Application of Marine Algae in Water Pollution Control

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Abstract. Water pollution is mainly caused by chemical pollution, especially inorganic and organic pollutants, including toxic metals and metalloids as well as various synthetic or organic chemicals. Marine algae have good adsorption capacity for heavy metals such as As, Zn, Cu, Cd, Pb et.al in polluted water, and can also have certain removal ability for pollutants such as nitrogen and phosphorus in sewage. This paper reviews the current application status of wastewater treatment and the mechanism and application of marine algae in wastewater treatment, aiming at providing reference for further research and development of marine algae in wastewater treatment.

1. Introduction

With the global fast development of industrialization in the 20th century, the rapid growth of social productivity at the same time brings a series of environmental pollution problems, including water pollution is one of the prominent problems, water quality is the main problems facing the 21st century, human water environment pollution caused to a third of the population in the world did not have enough safe drinking water, agricultural production is affected, in addition, the water pollution as a direct result of Marine plants and animals in vivo accumulation of toxic chemicals and disease and even death, causing great economic losses(Schwarzenbach et al. 2010). Marine ecosystem, with Marine organisms as the main body, plays an important role in maintaining the circulation of natural materials, purifying air and mitigating the greenhouse effect. The stability of Marine ecosystem is closely related to the realization of sustainable development Worldwide in recent years, however, with the development of Marine economy, increasingly intensified the development and utilization activities and urban sewage discharge has the unprecedented damage to the Marine ecosystem, inshore waters Bay pollution increased year by year, oxygen, phosphorus significantly overweight Eutrophication and so on, problems emerge in endlessly, Marine conservation and restoration are imperative(Hader et al. 2020). In addition to reducing the chemical oxygen demand (COD) and heavy metal ions of organic pollutants in the water, the biological treatment method can meet these requirements to ensure that the added substances can exist normally and have no negative impact on the original ecological structure and diversity of the water. In the current recycling of resources and energy, waste water is more than just waste. Rational use of substances contained in waste water can become the source of energy, renewable and non-renewable energy. For organic pollutants in waste water, we should not only remove them, but also upgrade them through biotechnology(Su 2021). As a primary producer in the ocean, Marine algae are widely distributed in the ocean. The organic matter
and accumulated energy created by them are the basis for the survival and development of the entire Marine biological community, and they are also one of the first to be affected by these pollution and produce the corresponding response. Through its own growth and metabolism, it can absorb a lot of nutrients such as nitrogen and phosphorus in water. Marine algae containing a lot of polysaccharides and proteins can use specific functional groups of polysaccharides and proteins to complexate, enrich different types of heavy metals or absorb organic pollutants that are difficult to degrade. In addition, higher class algae can spontaneously inhibit the growth of lower class algae and control the eutrophication of seawater, so Marine algae have great potential in sewage treatment. In this paper, the current situation of water environmental pollution, the research on the application of Marine algae in wastewater treatment in recent years and the purification mechanism of algae for nutrients and metal elements in water are summarized, the development trend of Marine algae in wastewater treatment is prospected.

2. Current situation of water environment pollution and wastewater treatment technology

2.1 Current situation of water pollution

The main pollution of water environment is chemical pollution, especially inorganic and organic pollutants. Persistent organic pollutants have even affected more than five water systems worldwide for several decades. During this period, geological pollutants, mining operations and hazardous waste sites have been the main pollutants (Schwarzenbach et al. 2010).

For a long time, due to the discharge of industrial wastewater, human sewage, household garbage, as well as a series of oil spills and other events, Marine pollution, especially near the coast pollution is very serious.

For example, China's coastal waters are seriously eutrophicated, and sudden environmental pollution accidents such as oil spills and chemical leaks are frequent. Sea for a long time by some substances such as organic compounds and heavy metal pollution, As heavy metals in sea water, the elements such as zinc, Cu, Cd, Pb content, nitrogen and phosphorus pollutants such as seawater eutrophication, destroy the Marine ecological balance, directly or indirectly lead to Marine animals, a large number of death, illness, and even extinction; In the oil-polluted ocean, a membrane appears on the surface of the ocean to block the contact between the ocean and the air, making the oxygen content of the sea within a certain range greatly reduced, resulting in the death of a large number of Marine organisms (Wang et al. 2020). In addition to the above chemical pollution, white pollution - microplastic (diameter of plastic products < 5mm), in recent years has become an "intruder" of Marine environmental pollution, and it has been reported that since 2004, the ocean, fresh water, waste water, soil and mangroves and other places of accumulation has increased year by year and the problem of plastic debris caused by it has become a global problem more relevant research points out and It can be driven by the wind and circulate in the ocean surface for a long time (Deng et al. 2021; Schuyler et al. 2016).

