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Energy Microalgae Based on Photobioreactor in the Purification of Heavy Industry Polluted Wastewater

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Abstract: In recent years, with the improvement of living standards, people's demand for aquatic products continues to increase, heavy industry develops rapidly, and the treatment of heavy industry polluted wastewater has become the focus of attention. The purpose of this work is to study the purification of heavy industrial polluted wastewater by high-energy microalgae based on photobioreactors. The algal-bacterial symbiotic system studies the pollution removal rule and the effect of microalgae cultivation. Light characteristics and average light intensity in algal liquid, degree of mixing of liquid in the reactor, and the effect of CO2 on microalgal growth and medium pH. The removal results of inorganic nitrogen continuous treatment showed that in the continuous treatment process of 6d, after treatment by the reactor, the concentration difference of NH4+-N in the effluent was controlled in the range of 0.39~0.51 mg-L-1, the average removal rate is 97.1%, the pH value remains stable, and the purification effect of heavy industry polluted wastewater is ideal.

1. Introduction

Our country is a water-deficient country, and the problem of water resources has become the main factor restricting social and economic development. At present, my country's sewage treatment rate is still relatively low, and my country's sewage discharge is about 100 million square meters per day. The survey found that 82% of the country's rivers and lakes have been polluted to varying degrees [1]. The main pollutants of lakes, rivers and coastal waters in my country are nitrogen, phosphorus and organic pollutants. Traditional sewage treatment methods mostly remove organic matter in water bodies, but the removal of nitrogen and phosphorus in water bodies is poor, and the cost is high and secondary pollution is likely to occur [2].

Microalgae are single-celled microorganisms that can grow in freshwater areas, saline waters and even wastewater that are not suitable for food crops. Jiménez-Llanos outlines the key parameters for hydrogen production from microalgae, especially the genus Chlorella. The current status of chemical and biological hydrogen production technologies, as well as the main metabolic processes of microalgae for this purpose, their characteristic enzymes, several strategies for inducing hydrogen production, key operating parameters, and finally some suggestions for scale-up and industrialization are presented [3]. Samuel assessed a comparison of estimates and described the global burden of disease associated with air pollution in WHO regions from 1990 to 2015. The study used available IHME data on the global burden of disease (mortality and disability-adjusted life years) for trachea, bronchi and lung cancer. This study shows that exhaust air pollution was one of the major environmental risk factors for the global disease burden from 1990-2015 and has remained relatively stable over the past 25 years. By region, the largest air pollution-related disease burdens are in the Western Pacific and Southeast Asia, reflecting heavy industry and air pollution hotspots in developing countries in these regions. In addition, DALYs have increased due to increased pollution, especially in Southeast Asia, Africa, and the Eastern Mediterranean where populations are growing and aging [4]. Arnetz BB's study involved a susceptible population of older adults (n=76; mean age 64.6 years; 48 women) in Detroit, Michigan, USA, who were diagnosed with asthma by their physicians. Exposure variables included measured outdoor PM2.5, self-measured outdoor and household environmental pollutants. Outcome variables were self-rated and measured lung function, and health care utilization related to asthma. Among older adults with asthma who lived near heavy industry and busy highways, objective and perceived environmental pollution was associated with participants' respiratory health and healthcare utilization. Importantly, air pollution may increase the use of corticosteroid-containing asthma control medications, which increases the risk of osteoporosis and cardiovascular disease in older adults [5]. Phytoremediation, the use of green plants to reduce or remove pollutants, is considered a simple and low-cost wastewater treatment technology.

In this paper, photobioreactor-based energy microalgae is applied in the purification of heavy industrial polluted wastewater. Chlorella can absorb heavy metals under overload conditions, utilize mineral salts, and degrade desired species, hydrocarbons and other organic substances, especially Under the guarantee of high-concentration cell culture technology research. Therefore, using photobioreactor to cultivate Chlorella to treat wastewater from coalification can not only reduce the cost of chlorella cultivation, but also avoid water pollution caused by direct discharge of wastewater from coalification. In addition, the results of this paper will help to clarify the mechanism of microalgae adaptation to aquaculture wastewater, and then provide a theoretical basis for the domestication of microalgae.

