CURRENT DEBATES in ENGINEERING SCIENCES

EDITOR

Assoc. Prof. Özlem SALLI BİDECİ

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Chapter 1

Advantages of Algae Pool Systems in Wastewater Treatment

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1 Fırat Üniversitesi, Bilimsel ve Teknolojik Uygulama ve Araştırma Merkezi, Elazığ

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1. INTRODUCTION

In waters rich in organic matter, there is a symbiotic relationship between algae and bacteria. In this relationship, algae produce free oxygen during photosynthesis and support aerobic bacterial oxidation of organic matter, while carbon dioxide and nutrients released by oxidation are used by algae in the production of new biomass (Fig. 1).

Most of the nitrogen in algae is bound in proteins, which make up about 45-60% of dry weight, and phosphorus is required for the synthesis of nucleic acids, phospholipids, and various ester phosphates. Algae, which use nitrogen and phosphorus for their own growth, can remove nitrogen and phosphorus load from wastewater in a few hours to a few days (Sen ve ark. 2013). The increase in the amount of oxygen in the pool water during photosynthesis causes the pH to increase, and accordingly the precipitation of phosphorus, the removal of ammonia and the decrease in the amount of hydrogen sulfide. It is also known that high pH values in the algal pool are lethal for many pathogenic organisms (Laliberte et al., 1994).

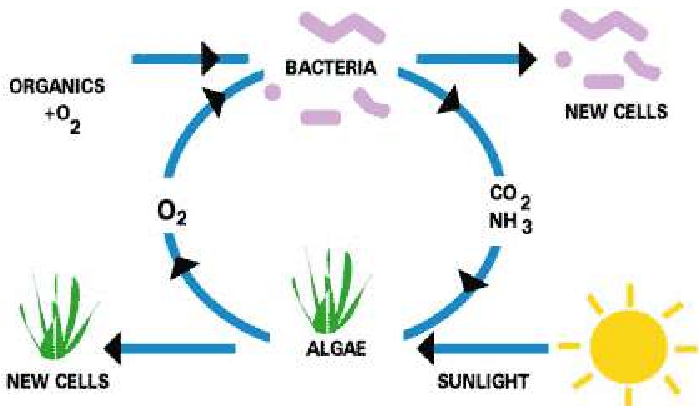

Figure 1: Symbiotic relationship between algae and bacteria

Heavy metal ions in wastewater can also be removed by the algae biome. In a laboratory-level study, Filip et al. (1979) states that 70-90% of the cadmium and copper in the wastewater pond is removed by the algal biome. The efficiency of removing heavy metals from water varies according to algae species. For example, Oscillatoria sp. It is a good chrome remover. Chlorella vulgaris mainly cadmium, copper and zinc, Chlamydomonas sp. lead, Scenedesmus chlorelloides were found to be capable of removing molybdenum. Although it is stated that algae will adapt to metal pollution in waters containing sublethal heavy metals, heavy metal accumulation in algal cells is potentially toxic to other links in the food chain (Wikfors and Ukeles, 1982).

2. GENERAL CHARACTERISTICS OF ALGAE

Approximately thirty thousand species of algae, also known as seaweed, have been described. They are generally classified into two groups as multicellular macroalgae and unicellular microalgae. However, it should be taken into account that algae are evolutionarily heterogeneous. The term algae was first introduced by Linnaeus in 1753. It has found its place ecologically all over the world. They can live in seas, lakes and rivers with their bodies or structures with similar functions, and on land by clinging to soil, trees and rocks. But their general distribution areas are waters. They can live with plants and animals. They can live almost anywhere in ice-covered areas, spring waters with a temperature of 70 °C or higher, very salty water environments, low light intensity and high pressure, lake and marine environments (Gümüş, 2006; Cirik and Cirik, 2011).

Algae have plant-like characteristics typically found in aquatic environments, algae are eukaryotic organisms that, like plants, contain chloroplasts and are capable of photosynthesis, and have similar characteristics to animals. Some algae also have flagella and centrioles and can feed on organic matter in their habitat. Algae vary in size from single cell to very large multicellular species and can live in a variety of environments such as salt water, fresh water, wet soil or moist rocks. Algae form the basis of the food chain in aquatic environments (Cirik and Cirik, 2011).