2.2 Existing wastewater treatment biotechnology and its mechanism

Recently, the methods of treating sewage mainly include physical methods such as flocculation, flotation, membrane filtration, reverse osmosis, ion exchange and electrochemical treatment (Pavithra et al. 2020; Karimi-Maleh et al. 2019). Chemical precipitation and chemisorption and Biotechnological processes, such as activated sludge process, solvent extraction, and biosorption, which are considered to be the most ideal to help restore water ecosystem and establish ecological balance without secondary pollution, which are considered to be the most ideal (Janet et al. 2020). Since 1989, the innovative application of biotechnology to deal with the "waal diss" tanker spill caused by large area of oceanic oil pollution incidents, both at home and abroad for the use of biotechnology management become a hot spot of research and application of water pollution to a certain extent, promote the development of biotechnology, with the development of biotechnology in recent years, biotechnology is widely used in sewage disposal. And bioremediation technology is eco-friendly, cost-effective and natural. It aims at removing heavy metals, radionuclides, biological compounds, organic wastes, pesticides and so on from contaminated sites(Singh and Tripathi 2007). In
recent years, biofuel production and biological denitrification biological technology is regarded as an important technology of the sewage factory will pollution-free processing sewage recycle treatment, including biological denitrification technology is mainly through nitrification and denitrification, nitrification is through the nitrification agent is added to water to water in total into nitrate, ammonia nitrate as raw materials for the denitrification of generally by facultative aerobic microbes such as pseudomonas alkaline unusual bacterium bacillus under hypoxia conditions. Figure 1. The process of biological denitrification, nitrification and denitrification.

Microbial flocculant is a kind of polymer organic matter produced by microorganisms in the process of metabolism. It has certain colloid properties and flocculating ability. Microbial flocculants, as natural biogenic flocculants, have the advantages of non-toxicity and biodegradability. Microbial flocculants have been considered by many scholars at home and abroad as potential substitutes for traditional chemical flocculants (Zhang et al. 2020). Membrane bioreactor (MBR) is developed on the basis of activated sludge process (ASP). It is a traditional urban sewage treatment technology in the last century. It is one of the most important innovative technologies in wastewater treatment. It has the advantages of small footprint, low civil construction cost, higher effluent quality, higher volumetric loading rate, longer solid retention time, shorter hydraulic retention time and lower sludge yield compared to previous biotech. At present, this technology is widely used in sewage treatment. At present, the main disadvantages that hinder the wider application of membrane bioreactors are membrane fouling caused by suspended particles (microbial and cell debris), colloids, solutes and sludge flocs, which significantly reduce membrane performance and life, leading to significant increase in maintenance and operating costs (Iorhemen, Hamza, and Tay 2016; Meng et al. 2009).

3. Application of marine algae in wastewater treatment
Physical and chemical methods for the treatment of heavy metal polluted water bodies, although the purification efficiency is high, but generally for high technical requirements and cumbersome operation cost. A more environmentally efficient alternative is the target of research. Among them, Marine algae, a very rich resources, as the primary producers of the ocean in the sea water in large numbers, including macroalgae and Marine microalgae. Compared with other bioremediation methods, Marine algae have strong adsorption, high enrichment ability and high removal efficiency for heavy metals. At present, algae is mainly used in water pollution treatment to adsorbate heavy metals and regulate water eutrophication.

3.1 Marine algae adsorb heavy metals from sewage
3.1.1 Principles of marine algae adsorption of heavy metals in sewage

The algal cells used to adsorb heavy metal ions can be in active or inactive states. The adsorption process of cells in active states can also be called the bioaccumulation process (Kai et al. 2013). After many years of metal ions on algae absorb research found that the algae mainly through biological adsorption and biological accumulation of two kinds of effects of metal ions absorption, is a biological adsorption without consuming energy and is rapid and selective, metal ions, the combination of passive on the cell surface, it is because of this feature, that inactive algae cell also has the ability of adsorption of metal ions; The bioaccumulation reaction is a process in which metal ions are directly absorbed into algal cells and the mechanism behind the reaction is defensive. In order to avoid poisoning, algal cells absorb metal ions and accumulate metal ions in cells by secreting metallothionein (Jahan 2004). Figure 2 The absorption of heavy metals by algal cells.

