# Comparison of the typical traditional and advanced sewage treatment technologies

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**Abstract.** Wastewater treatment process is an important means to promote water circulation and save water resources. This paper selects several typical traditional and advanced sewage treatment processes and analyzes and compares their principles, advantages, disadvantages, and application range. Traditional processes, such as activated sludge and oxidation ditch processes, are widely used worldwide because of their low cost, simple operation and mature process. However, they all have the problems of large footprint, long operation cycles and poor sewage treatment effect. Compared with the advanced process, the scale variability is stronger, the sewage treatment effect is better, and the operation cycle is short. Among them, advanced oxidation processes and membrane bioreactor processes show important potential. They can treat different water quality and better treat refractory organic matter with fewer byproducts. Membrane technology and new materials use semi-diaphragm separation technology, which is more suitable for the treatment of inorganic substances, and the water is fast. However, these advanced processes have the problem of high material cost and energy consumption, which is the primary problem that needs to be solved.

**Keywords:** Sewage treatment technologies, Traditional processes, Comparison.

## 1. Introduction

Water resource is an indispensable material in life and production work. The quantity of water resources in any region is not unlimited. Under the intervention of urbanization and human activities, the structure and process of the natural water cycle are broken. The irrational use of water resources leads to water shortage, water pollution and the degradation of ecosystems. Therefore, sewage treatment is particularly important in the closed-circuit water cycle strategy [1].

At present, the research in the field of sewage treatment is constantly evolving and innovating. Traditional physical, chemical and biological treatment methods continue to improve, and advanced oxidation technologies such as photocatalysis and ozone oxidation are expected to deal with difficult-to-degrade pollutants. Membrane technology has progressed in microfiltration, ultrafiltration, reverse osmosis and other aspects, and resource recovery has become a research focus. At present, the application of traditional and newer processes is uneven around the world, and the understanding of the principles and characteristics of the processes is not clear [2]. Therefore, in this paper, the oxidation ditch process and activated sludge process in the traditional process and advanced oxidation process (AOPs), membrane bioreactor process (MBR) and reverse osmosis process (RO) in the advanced process are selected as examples to introduce their principles, advantages and disadvantages, and summarize and compare. In addition, some suggestions for improving the process are also given.

## 2. Traditional technologies

### 2.1. Activated sludge method

The activated sludge process is widely used in water plants worldwide to treat urban domestic sewage. The main steps in the wastewater treatment process include primary sedimentation tank, aeration tank, secondary sedimentation tank and disinfection treatment (Fig. 1). In the primary sedimentation tank, suspended matter and sediment in the sewage are removed by standing and chemical agents. The aeration tank is the core of the activated sludge process and promotes microbial growth by supplying oxygen, where the sewage is mixed and treated. After flowing through the aeration tank, the sewage enters a secondary sedimentation tank, where the sludge and liquid are separated by gravity. The return system returns part of the sludge to the aeration tank to maintain the microbial concentration. Eventually, the sewage may need to be sterilized to ensure that the effluent meets the standard discharge [3].

