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Cultivation of microalgae in municipal waste-water in Vaasa

The search for renewable and sustainable sources of energy, to compensate for fossil fuels, has drawn attention to the possibility of utilizing microalgae as a feedstock for energy production. Microalgae can be cultivated in wastewater, and the produced biomass can be used in biogas production, or further processed into biofuel. Wastewater treatment by microalgae and algal biomass yield is being studied in Vaasa.

INTERESTING BIOFUEL FEEDSTOCK

Microalgae have high photosynthetic efficiency and high growth rate, and are under optimal conditions capable of doubling its mass in 24 hours or less. Microalgae are an interesting feedstock for production of biofuel or biogas. The production of third generation biofuel from microalgae can be locally produced.

GROWTH REQUIREMENTS

The most important growth parameters for microalgae are the provision of photosynthetically active radiation, suitable temperature conditions and adequate mixing. Light can be provided artificially, but natural sunlight is most energy efficient. The light intensity must be strong enough to enable photosynthesis, but too intense light damages the cells. The optimal temperature range for most microalgae species are between 20 to 30°C. Microalgae endure colder temperatures better than warmer, and are able to adapt to temperatures up to 15°C below their optimum. Mixing of the water column is important to keep the algae cells from settling, to circulate the cells closer to the light and to promote gas exchange. The challenge of cultivating microalgae in the Nordic climate is the cold temperatures and lack of light during the winter season.

NUTRIENTS

The most important nutrients are carbon, nitrogen and phosphorous. Carbon dioxide is utilized during photosynthesis, and is bound to the biomass. Nitrogen and phosphorous are two of the most abundant compounds in wastewater. Discharge of nitrogen and phosphorous cause eutrophication of natural waterbodies and is thus strictly regulated and monitored by public authorities.

PHYCOREMEDIATION

The most sustainable way of producing microalgal biomass for energy production is by utilizing wastewaters derived from municipal, agricultural and/or industrial services. The wastewater provide the microalgae with essential nutrients, which simultaneously are removed from the wastewater. Utilizing microalgae in wastewater treatment, called phycoremediation, has been studied since the 1950's. Since then it has been widely used in pond wastewater treatment in areas with warm climate. It is recommended by the World Health Organization as the process to choose when resources and skills are limited, due to the simplicity and reliability of the system, and the efficiency of pathogen destruction. In developed countries, however, this kind of process has lost ground to the Activated Sludge process, which is faster and less space demanding. However, the possibility of simultaneous wastewater treatment and production of valuable biomass as well as carbon capture has reawaken the interest for phycoremediation.

Fig. 1. Algae cultivation experiment in wastewater.

LABORATORY STUDY

A laboratory study was conducted at the University of Vaasa in cooperation with the local municipal wastewater treatment plant in the city of Vaasa. The aim of the study was to examine if cultivation of microalgae would be feasible in wastewater from the wastewater treatment plant. The study also aimed to examine what point of the wastewater treatment process is most suitable for cultivation of microalgae, in terms of production of algae biomass, at what point of the treatment process the microalgae remove most nutrients from the wastewater, and if there is a difference in growth of algal biomass and nutrient removal at different temperatures.

The microalgae Scenedesmus sp. was cultivated in wastewater from three different points in the wastewater treatment process, see Fig. 1. The first point was after the pre-sedimentation pond, the second after the sedimentation pond and the third was effluent that was about to be dispatched to the sea. The study was conducted in two different temperatures (24°C and 16°C) and light intensities. Microalgal biomass accumulation was determined, and growth parameters were calculated. Removal of total nitrogen, total phosphorous, ammonium and chemical oxygen demand from the wastewater were measured.

RESULTS

The laboratory study indicates that cultivation of microalgae in wastewater at the local wastewater treatment plant in Vaasa could be feasible. The accumulation of biomass was quite similar in all three tested waters (see Fig. 2) and most efficient in higher temperature and higher light intensity.

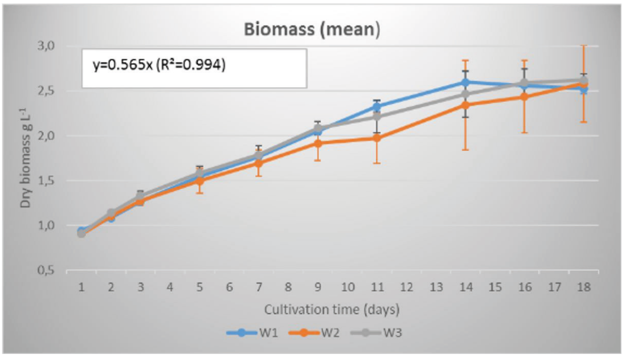

Fig. 2. Biomass accumulation in 24°C.

The removal of nutrients was most efficient in the first test point, the water collected after the pre-sedimentation pond, see examples in Fig. 3 and Fig. 4. At this point of the wastewater treatment process the nitrogen is mostly in the form of ammonium, which is easily available for the microalgae. The removal of ammonium was complete, but faster in warmer temperature where most of the ammonium was removed during 24 hours. The removal of nitrate was slower than removal of ammonium.

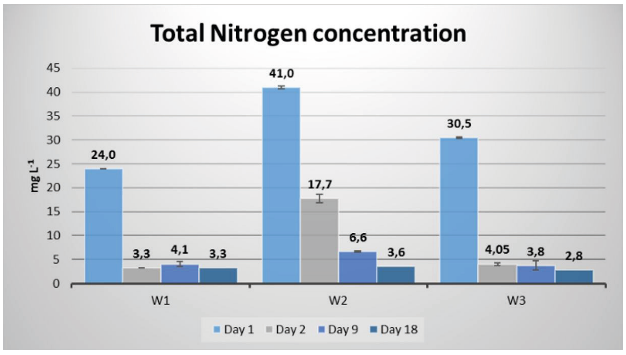

Fig. 3. Concentrations of total nitrogen in the wastewater at the beginning of one of the experiments, after 24 hours, and on day 9 and 18 of algae cultivation in the three test points W1, W2 and W3.

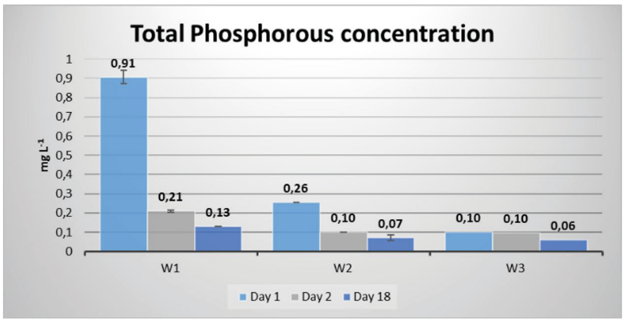

Fig 4. Concentrations of total phosphorous in the wastewater at the beginning of one of the experiments, after 24 hours and on day 18 of algae cultivation in the three test points W1, W2 and W3.

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