![Figure 2](image_url)

**Figure 2** The forms of heavy metal ions absorbed by algae cells

3.1.1.1.1 Adsorption principle of active algae to heavy metals

3.1.1.1.1 Binding of heavy metals to the cell walls and surfaces of algae

Algae cell wall can be roughly divided into two layers, the outer layer is mainly composed of cellulose, pectin, ammonium alginate, rock polysaccharide and other multilayer microfibrils with porous structure, the main component of the inner layer is cellulose, has a large surface area. Extracellular products such as polypeptides and polysaccharides in the outer wall of algae cells make algae cells have a large number of functional groups (such as phosphate group, hydroxyl group, aldehyde group, sulfur group, amino group, carboxyl group, carbonyl group, etc.) that can combine with metal ions (Demey, Vincent, and Guibal 2018; Shahid et al. 2020). Some functional groups can be negatively charged by losing protons and rely on electrostatic attraction to adsorb metal ions. Some functional groups themselves with lone pair electrons can form coordination bonds with metal ions and complexation. A series of functional groups arranged on the cell wall of algae complexed with heavy metals to form organometallic compounds, which well bound toxic heavy metal ions, and then enriched heavy metal ions on the cell wall, thus reducing the concentration of metal ions in water.

3.1.1.1.2 Intracellular metal-binding proteins (or polypeptides) from algae

Active algae absorb metal ions through active transport and free diffusion. Some active algae not only have the ability to repair high concentration heavy metal wastewater, but also can survive in sewage environment continuously. This shows that these algae to enter the intracellular metal ions with certain resistance and adaptation mechanism, which is mainly plant complexation of algae cell (PCs) and metallothionein (MTs), glutathione (GSH) and other macromolecular substances with heavy metal ions into the cell complex to reduce its influence on the metabolism of cells which have the effect of adaptive survival. (Li, Watson, et al. 2020; Kai et al. 2013).

3.1.1.1.3 Other adaptation mechanisms of algae to heavy metals

In the process of enrichment of heavy...
metals in active algae, the complexation of polyphosphates in algae cells to heavy metals, polyphosphates (PPB) is the polymer of orthophosphate, which contains a large number of metal cations such as K\(^+\), Na\(^+\), Ca\(^{2+}\). Many studies have shown that polyphosphate is one of the binding sites of heavy metals, which not only has the function of storing phosphorus, but also has detoxification effect on heavy metals, and can enrich a variety of heavy metals. Singh A L (Singh et al. 2010) et al. pointed out that polyphosphates are the main enrichment reservoir of Ni ions in the experiments on nickel absorption and localization of cyanobacteria. In addition, under stress, algae accumulate proline inside their cells, Proline plays a certain role in the resistance of algae to heavy metal stress, which improves the tolerance and detoxification ability of the cells to heavy metals. The synergistic effect of heat shock proteins may play an important role in scavenging denatured heavy metal proteins, maintaining normal metabolism of cells and improving heavy metal resistance of cells.

3.1.1.2 Mechanism of adsorption of heavy metals by inactive seaweed After many years of metal ions on algae absorb research found that the adsorption effect of algae cells is not only the main way of accumulation of heavy metal ions or algae cells a without consuming energy and is rapid and selective, metal ions, the combination of passive on the cell surface, it is because of this feature is not active algae cell also has the ability of adsorption of metal ions. Inactive algae adsorb heavy metal ions mainly through ion exchange mechanism, complexation mechanism, REDOX and microprecipitation (Kai et al. 2013).

3.1.1.3 Detoxification mechanism of heavy metals in marine algae Algae develops a series of adaptive mechanisms in response to long-term heavy metal stress. Structure and characteristics of algae cells is the basis of its from heavy metal poisoning, such as the outside effect of algae cell walls of macromolecules with many functional groups can be combined with heavy metal ions, through the formation of organic - shackled by metal compounds and metal ions to prevent the amount into the cells, so as to achieve the algae by controlling the heavy metal absorption and accumulation, transshipment and detoxification, make different cell components to maintain the normal concentration of heavy metals in the rang.