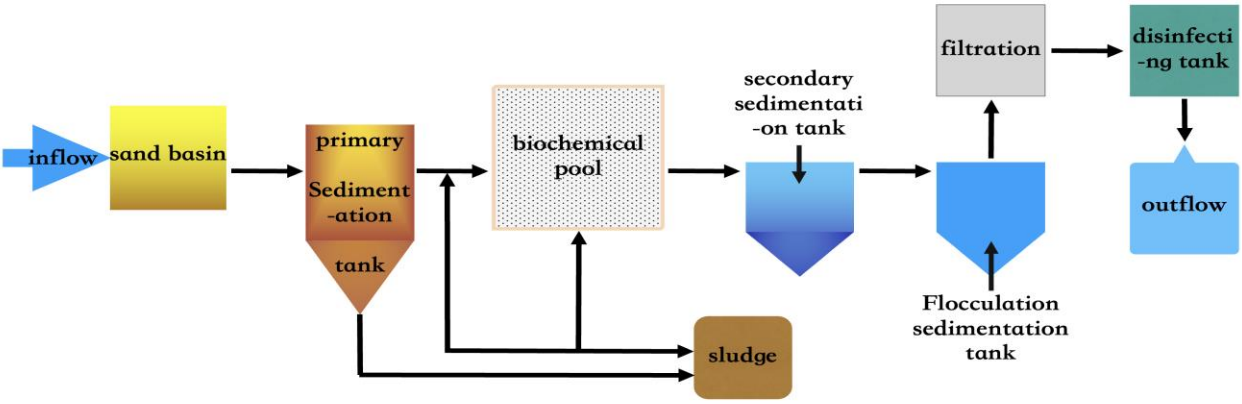


**Figure 1.** Activated sludge process

Although the activated sludge process has wide application and efficient treatment effects in sewage treatment, there are still some shortcomings. For example, the treatment process is complex, the construction and operation cost are relatively high, and the adaptability to water quality and quantity change is poor. It is easy to produce sludge swelling, which may lead to the deterioration of sludge precipitation performance and increased suspended matter content in effluent. Also, the activated sludge method will produce a large amount of residual sludge in purifying sewage, and improper treatment may lead to environmental pollution and increase operating costs. The aeration system is an important part of the activated sludge method, which consumes a lot of energy. Meanwhile, it will produce odor and affect the surrounding environment. In addition, the aeration equipment generates a lot of noise when it is run [4].

## 2.2. Oxidation ditch process

The oxidation ditch process is a common sewage treatment technology used to treat domestic and industrial wastewater in small and medium-sized sewage treatment plants. The main feature of this process is using microorganisms to degrade organic matter into carbon dioxide and water in the presence of oxygen. Oxidation communicates natural oxidation and microbial metabolism to treat wastewater without adding chemicals.

The treatment unit of the oxidation ditch process generally consists of rectangular or circular channels, which are usually long and narrow (Fig. 2). An aeration device is provided at the bottom to supply oxygen into the water body and keep the water body stirred to promote oxygen transfer and microbial degradation of organic materials. The oxidation ditch can be an open concrete channel or a closed pipe. Aeration units often use aerators or sprinkler heads to inject gas into the water to increase dissolved oxygen concentration. In oxidation ditches, wastewater passes through flowing channels, comes into contact with microorganisms and is degraded. Microorganisms gradually degrade organic matter into harmless substances, such as carbon dioxide and water, through adsorption, assimilation and oxidation. At the same time, the plants in the oxidation ditch can absorb nutrients and microorganisms, promoting the degradation of the bottom sediment. The oxidation ditch can strongly remove pollutants such as organic matter, total suspended matter, nitrogen and phosphorus. This process has the advantages of stable treatment effect, simple process and low operating cost [5].