2. Photobioreactor-based Energy Microalgae in the Purification of Heavy Industry Polluted Wastewater

2.1. Energy Microalgae

With the rapid economic and social development, the demand for energy, especially fossil fuels such as coal, oil, and natural gas, is increasing year by year. At present, about 90% of the world's energy comes from fossil fuels, and only about 10% of renewable energy. However, fossil fuels are non-renewable, and according to forecast energy demand, there will be no conventional oil reserves available for commercial exploitation after 2050. In addition, the application of fossil fuels will emit a large amount of CO, CO2, NOx, SOx gas into the atmosphere, resulting in global environmental pollution, climate change, ecological degradation and biological health problems [6-7]. Therefore, the development of a clean, renewable, sustainable energy and technology has become a hot issue in global research, and the production of biofuels has attracted more and more countries' attention. Biodiesel currently accounts for 82% of the total biofuel production in the EU, and the demand for biodiesel will continue to grow. According to the raw materials for producing biodiesel, biodiesel can be divided into three generations. The first-generation biodiesel comes from edible raw materials such as wheat, corn, soybean, and rapeseed; the second-generation biodiesel comes from agricultural waste, wood, etc. The third-generation biodiesel is derived from microalgae. Compared with the first- and second-generation raw materials, microalgae have higher energy yield and less floor space [8-9].

2.2. Important Indicators of Industrial Wastewater Purification

(1) Suspended impurities (SS)

Suspended Solids (SS) or Short Suspended Solids is a heavy industrial wastewater standard used for wastewater testing, referring to industrial wastewater treatment. The content of SS directly affects the appearance of the water. If the wastewater is treated as industrial wastewater, the effect of precipitation may be reflected, and impurities can be easily removed [10-11].

(2) Biochemical oxygen demand (BOD)

Biochemical demand (BOD) is a widely used pollution indicator for urban sewage and large-scale industrial wastewater. It refers to the amount of dissolved oxygen produced by the oxidative degradation of organic pollutants in one liter of wastewater under the action of aerobic microorganisms. High BOD content indicates serious water pollution and lack of oxygen in the water. It can compare the oxygen consumption process of the water supply system after the sewage enters the industrial sewage system, and can also be used to judge the sewage process of the industrial sewage system, and determine the water quality and production water of the water supply system. In practice In the test, the five-day chemical demand (BODS) is often used to express the concentration of organic matter in industrial wastewater [12-13].

(3) Chemical oxygen demand (COD)

Chemical Oxygen Demand (COD) refers to the amount of oxygen that chemically oxidizes industrial waste using strong oxidants in the wastewater being tested. When potassium dichromate is used as the oxidant, the chemical oxygen demand is expressed by CODcr; when potassium permanganate is used as the oxidant, the CODM-oCOD assay is more accurate and faster than the BOD assay, so it is widely used in the treatment of water [14 -15].

(4) PH value

pH stands for the pH of water and is the negative logarithm of the concentration of hydrogen ions in water. PH=7 is neutral, PH<7 is acidic, and PH>7 is alkaline. The pH value of general industrial wastewater is between 6-9. When PH<6 or PH>9, it will affect the biochemical treatment and affect the concrete. It has a loss effect on metals. At this time, industrial wastewater is pretreated and treated materials are treated with anticorrosion. For biochemical treatment, PH value is a very important parameter [16-17].

