water, and has a good removal effect on inorganic reducing substances, color and turbidity in water, and can effectively reduce mutation-causing activity of effluent, thus ensuring the safety of drinking water. However, the method is not perfect, so how to perfect the method further needs further study. With the continuous improvement of people's understanding of environmental quality standards and tap water quality, ozone-biological activated carbon process, as a green industrial water treatment technology with excellent water quality, low energy consumption and no pollution, is bound to be more widely developed and applied.

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