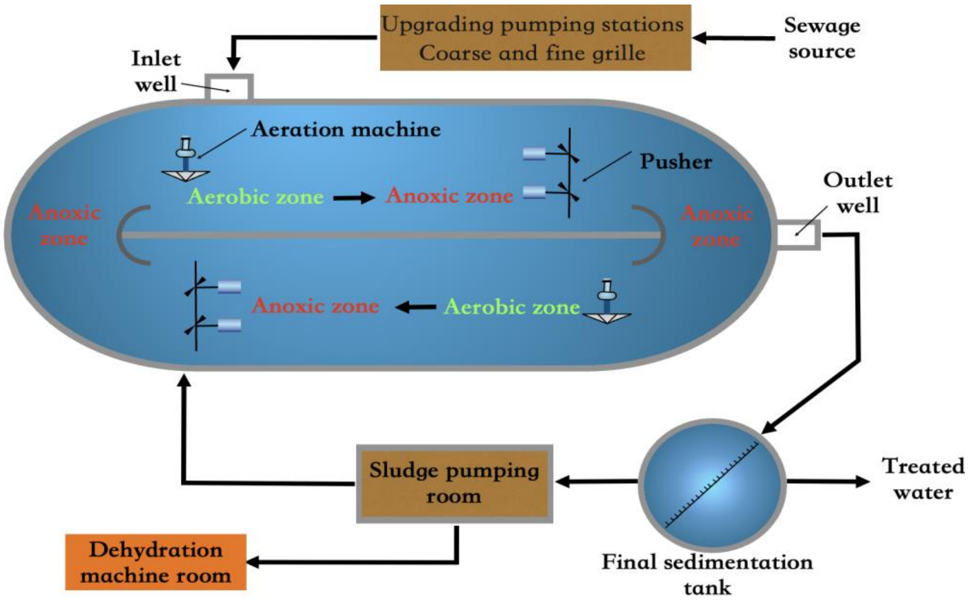


**Figure 2.** Oxidation ditch process

However, due to the need for a large footprint and a long residence time, the oxidation ditch process is usually suitable for treating relatively diluted sewage, and the treatment effect of high-concentration organic matter is low. In addition, oxidation ditches are also susceptible to factors such as temperature, water quality and working conditions, which require reasonable design and management [6].

## 3. Advanced technology

### 3.1. Advanced Oxidation Process

AOPS is an advanced and efficient water treatment technology whose main purpose is to improve water quality and reduce environmental pollution by introducing specific oxidants to break down organic and inorganic pollutants in water into harmless compounds. The process mainly includes key steps such as pre-treatment, oxidizer addition, reaction chamber treatment, advanced oxidation process, product treatment, and monitoring and analysis (Fig. 3).

First, the wastewater goes through preliminary pre-treatment, such as precipitation and filtration, to remove most of the solid particles and suspended solids to reduce the interference of subsequent treatment. Next, appropriate oxidizing agents are added to the wastewater, which can initiate oxidation reactions and produce highly active oxidizing substances. The mixed wastewater goes to a specialized reaction chamber with the oxidizer, where the advanced oxidation process takes place. The oxidizer reacts with the pollutants to produce reactive oxygen species and free radicals, which are highly reactive substances capable of rapidly degrading organic and inorganic pollutants, converting them into simpler molecules such as water and carbon dioxide. Subsequent steps involve precipitating or filtering the resulting solid product to facilitate further solid-liquid separation. At the same time, the pH of the reaction solution needs to be adjusted to ensure advanced oxidation in a suitable acid-base environment. The whole process needs to be closely monitored and analyzed to ensure the control of reaction conditions and the treatment effect of wastewater [7].

The advanced oxidation process has many advantages. First, it can quickly and efficiently decompose and degrade organic and inorganic pollutants in water, including organic compounds that are difficult to treat, so that pollutants in wastewater can be removed entirely, thus significantly improving water quality. Secondly, the advanced oxidation process produces highly active oxidants and free radicals in the chemical reaction, which can quickly and thoroughly decompose pollutants into simple and harmless products, reducing the risk of secondary pollution. In addition, this technology does not need to add many chemical agents, avoiding the by-products and chemical residues produced in the traditional treatment methods, which helps reduce the impact on the environment. Finally, the advanced oxidation process also has certain treatment capabilities for organic matter and micro-pollutants that are difficult to degrade, giving it an advantage when dealing with complex wastewater treatment problems.