2.3. Factors Affecting the Performance of Photobioreactors

(1) Light-receiving specific surface area

Microalgae are autotrophic organisms that can convert light energy into chemical energy biomass, which is an ideal growth environment. In microalgal systems, electrical energy is distributed through direct evolution. Therefore, the low-dose electrical energy produced by microalgae is related to light conditions. With the highest use of light energy, the algal cells should be able to receive electricity starting in May. Light intensity decreases rapidly in the medium due to shadowing of the cells. Increasing the surface area for absorbing specific light is one of the typical loopholes in the development of high-performance photobioreactors [18-19].

(2) Inhibition of oxygen production in photobioreactors

When microalgae are photoautotrophic, with the rapid growth of algal cells, the oxygen content produced increases accordingly, and the oxygen content dissolved in the algae solution also increases accordingly. Block or reduce the contact area of algal cells with carbon dioxide and nutrients, photosynthesis is blocked, and the growth rate is reduced. Therefore, reducing the dissolved oxygen content in the algae solution is one of the key issues that must be solved to realize the large-scale and high-density uplifting of microalgae. During the cultivation process, the dissolved oxygen is generally resolved as soon as possible by external power, such as the use of power agitation and idle circulation. and other technologies to enhance the degree of algal fluid movement, driven by external force, the bonding force between oxygen bubbles and algal cells weakens, and the force increases and precipitates.

(3) Carbon source supply method

In the design of photobioreactor, the structure of the reactor is generally different due to the same carbon source supply. If the carbon dioxide mixture is used as the carbon source supply method, the external system of the reactor and the internal body distribution device need to be added to meet the optimal concentration of carbon dioxide required for the photosynthetic growth of microalgae, and to disperse the carbon dioxide mixture into a smaller gas. The bubbles are allowed to dissolve in the algae liquid, prolong the residence time of the bubbles in the algae liquid, increase the liquid two-phase contact surface, extract the mass transfer efficiency of the liquid, and promote the photosynthesis rate of the microalgae. Mixing air and carbon dioxide to dissolve the algal liquid in high dissolved oxygen will inhibit the growth of algal cells, so dynamic measures such as rack circulation and mechanical stirring are often used to enhance the algal liquid movement and prevent the phenomenon of oxygen suppression. The core uses inorganic salts such as sulfates, bicarbonates, etc. as the carbon source supply method, so there is no need for a gas distribution system and a gas separation device inside the reactor, which can simplify the internal and external structure of the reactor to a certain extent and save costs, but from the From the perspective of the long-term development of microalgae and the source of carbon source supply, it is bound to increase the cost of cultivation.

3. Experiment and Research of Energy Microalgae Based on Photobioreactor in the Purification of Heavy Industry Polluted Wastewater

3.1. Test Material

(1) Algae species

The algal species used in this paper is Chlorella vulgaris, which has a good effect on the purification of heavy industrial polluted wastewater. Before the test, the algae seeds were placed in a light incubator for expanded culture with BG-11 medium. The culture conditions were: the light intensity was 3000 lux, the temperature was 25 ℃, the light-dark cycle ratio was 12h:12h, and HCl solution or NaOH solution was used. The solution adjusts the initial pH of the medium to about 7.1.

(2) Wastewater

Due to the complex composition of substances in the actual heavy industry polluted wastewater, in order to avoid its influence on the growth of Chlorella, some experiments were conducted using simulated heavy industry polluted wastewater. The water quality of artificially simulated wastewater is shown in Table 1.

Table 1. Composition of artificially simulated wastewater

Component	Concentration/mg-L^{-1}	Component	Concentration/mg-L^{-1}
(NH4)SO4	1600	CaCl2.2H2O	35
KH2PO4	50	Na2CO3	15
Sodium acetate	50	Trace elements I	2
MgSO4 7H2O	70	Trace Elements II	2

3.2. Determination of Biological Indicators of Chlorella

(1) Determination of algal biomass

In order to ensure the accuracy and stability of the experiment, counting method, optical density method and chlorophyll content method were used to observe the growth law of Chlorella. A certain amount of Chlorella cultivated in the aquaculture wastewater of the red-fin orientalis was taken every day to measure the biomass.