The internal protective mechanism of algal cells mainly includes: the algal cells can synthesize metal binding proteins or polypeptides under the induction of heavy metals; Heavy metals induce algal cells to synthesize some metabolites to protect them from damage or repair the damage caused by heavy metal stress. Algae cells can keep heavy metals away from metabolism through vacuolar compartmentation. Rejection and expulsion of heavy metals by algal cells at a certain amount of adsorption(Moenne et al. 2020).

3.1.2 Adsorption of heavy metals from sewage by marine algae

3.1.2.1 Effects of different marine algae on the adsorption of heavy metals in sewage Previous studies on the biosorption of heavy metals by Marine algae have particularly pointed out the remarkable adsorption effect of algae. In 1999, Yang & Volesky studied the adsorption capacity of heavy metals by brown algae and found that the adsorption capacity was quite high. Experimental data showed that the adsorption capacity ranged from 0.39 to 1.66mmol/g, and the order of heavy metal uptake by brown algae was Pb\(^{2+}\) >Cu\(^{2+}\)(Ni\(^{+}\))>Cd\(^{2+}\)>Zn\(^{2+}\).

In 2009, Mata et al. successfully removed uranium UO2 (II) with brown algae, and the research data showed that its maximum adsorption capacity was above 1.59mmol/g. In addition, the biosorption of Pb, Cu, Cd, Zn and Cr by green algae and red algae has been studied. Results Both chromogenic algae can remove heavy metal ions from aqueous solution, but their performance is much lower than that of brown algae, but the specific reasons are not clear(Yang and Volesky 1999; He and Chen 2014). Among Marine algae, diatoms have become the dominant population of Marine algae, accounting for about 45% of Marine primary productivity, due to their superior CO2 enrichment mechanism and larger specific surface area of their own storage vesicles, which enable them to obtain nutrients for growth and reproduction in more extreme water environments (Marella, Saxena, and Tiwari 2020; Armbrust 2009; Slocombe 2016). Diatoms with high tolerance to heavy metals and significant
adsorption effect have been determined by studies in the past decade as follows: *Aulacosera granulate* (Li et al. 2011), *Nitzschia palea*; *Ulnaria ulna* (Luis et al. 2011; Roubeix et al. 2012), *Planothidium frequentissimum* (Arini et al. 2013), *Nitzschia palea*, *Cymbellales*, *Naviculales*, *Bacillariales* (Larras et al. 2014; Chen et al. 2014), *Nitzschia*; *Pinnularia*; *Ulnaria ulna* (Pandey and Bergey 2016), *Gomphonema pseudoaugur* (Gautam et al. 2017; Loix et al. 2018), *Nitzschia closterium*; *Nitzschia pelliculosa* (Loix et al. 2018; Ma et al. 2018).

### 3.1.2.2 Adsorption of heavy metals by inactive marine algae

Compared with most active seaweed, inactive seaweed adsorption of heavy metal ions has the advantages of wide applicability, adsorption effect and capacity is less affected by the surrounding environment, low cost, faster adsorption speed, and repeatability. In addition, it is easy for people to use chemical and physical means to optimize treatment to enhance the adsorption capacity. Wang Jingfeng et al. made the three kinds of Marine diatoms (Angle trichodesmium, diamond algae, sea chain algae) as the research object, through the processing of dry powder after exploring the effect of adsorption of heavy metal cadmium ion in water results show that the Angle of trichodesmium, diamond chain of algae and sea alga maximum experimental adsorption capacity were 275.25, 303.75, and 224.36 mg/g, significantly higher than that reported various biological adsorption dose. The experimental results of Sandau E(E. et al. 1996) also proved that the by-products of Marine ferns, even the heavy metal organisms with higher cost efficiency, could reduce the concentration of iron by 98% and copper by 99% within 50 min. Table 1 The average adsorption capacity of inactive algae for several common heavy metal ions.

| Heavy metal | Mean adsorption capacity/ ( mmol·g⁻¹ ) |
|-------------|--------------------------------------|
|             | Brown algae | Red algae | Green algae | Average |
| Cd          | 0.930        | 0.260     | 0.598       | 0.812   |
| Ni          | 0.865        | 0.272     | 0.515       | 0.734   |
| Zn          | 0.676        | —         | 0.370       | 0.213   |
| Cu          | 1.017        | —         | 0.504       | 0.909   |
| Pb          | 1.239        | 0.651     | 0.813       | 1.127   |

### 3.1.3 Factors influencing the adsorption of heavy metals from sewage by marine algae

#### 3.1.3.1 PH
Surface charge studies have shown that the availability of free sites depends on pH. With the increase of pH value, the amount of negative charge and negative electrode sites on the surface of algae cells increased, and the absorption of metal ions was enhanced. Therefore, when the water sample was at high pH value, the metal removal rate increased. The higher the pH value in a certain range, the higher the adsorption rate of algae to heavy metals will also be (Jin-Fen et al. 2000).