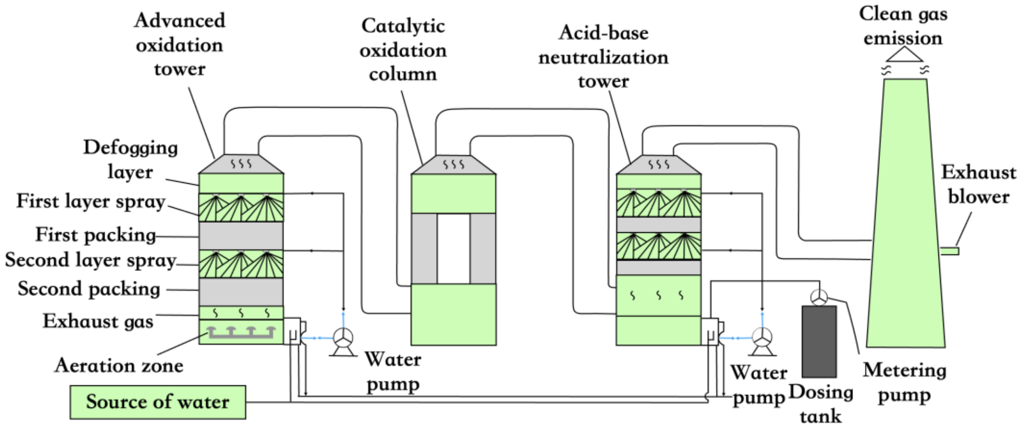


**Figure 3.** Advanced oxidation process

However, there are some limitations and challenges in the advanced oxidation process. First, implementing the technology requires a certain investment cost, such as equipment, oxidants and energy. Secondly, the operating conditions of the advanced oxidation process and the selection of oxidants need to be carefully controlled to ensure the best reaction effect [8].

### 3.2. Membrane Bioreactor Process

MBR is an advanced wastewater treatment process integrating bioreactor and membrane separation technology. It combines the advantages of traditional biological treatment and membrane separation to efficiently remove pollutants from water bodies, especially suspended matter, organic matter and microorganisms.

The process includes two key parts: bioreactor and microporous membrane (Fig. 4). First, after primary pre-treatment to remove larger particles, the wastewater enters the bioreactor, where microorganisms degrade organic matter and pollutants. A bioreactor is typically an activated sludge system that contains a range of microorganisms capable of degrading organic matter and pollutants such as nitrogen and phosphorus. A bioreactor provides a suitable environment where microorganisms can metabolize and grow [9]. The key feature of the membrane bioreactor is using a microporous membrane within the bioreactor to separate water from the activated sludge mixture. These microporous membranes have a small enough pore size to effectively block the passage of microorganisms such as suspended solids, bacteria and most viruses, but can allow water molecules to pass through, thus enabling the separation and filtration of sewage [10]. Usually, in order to maintain the microbial concentration and activity in the bioreactor, a portion of the activated sludge filtered through the microporous membrane is returned to the bioreactor. This helps to maintain the efficiency and stability of wastewater treatment [11].

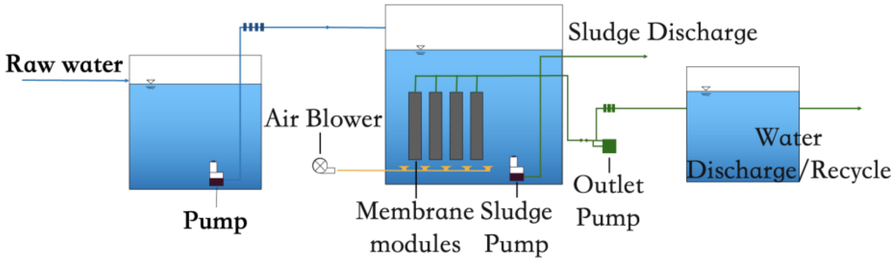


**Figure 4.** Membrane bioreactor

Membrane bioreactor has many advantages. MBR can use different types of membrane, such as hollow fiber and flat membrane, to adapt to different application needs. MBR can effectively filter microorganisms, suspended matter and organic matter to produce very high-quality water, which is suitable for applications with strict water quality requirements, such as drinking water and industrial reuse water. Compared to traditional activated sludge processes, MBR does not require a sedimentation tank and, therefore has a smaller footprint. This makes MBR more viable in limited space, such as inside cities. In addition, the MBR can adapt to changes in different flows and water quality, giving it greater flexibility. This makes it more advantageous when dealing with seasonal changes and unexpected events.