(2) Determination of nitrate reductase

Nitrate reductase promotes the reduction of salts in algae to nitrite, so under acidic conditions large amounts of nitrite and sulfonamides and ulf-naphthylamines will ignite red azo compounds: NO3-+NAD(P)H+H+ → NO2_+NAD++H20 forms a red azo compound, with a maximum absorption peak at 520nm, measured by spectrophotometry, the activity of nitrate reductase can be expressed as the amount of nitrogen produced.

(3) Determination of net photosynthetic rate

Take the aquaculture wastewater Chlorella cultivated to the logarithmic phase and the Chlorella cultivated in the BG-11 medium to measure the net photosynthetic rate, put the dissolved oxygen analyzer together with the microalgae into the constant temperature incubator, and keep the instrument of stability. The instrument automatically calculates the change value of dissolved oxygen per unit time to measure and record, and measure the value every 10min. Adjust different light intensities in the light incubator, measure each illuminance continuously for 24h, 12h light and 12h dark, temperature: 25-28 degrees Celsius, take the average value of dissolved oxygen in each hour to calculate the net photosynthetic rate net.

3.3. Bioreactor

(1) Average light intensity

The logarithmic decay characteristics of light in the algal fluid determine the non-uniform distribution of light in the reactor, which is different from the general nutrient matrix. Previous studies have mainly used incident light intensity as a parameter to describe the light supply of photobioreactors. Mathematical models of events based on event intensity always assume that event light energy is received by all cells, but this approach only works at low intensities. The idea of cell concentration and short light path leads to large deviations in the growth of high-density microalgae, so the intensity of incident light is not an optimal parameter when calculating light conditions in a photobioreactor tracker. Compared with the intensity of incident light, it is easier to understand the light conditions in a photobioreactor in terms of average light intensity per unit size.

For the cylindrical bioreactor designed in this study, the following relationship exists:

$$VI_{avg} = \int_0^{r_0} 2\pi IH(r_0 - L)dL \tag{1}$$

where V is the volume of the photobioreactor (cm3); Iavg is the average light intensity in the reactor (μE:(M2·S)-1); .ro is the cross-sectional radius of the photobioreactor (cm); H is the effective height of the photobioreactor (cm); I is the light intensity at the reactor radius (ro-L) (μE:(M2·S)-); L is the light path (cm).

(2) The degree of mixing of the liquid in the reactor

In microalgal bioreactors, the mixing effect of liquids is an important factor affecting the growth of algae. The mixing degree of the liquid in the reactor is generally characterized by the Reynolds number (Re). When the Reynolds number is greater than 4000, the liquid is in a turbulent state, that is, the mixing is uniform. The formula for calculating Re is:

$$R_e = \frac{vD_r\rho}{u} \tag{2}$$

In the formula, v is the flow rate of the liquid (m s-1); Dr is the inner diameter of the guide tube of the reactor (m, in this study, Dr, = 0.08m), p is the density of the liquid (kg m-3), u is the viscosity of the liquid (kg (s m)-1).

4. Analysis and Research of Energy Microalgae Based on Photobioreactor in the Purification of Heavy Industry Polluted Wastewater

4.1. Removal Effect of Continuous Treatment on Inorganic Nitrogen

During the continuous treatment process for 6d, the concentration difference of the three kinds of inorganic nitrogen is shown in Table 2.