#### 3.1.3.2 Ionic strength
In addition, ionic strength also plays an important role in the adsorption of metal ions. It is generally believed that the ionic strength is negatively correlated with the removal of metal ions in the solution by algae cells. For example, in 1997, Chen J (Chen, Tendeyong, and Yiacoumi 1997) et al. studied the equilibrium and kinetic experiments of Cu²⁺ adsorption by sodium alginate microspheres and used sodium perchlorate at 0.005, 0.05 and 0.5 mol/L to adjust the ionic strength in the solution. The results showed that when the ionic strength decreased from 0.5 mol/L to 0.005 mol/L, the removal rate of Cu²⁺ in the solution by sodium alginate increased from 80% to 95%. And the result shows that metal ions compete with other ions in the solution in the adsorption process, and the number of functional groups is fixed at a certain pH value, so the stronger the ionic strength of...
the solution is, the lower the adsorption rate of metal ions will be.

3.1.3.3 Adsorption time and temperature In the experiment of Wang Jingfeng (Jingfeng et al. 2017) et al. the results showed that the adsorption of Cd\(^{2+}\) by the three diatoms accorded with the Pseudo second-order kinetic model, that is, the adsorption can be roughly divided into two stages: (1) the first stage: the adsorption reaction speed is fast and the adsorption amount increases rapidly; (2) The second stage: the reaction speed is slow, the adsorption capacity increases slowly, until the adsorption equilibrium is reached. The adsorption equilibrium time of each diatom adsorbent for Cd\(^{2+}\) was prolonged with the increase of the initial Cd\(^{2+}\) concentration. The experimental results of adsorption isotherm are in good agreement with Langmuir isotherm adsorption model. In a certain temperature range, the increase of temperature is conducive to the adsorption reaction, which is endothermic reaction. With the increase of temperature, the adsorption sites on the surface of diatoms gradually reached saturation, and the space for increasing the adsorption amount decreased.

3.1.3.4 Seasonal effect Malea P et al. (Malea, Chatziapostolou, and Kevrekidis 2015) by the gulf of thessaloniki, YiGenHai acquisition of algae in the form of different functional groups (Ulva intestinalis, Ulva rigida and Codium fragile, Gracilaria gracilis). As the research object, determination and comparison of the algae cells As, Ba, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Se, Sr, U, V, and zinc, etc. and the distribution of elements in different seasons. By using single factor and multiple factor to analyze the data, it was found that the metal content in different algae cells was generally low in spring and summer, which was speculated to be caused by the effect of algae growth. However, most of the metal ions in the Ulva Intestinalis group (Cd, Co, Cr, Cu, Mo, Ni, Pb, and Sr) are scarcely affected by the season, and the experimental data show that the contents of Cd, Co, Cr, Cu, Mo, Ni, Pb, and Sr in the large, rapidly growing sheet algae scarcely change with the season.

3.2 Marine algae remove nitrogen and phosphorus and regulate water eutrophication Domestic sewage and industrial wastewater contain a large number of plant nutrients such as nitrogen and phosphorus. Organic materials are decomposed into nutrients that can be used by organic matter in water under the action of microbial decomposition, which leads to the accumulation of organic matter in water and the decline of dissolved oxygen in water, resulting in the destruction of aquatic ecological balance. Eutrophication itself is a process of spontaneous evolution of water bodies, and human factors greatly accelerate the extinction process of water bodies. Generally, there are four basic conditions for eutrophication of water bodies, as shown in Figure 3.

![Figure 3 Four basic conditions of water eutrophication](image)

N and P are essential elements for the growth and reproduction of organisms, and also the main nutrient elements for eutrophication of water bodies. Fe and Si elements are important factors in the nutrient nitrogen cycle, which affect the nitrogen content in water. Appropriate temperature, light and
dissolved oxygen are the prerequisites for plankton growth. The slow flow pattern enriches nutrient elements.