There are obvious drawbacks to MBR. The use of membrane in MBR requires a certain amount of energy, including pumping and membrane cleaning, so compared with traditional processes, MBR has a high energy consumption. The membrane is prone to biological contamination and the accumulation of membrane pollutants, which affects the flux and performance of the membrane. And in the process of membrane cleaning and maintenance, chemicals may need to be used, and the cost of regular cleaning and maintenance is relatively high [12]. Due to the need for membrane modules, system design and automation equipment, the initial investment of MBR is large, which may have an impact on some projects with limited budgets [13].

To sum up, the membrane bioreactor has the advantages of high-quality effluent, space-saving and strong adaptability. However, it also needs to face challenges such as high energy consumption, membrane pollution and sizeable initial investment. When choosing whether to adopt MBR process, it is necessary to consider the demand, feasibility and economy of the project comprehensively.

### 3.3. Reverse osmosis Process

RO technology is an efficient separation and concentration method in wastewater treatment, separating solutes and impurities from water through a semi-permeable membrane.

The entire process includes key steps such as pre-treatment, ultrafiltration treatment, reverse osmosis membrane separation, concentration and concentrated water treatment, production water recovery, and membrane maintenance and cleaning (Fig. 5). First, large particles of impurities are removed by pre-treatment, followed by ultrafiltration to remove bacteria and colloids, etc. Next, the sewage is fed into a reverse osmosis membrane system where, under high pressure, only water molecules can pass through the tiny pores, while solutes and impurities are trapped on one side of the membrane. This creates a concentrated solution that requires further processing. Eventually, the purified produced water is separated by reverse osmosis and can be used for industrial, drinking or other purposes. Regular membrane maintenance and cleaning are essential to ensure the long-term efficient operation of the system.