It is known that secondary metabolites obtained from algae have benefits for the skin such as prevention of hard tissue wrinkles and skin sagging, protection from ultraviolet rays In addition, it also delays skin aging due to the presence of antioxidants it contains. Since algae extracts and biological extracts contain environmentally safe components, their use in the formulations of cosmetic products is increasing. Although the use of some of these algae compounds in cosmetics is known, most algae extracts are still not used in the field of cosmetics. Also, the types and systematics of algae compounds used in the field of cosmetics are stated in the patents without a full explanation. (Gümüş, 2006). Algae have three different reproductive systems: vegetative reproduction, sexual and asexual reproduction. Vegetative reproduction is the most common among these varieties. There are also algae species where cells grow and form colonies. These algae then divide as a result of normal growth (Dural, 1989).

3. ALGAE POOLS

3.1. Algal-Bacterial Pool Systems

Algal-bacterial ponds are water bodies established to hold and treat wastewater for a predetermined time. Although wastewater is treated mechanically in the pool by physical, chemical and biological processes, pool systems are also common, where mechanical tools such as aeration pumps are not used and the treatment process is carried out completely according to natural conditions. Generally, the pools in which the stabilization of dissolved and suspended solids is carried out under fully aerobic conditions are called "oxidation pools", and the pools in which they are carried out under anaerobic or facultative conditions are called "waste stabilization pools". There are four types of stabilization ponds: facultative, anaerobic, aeration and maturation ponds (Rich, 1980).

The most common type of stabilization pond used from algae in wastewater treatment is facultative. Facultative pools are built for purposes such as shortening the holding time of wastewater, performing a more effective treatment, and cultivating algae. High-rate algal pool and advanced integrated pool systems are also developed by using it together with other pool types.

The principle of algal-bacterial pond systems used for wastewater treatment is to exploit the photosynthesis abilities of algae and the ability of bacteria to break down organic matter. Operations in pool systems used for oxidation of organic matter, precipitation of suspended matter, adsorption and precipitation of heavy metals, nutrients, toxins, salts, and reduction of harmful microorganisms such as Escherichia coli are the result of the symbiotic relationship between these two important populations of organisms. Bacteria convert organic carbon into carbon dioxide by oxidation and convert organic matter into ammonia, phosphate and other nutrients by hydrolysis. Algae produce oxygen for bacterial oxidation by photosynthesis (NRC, 1979).

3.2. Air Stabilization Pools

The depth in these pools is approximately 0.3 m or less to maximize light transmission and photosynthesis and algae growth. Weather conditions are always maintained in the entire depth of the pool.

3.3. Airless Stabilization Pools

In this type of stabilization pools, microbiological activity takes place in an airless environment. Anaerobic and facultative microorganisms use the oxygen in nitrates and sulfates. Such ponds can accept high organic loads and operate without algal photosynthesis. Since light transmission is not important in these pools, 3-4 m depths are used.

However, nowadays, airless sludge bed reactors (ABCR) anaerobic sludge blanket (AWBC) systems can be used instead of these pools, as they are more efficient.

3.4. Facultative Pools

These are pool systems designed to decompose organic matter with aerobic and anaerobic activity, stabilize waste water, and reduce the concentration of harmful microorganisms, in which treatment is carried out in 5-30 days depending on factors such as climate, temperature, wind, surface area. Facultative pools are generally 1-2.5 m deep (Tebbutt, 1998). Three different regions are formed in the facultative pool. While the first two regions are oxygenated, anaerobic conditions are present in the substrate. The oxygen source in the upper regions is the atmosphere and algal photosynthesis, in the upper region the wastes are stabilized by aerobic bacteria and in the middle layer by facultative bacteria. On the other hand, wastes in the lower region are broken down by anaerobic bacteria (Mara et al. 1992). The zooplankton population formed in the pond, on the other hand, contributes to the production of carbon dioxide for photosynthesis, limiting the overgrowth of these organisms by feeding on algae and bacterial populations.