3.2.1 Principle and application of removing nitrogen and phosphorus from water by algae

Marine algae, as a producer in the ocean, are diverse and rich in resources, including macroalgae and Marine microalgae. Np element is needed for the growth of algae. Algae can associate the nitrogen and phosphorus elements absorbed from sewage to the carbon skeleton through photosynthesis. In order to get rapid proliferation, a large number of N nutrients are needed as raw materials to form various complex organic compounds in algae cells. The growth and proliferation effect of algae promotes the absorption and recycling of nitrogen and phosphorus elements by algal cells, thus reducing the content of N and P elements in the water body and achieving the effect of water antieutrophication (Tongyu 2014). The approximate molecular formula of protoplast of algae is $C_{106}H_{263}O_{110}N_{16}P$. During the growth process, CO$_2$ in the environment is used as carbon source, and chemical forms such as nitrogen and phosphorus are absorbed and photosynthesized through chlorophyll in algae cells to produce organic substances needed for growth and reproduction, and oxygen is released during the process. The growth reaction formula of algae is

$$106CO_2 + 16NO_3^- + HPO_4^{2-} + 122H_2O + 18H^+ \xrightarrow{\text{sunrise}} C_{106}H_{263}O_{110}N_{16}P + 138O_2$$

Gomez (Montingelli, Tedesco, and Olabi 2015) et al. studied the treatment of artificial sewage by obile-growing gate algae in the outdoor culture system and found that there were significant seasonal differences in the removal of N and P elements in the water by microalgae. In winter, the removal rate of dissolved nitrogen and phosphorus by microalgae was 47% and 45%, respectively. In the summer, they reach 79% and 73%.

3.3 Application of macroalgae to inhibit the growth of red tide algae

However, when a single algae is put into the treatment wastewater, the excessive reproduction of microalgae will cause water bloom, which is one of the signs of water eutrophication and also the key points that should be paid attention to in the treatment process.

As an important biological regulator, macroalgae has been widely used in the control of water eutrophication and red tide. They can not only absorb a large number of nutrients, purify water quality, but also secrete complementary compounds into the water, affect the growth of microalgae, inhibit the explosive reproduction and growth of red tide organisms. With the in-depth observation of the phenomenon of red tide, it has been found that due to the growth of a large number of macroalgae in some coastal areas, even though the nutrients are rich, the occurrence of red tide rarely occurs throughout the year, indicating that macroalgae have a certain inhibitory effect on the growth of red tide algae. In 1949, Hasler et al. first discovered the restraints of aquatic plants on the growth of algae (Jones 1949). Recent studies at home and abroad have also shown that some macroalgae can secrete allelochemicals directly or contain allelochemicals naturally in their bodies, which can restrain the growth of red tide organisms. At present, it has been found that many macroalgae, such as Ulva, Enteromorpha prolife and so on, can control the red tide algae such as Prodino flagellates of East China Sea, Cyclocystis polycyclic, Alexandria tamarinensis, Phaeocystis globosa, and Cardonia oceanica. However, further research on the specificity and specificity of the effects of red tide algae should be conducted (Meixia 2011).

3.4 Composite application of marine algae in wastewater treatment

3.4.1 Application of marine algae and bacteria in wastewater treatment

Algae has been widely concerned because of its remarkable ability to consume inorganic compounds in water bodies. Since the 1970s, with the rapid development of biotechnology, the synergistic interaction between bacteria and algae in this process has been confirmed (Kouzuma and Watanabe 2015). The harmonious symbiotic relationship between fungi and algae makes them considered as the pillar of water ecosystem. However, since fungi and algae are separated naturally under natural conditions and their
combination is not inevitable, it is very difficult to further explore their interaction. The commonly recognized bacteria-algal interaction mechanism is shown in Figure 4. (Ramanan et al. 2016)

![Figure 4 Interactions between algae-bacteria and their mechanism](image)