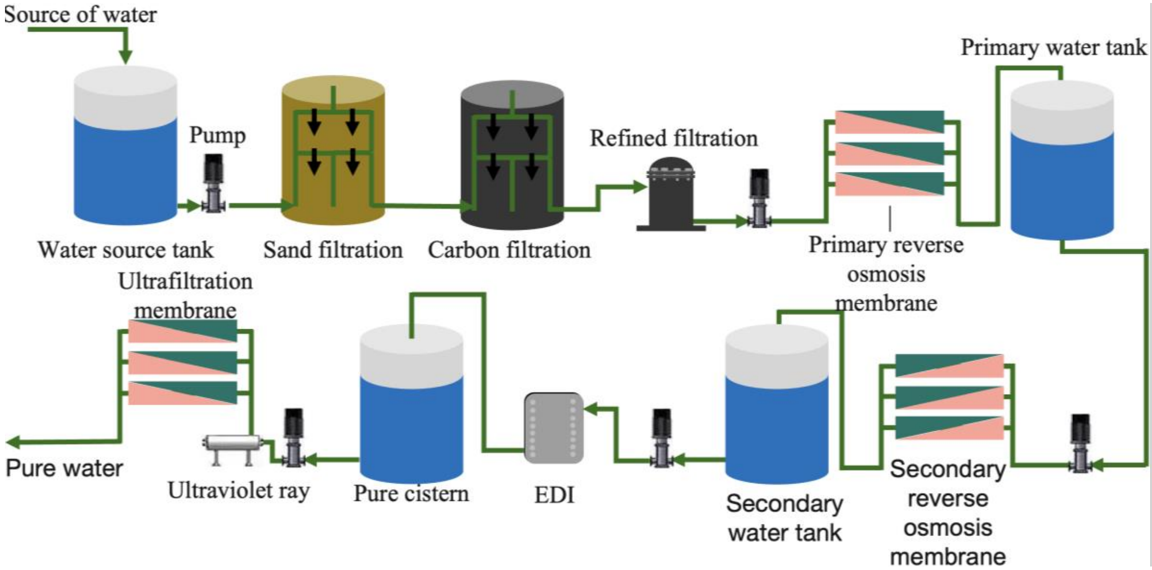


**Figure 5.** Flowing chart of reverse osmosis pure water equipment

Reverse osmosis technology has many advantages and some limitations in wastewater treatment. Reverse osmosis technology can efficiently remove dissolved ions, organic matter, microorganisms, colloids and other pollutants in water, resulting in high-quality water production. At the same time, the tiny pores of the reverse osmosis membrane can effectively intercept most solutes and impurities, so the quality of the water produced is usually very high. Reverse osmosis technology can realize the recovery and reuse of sewage resources, reduce the demand for freshwater, and help alleviate the problem of water shortage. The reverse osmosis system can be expanded and customized according to the required requirements, adapt to different scales of water quality requirements and applications, and be competent from small household systems to large industrial treatment facilities.

However, reverse osmosis technology requires high pressure to overcome osmotic pressure, which consumes a lot of energy and increases operating costs. At the same time, the reverse osmosis membrane is prone to pollution, and the dirt and bacteria attached to the surface of the membrane will affect the quality and efficiency of water production, which requires regular maintenance [14].

## 4. Discussion

By comparing the principles, advantages and disadvantages of traditional and advanced processes, the traditional process has low cost but occupies a large area and the filtration effect is biased. The advanced process has stronger scale variability, good filtration effect, high quality of produced water and short operation cycle. Among them, membrane technology and new materials are more suitable for treating inorganic substances, and advanced oxidation and membrane bioreactor processes play a key role in the treatment of difficult-to-degrade organic matter. However, these advanced processes all have the problem of high material cost and energy consumption (Table 1). Therefore, the consumption and recovery of energy and resources will become the key to the wide application of advanced processes [15].

**Table 1.** Comparison of traditional and advanced processes

| | Applicable water quality range | Water production quality | Energy consumption | Operation and maintenance | Applicable scene | Cost consideration |
|---|---|---|---|---|---|---|
| Activated sludge process | High organic content | Basic emission standard | Low | Stable | Urban size | The second-lowest |
| Oxidation ditch process | Moderate organic content | Basic emission standard | Low | Simple | Rural scale | The lowest |
| Advanced oxidation process | Refractory organics | Drinking water or industrial water | High | Complicated | About a thousand people in size | The second-highest |
| Bio-membrane reactor | Biodegradable organic | Drinking water or industrial water | High | Sensitive | Tens of thousands of people | The third-highest |
| Reverse osmosis process | Inorganic dissolved substances | High purity water | Very high | Complicated | About a thousand people in size | The highest |

## 5. Conclusion

This paper states the principles, advantages and disadvantages of traditional and advanced processes and compares the characteristics of each process:

Traditional processes such as activated sludge and oxidation ditch processes have been widely used worldwide. Activated sludge process can effectively remove suspended matter and organic matter in sewage through the steps of primary sedimentation, aeration and secondary sedimentation. However, there are problems such as complicated process, high cost and sludge treatment. The oxidation ditch process relies on microorganisms to decompress organic matter in the presence of oxygen, and its simplicity and low operating cost have been applied in small and medium-sized treatment plants. However, the treatment capacity of high-concentration sewage is limited and greatly affected by external factors.

Advanced oxidation and membrane bioreactor processes show important potential among the advanced processes. Advanced oxidation processes decompose organic and inorganic pollutants with oxidants, which has the advantage of efficient degradation and reduced byproducts. Membrane bioreactor and membrane separation fusion, through the microporous membrane efficient removal of pollutants, high quality water production, strong adaptability. However, the advanced oxidation process requires attention to energy consumption and operational control, and the membrane bioreactor needs to be carefully handled in terms of maintenance and cleaning. In the promotion of advanced processes, energy and resource recovery is an urgent problem to be solved.

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