The most important advantage of facultative stabilization ponds is that they produce purified water of appropriate quality with low operating and maintenance costs. The most important disadvantages are the need for more land, the possibility of odor with excessive waste entry, the loss of nitrogen to the atmosphere and the limitation of the reusability of nutrients as a result of sedimentation of phosphates, and the limitation of its use as irrigation water due to the increase in salt concentration in the pool water in seasons when evaporation is more than precipitation (NRC, 1979).

3.5. High Rate Algal Pool Systems

Urban wastewater treatment with high-rate algal pool systems was first proposed by Oswald and Golouke (1963) and has been used by various researchers in later years. High-rate algal ponds are equipped with shallow (usually 20-50 cm) mechanical mixers and channels that allow water to flow continuously in one direction. The high oxygen level as a result of the aeration performed by photosynthesis and mechanical mixers allows the waiting time of the waste water to be shortened in the pool. Accelerated photosynthetic processes that can be used in the treatment of industrial or wastewater and the production of algal proteins are shown in Figure 2. A treatment plant arranged with this system performs a more effective treatment in a similar function to traditional treatment methods, even in a shorter time. In addition, the establishment cost is five times lower than other treatment systems and the energy requirement is less, and the land used is half that used for facultative pools. In high-rate algal ponds, approximately 90% of the BOD and more than 80% of the nitrogen and phosphorus can be purified in a few days, while with conventional activated sludge and biofiltration methods, 85-90% of the BOI and nitrogen and phosphorus can be removed in 5-8 hours. less can be purified. Moreover, secondary treatment methods such as activated sludge and biofiltration require expensive chemicals and complex systems. If the pH value of the pool water rises above 9, it causes the death of coliform bacteria and the precipitation of ionic heavy metals and salts (Esen and Purkas, 1991).

The most important problem in high rate algal ponds is harvesting costs. When the mechanical mixers are stopped to harvest the algae, it is desirable that the algae flocculate and settle to the bottom. It is undesirable to have algae resistant to precipitation such as Chlorella, Euglena, Chlamydomonas and Oscillatoria in the pond (Sen ve ark, 2013). In almost all well-mixed ponds, Scenedesmus or Micractenium are dominant organisms, which are generally fast growing and not preferred by zooplankton for feeding due to their spiny appendages (Oswald, 1988).

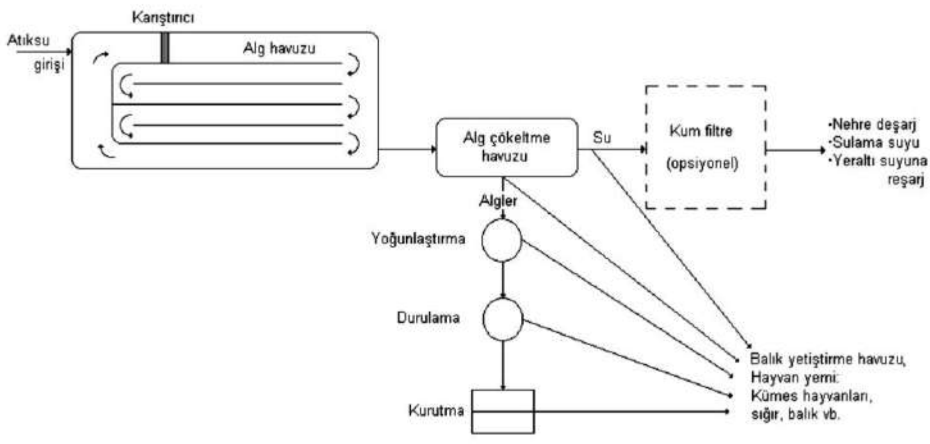

Figure 2: Accelerated photosynthetic processes for wastewater treatment and algal protein production (Shelef et al., 1978).

3.6. Advanced Integrated Pool Systems

It is a system consisting of advanced integrated pools, anaerobic pool, facultative pool, high rate algal pool and settling pool for wastewater treatment. Raw wastewater enters the pools in order.

The first pool in the treatment series is anaerobic and the wastewater is pumped from the bottom to the middle part of the pool at a depth of approximately 4-5 m via channels. After waiting for 5-10 days in the anaerobic pool, after the organic matter is decomposed anaerobically, the waste water is taken to the shallower facultative pool and then to the high-rate algal pool and treated. Suspended algae that grow in the facultative and high rate algal pool are precipitated in the settling pool. With the wastewater treatment in the four-step advanced integrated pond system (Fig. 3), a treatment equivalent to secondary treatment with complex and expensive processes is achieved (Oswald, 1991).