Table 2. Inorganic nitrogen removal by continuous treatment

Concentration/mg-L^{-1}	1	2	3	4	5	6
NH4^{+}-N	0.39	0.5	0.48	0.5	0.51	0.48
NO_2^--N	0.14	0.15	0.16	0.14	0.16	0.15
NO_3^--N	0.5	0.55	0.51	0.6	0.52	0.5

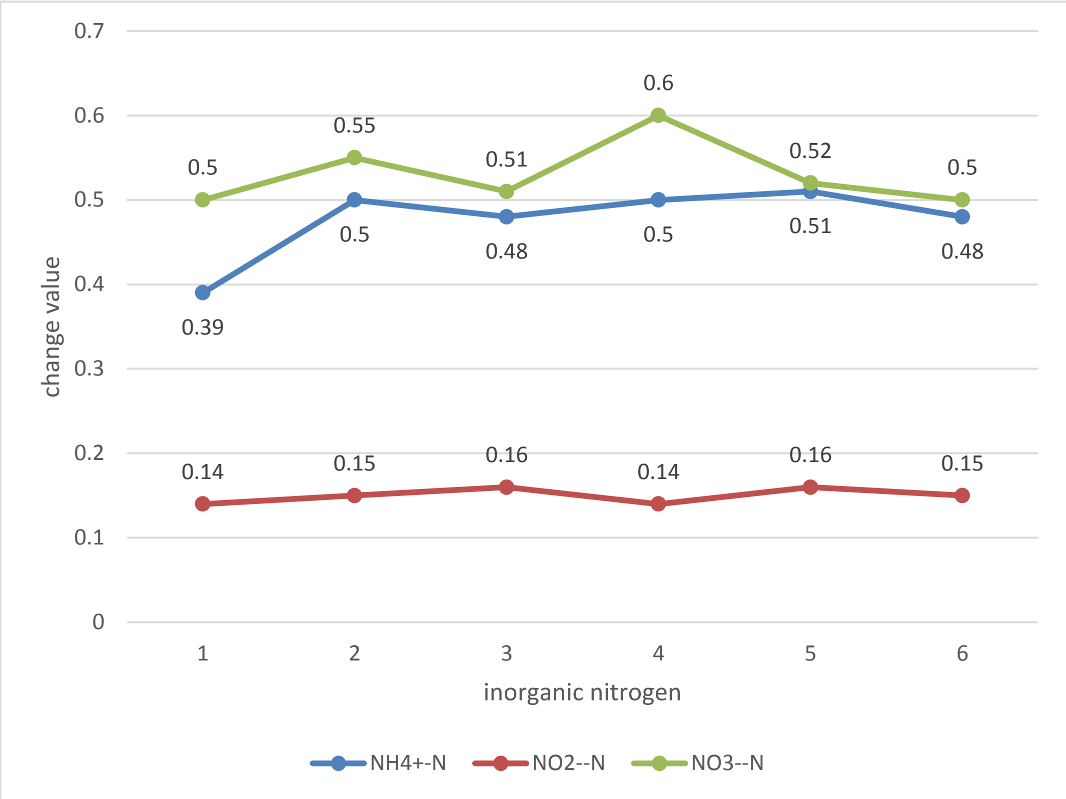

Figure 1. Removal effect of continuous treatment on inorganic nitrogen

As shown in Figure 1, in the continuous treatment process of 6d, after treatment by the reactor, the concentration difference of NH4+-N in the effluent was controlled within the range of 0.39~0.51mg-L-1, and the average removal rate was 97.1%. After treatment by the reactor, the concentration difference of NO2--N in the effluent was controlled within the range of 0.14-0.16 mg-L-1, and the average removal rate was 98.1%. After treatment in the reactor, the concentration difference of NO3--N in the effluent was controlled in the range of 0.5-0.6 mg-L-1, and the average removal rate was 84.5%. Therefore, in terms of absolute value, the processor has the best removal effect of NO3--N, and in terms of relative value, the processor has the best removal effect of NH4+-N.

4.2. PH Value of Wastewater before and after Continuous Treatment

In the continuous treatment process of 6d, the PH value of water before and after treatment is shown in Table 3.