The technology of large-scale cultivation and application of bacteria and algae system has also been further improved, and the research on the application of bacteria and algae in sewage purification has made great progress. The synergistic activity of algae and prokaryotes can be used to improve the efficiency of algae biological wastewater treatment, especially regarding nitrogen removal (Wang et al. 2018). Moreover, some studies have shown that the bacteria-algae composite system in sewage treatment plant can significantly improve the yield of biofertilizer and make full use of the resources in wastewater (Fang et al. 2017; Tang et al. 2018). In addition, some scholars have studied the process of treating sewage with bacteria and algae system. At present, there are mainly three forms of bacterial-algal system used in sewage treatment: suspended bacterial-algal system, immobilized bacterial-algal system and bacterial-algal biofilm system (Xu 2017). Among them, the immobilized bacteria and algae system is an improved system aimed at solving the problems that the effluent quality of the suspended bacteria and algae system is susceptible to the influence of suspended algae, the suspended algae and water are difficult to separate, and the mud production is large. The immobilized microorganism technology can immobilize the dominant bacteria, maintain high activity, improve degradation efficiency, and the immobilized cells have the advantages of fast reaction rate, strong toxicity resistance and so on. At present, the carrier materials of immobilized microorganism are mostly polyvinyl alcohol (PVA) and sodium alginate, which have the characteristics of high mechanical strength, good mass transfer performance and resistance to biological decomposition. Immobilized microorganism technology for the difficult degradable organic pollutants in water is widely used in the repair, use of immobilized algae adsorption system relative to the suspended state for the difficult degradable organic pollutants degradation algae system has a high removal efficiency, can endure high toxicant concentration etc, and can be selectively fixed some advantages of refractory organic matter relatively quickly decompose and mineralization, is of great research value. Bacterial and algal biofilm system is also developed on the basis of immobilization. Taking advantage of the characteristics of easy attachment of algae itself, the density of microalgae in the bacterial and algal biofilm is higher after cultivation and acclimation under certain conditions, so it can express a more stable effect on nitrogen and phosphorus removal in water.

### 3.4.2 Marine algae are combined with an A/O process

The A/O denitrification process includes two parts: anoxic and aerobic. The traditional and classic A/O process mainly produces nitrate along with activated sludge precipitation through denitrification and nitrification in the biological treatment system of the two parts of anoxic and aerobic sewage, thus achieving the purpose of biological nitrogen and phosphorus removal. The traditional A/O process has poor treatment effect on petrochemical wastewater with complex composition, toxic and difficult to be treated (Lai et al. 2012). As a new biotech purification method for wastewater treatment, the bacterial-algal system is significantly better than the traditional treatment method in removing organic pollutants in water,
which has been confirmed, and a large number of experimental results show that the bacterial-algal system can quickly reduce the concentration of nitrogen and phosphorus in water to 2mg/L and 0.1mg/L for pollutants in water (Liu et al. 2017). By combining the bacterial-algal system with the traditional classical A/O treatment process, the different properties and characteristics of algae can optimize the A/O process without targeted deficiencies, and the combination of algae and A/O process is a typical example of "bacterial-algal system technicalization". The combination principle of algae and A/O process is shown in Figure 5. In addition, it can enhance the wastewater treatment effect by changing the bacteria and algae species of the system and optimizing the physiological function of algae, which can better adapt to the high complexity of sewage itself. Huo et al. (Huo et al. 2018) used Tribonema sp, a filamentous microalga grown in an open photobioreactor (PBRS). It is directly combined with the traditional anaerobic/oxygen (A/O) process for the deep treatment of low concentration petrochemical wastewater. The comparison results show that the COD removal rate of alga-A/O process combined with algae can reach 97.8% and achieve deep purification, and can accumulate higher biomass concentration and oil content, while the COD removal rate of petrochemical wastewater by single A/O process is only 71.7% for the direct treatment of petrochemical wastewater by open PBRS primary sedimentation tank, and can not achieve deep purification. Different algae cells, however, demand for N and P ratio is different, and the optimal N, P than low toxic algae in sewage system each kind of material is not qualitative, can control N, P in water than algae is the premise of A/O process can exert governance effect, therefore in the governance of A/O process using algae should according to different combination with other methods of management synergy water application has to achieve sustainable management (Li, Chen, et al. 2020).