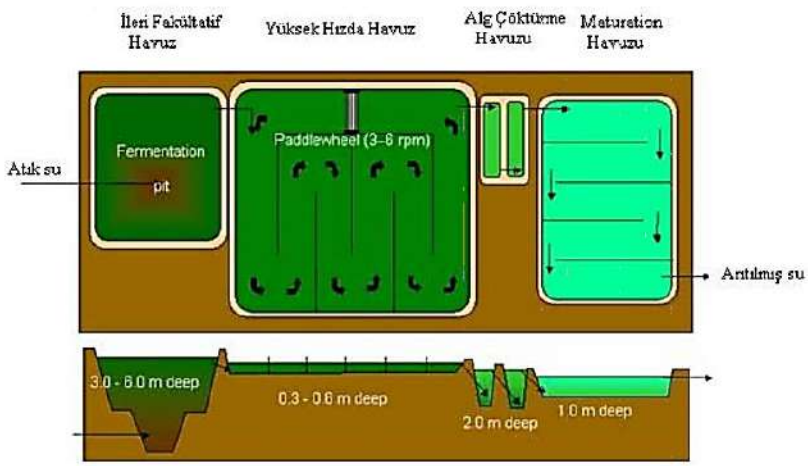

Figure 3: Advanced integrated pool system.

In an advanced integrated pool project conducted by the US Department of Energy (DOE), a system consisting of five pools is implemented. The first of these pools is the facultative pool with a depth of 4-5 m. This is followed by a high rate algal pool where dissolved organic matter is broken down by aerobic bacteria. The third pool is a settling basin used for sedimentation of growing algae. The treated water from the settling pond is discharged to the receiving environment after resting in two separate maturation ponds, or it is used in agricultural applications if it has the quality to be used as irrigation water.

The initial capital and maintenance costs of this DOE-built pool system are very low compared to a secondary treatment system that would provide the same function, and the use of mechanical tools is also minimized. Another important advantage of the treatment system is that very little residual sludge builds up in the pond. Residue removal is not carried out in the wastewater treatment plant during the application period of approximately 30 years. During this period, less than 1 m of mud accumulates in the facultative pond, which is the first component of the system (DOE, 1993).

4. RESULT

Algae have an important place among the organisms commonly used in wastewater treatment, with their ability to remove hazardous pollutants such as nutrients, heavy metals, pesticides, organic and inorganic toxins, and radioactive substances in wastewater. 90% of the commercial scale algae pools in the world are open pools because of their low operating cost. In recent years; Many pilot plants have been built in California, New Mexico, Hawaii, and Florida. In San Diego, Sapphire Energy has planned to produce 16000 L/day of fuel in 10 units of 4ha. Petro Sun company aims to produce 16 million L of algae oil and 50000 tons/year biomass in its 445 ha salt ponds in South Texas. Algerol Biofuels company aims to produce 379000 L of ethanol equivalent fuel by using Florida closed photobioreactors in a 15 ha area.

Algae systems for urban and industrial wastewater treatment provide a treatment equivalent to secondary treatment systems using mechanical tools and chemicals, and are one of the most preferred treatment systems in the world due to their low cost and operating costs. Many companies are working to obtain patents for different reactor types. Green Star Products company was able to operate its 40000 L facility in Moutana even on cold days with -18 °C at night. Although there are many studies that have been successful in laboratory scale, problems such as species pollution-mixing, change of wastewater components and appropriate biomass production occur in pilot plants. Algal solid concentration in algal pools is less than 0.2%.

The effectiveness of algae in removing nitrogen, phosphorus and pathogens has been demonstrated by various studies, and it has also been proven to be effective in removing toxins such as heavy metals and pesticides. Basic components such as protein, carbohydrates and vitamins are obtained from dense algae cultures produced in algal pools. It is known that the nutritional value of the products increases by adding the obtained content-rich biomass to animal feed or foodstuffs.

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