3.5 Other applications of marine algae for wastewater treatment

3.5.1 A Marine bacteria-algae symbiosis system was established to treat synthetic seawater toilet flushing wastewater. Li, Yating et al. (Li et al. 2018) studied Marine bacteria-algae symbiosis system to process the synthetic seawater flushing toilet wastewater, the research results show that the symbiotic system for total nitrogen (TN) in the water removal rate can reach 85.5%, the total phosphorus (TP) with 91.0% removal efficiency, 98.7% of the chemical oxygen demand (COD) removal effect and the removal rate of 4.28090004 g/L biomass production; The algae-bacteria system provides a potential energy saving and environmental protection method for seawater black water treatment and nutrient recovery.
3.5.2 Participate in the construction of Marine aquaculture systems Integrated tertiary wastewater treatment - Marine aquaculture system. Single-celled Marine micro algae growth in diluted wastewater, can effectively the inorganic and organic pollutants in waste water as their proliferation of nutrients so as to achieve the effect of purifying water body, and algae cells through photosynthesis fixed nutrients and can be used as an oyster or other filter feeders bivalve mollusks of the food.

3.5.3 Algae biofilm technology for wastewater treatment Algae biofilm technology, as a new biofilm method, has been used by many researchers in the treatment of nitrogen and phosphorus wastewater, and achieved good results. And a large number of studies have shown that algae biofilm technology in the removal of pollutants show great potential and commercial value (Abinandan et al. 2018).

3.5.4 Application of Marine algae in monitoring heavy metals in the ocean Determination of heavy metal concentrations in Marine organisms is usually preferable to determination of metal concentrations in seawater and sediment samples. The metal concentration in seawater is low and the fluctuation range is unstable. The content of heavy metals in sediments varies with the change of organic matter content, particle size composition, pH value and REDOX potential. At the same time, the fluctuation range of the metal content in sediments is small, so it cannot accurately and reliably reflect the change of the heavy metal content in seawater. Marine algae can reflect the content of heavy metals in seawater through the enrichment of and heavy metals in water, and because the content of heavy metals in algae cells is relatively stable, the determination is more representative (Topcuoğlu et al. 2003).

4. Conclusion and prospect
Marine algae has a wide range of applications in wastewater treatment. In addition to the metal in wastewater treatment, it can also be used to treat organic pollutants and radioactive contaminated wastewater, and can even be used to treat and recycle metals in seawater (Zhu Jingwen 2013). Algae has the advantages of low raw material cost, large adsorption capacity and no secondary pollution. This ecological sewage treatment method is bound to attract more and more attention, and is also the mainstream technology in the future sewage treatment application; In the current study of Marine algae, the effect of Marine algae adsorption of heavy metals has transcended the traditional method to remove the effect of heavy metals in sewage, such as copper, lead, cadmium in the wastewater pollutants can be in a short period of time can the removal rate of more than 90%, and the removal of nitrogen and phosphorus in algae research also suggests that in Marine algae have a very good for the inorganic pollutants in the water removal rate, in order to prevent the water pollution phenomenon such as red tides. In the sewage treatment system constructed by Marine algae and microorganisms, bacteria and algae are symbiotic, and the utilization of each other's metabolic characteristics can have a good effect on the treatment of pollutants in sewage. In addition to removing pollutants in sewage, Marine algae can also reduce the concentration of metals in the soil by adsorption, which helps to improve the soil quality by adsorption of metals on algae. Significant improvements in leaf size of legumes were observed in treated sewage sludge due to increased chlorophyll content compared to untreated plants; Reduced uptake of metals by the plants in the sludge was recorded as compared to the untreated sludge, as the nutrient level of the plants was improved (Rafia, Uzma, and Fahim 2007).

Application of Marine algae in sewage treatment is still on the stage of a mining, and currently used in wastewater treatment is mainly for Marine algae in a relatively closed system, and for offshore sewage and river and so on effect of open system management and technology to explore the construction phase is still in theory, but the ocean as resources treasure, and the development of biotechnology believe algae in the ocean resources are rich and varied environment must still exist many can has the huge potential of algae in sewage treatment waiting. The creation of the process needs a long time of exploration and verification, and when it is difficult to deal with the current situation of water pollution, it may be more appropriate to combine the new material with the classic treatment process and continuously optimize the conditions in the process. Finally, with the continuous development of modern technology, the author makes the following prospects for the application of Marine algae in wastewater treatment: (1) Further research on the combined immobilization of Marine
algae and bacteria for wastewater treatment is carried out to explore the combined system of bacteria and algae for wastewater treatment with high efficiency. Based on the adsorption characteristics of marine algae on heavy metals, combined with labeling technology and GPS positioning technology, the water pollution caused by heavy metals can be warned in advance. Artificial intelligence is a new technology with rapid development. Through the artificial intelligence technology, the water environment can be monitored in real time. Combined with the algae sewage treatment system, the sewage can be treated efficiently.

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