Table 3. Comparison of wastewater pH values before and after continuous treatment

pH value	1	2	3	4	5	6
Before processing	8	7.9	8	8.1	8	7.9
After processing	7.9	8	8	8.1	8	7.7

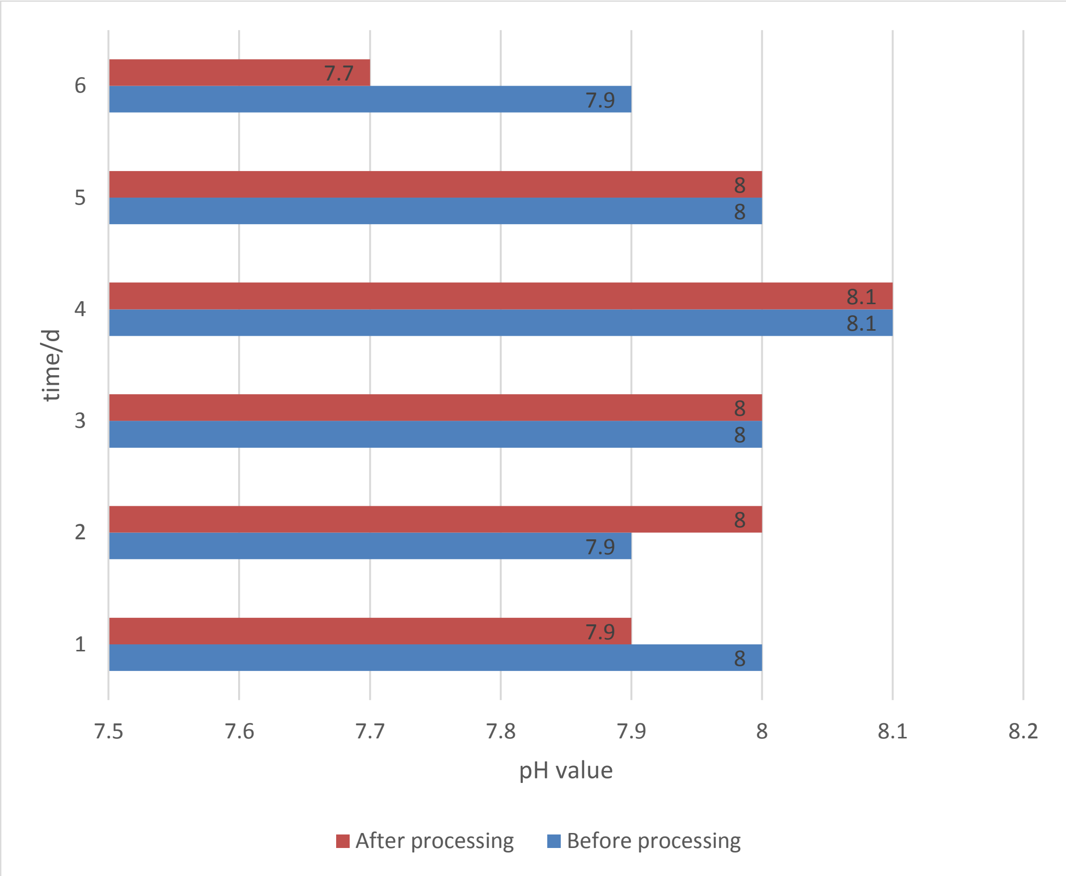

Figure 2. Changes in pH of wastewater before and after continuous treatment

As shown in Figure 2, during the continuous operation of the reactor, the pH value of the wastewater before and after treatment did not change much and remained at around 7.9. This is because the inflow ratio of CO2 is appropriate, and there is no shortage or excess of CO2, so the pH value remains stable. The pH value of the continuously treated effluent meets the standard (7-8.5) and reaches the Class I water quality standard (7.8-8.5).

5.Conclusion

In this paper, the photobioreactor-based energy microalgae is used to treat heavy industry polluted wastewater, and its pollutant removal performance, influencing factors and reaction mechanism are discussed, and the application of photobioreactor-based energy microalgae in the field of water pollution control is provided. The use of heavy industry polluted wastewater for the cultivation of energy microalgae can not only reduce the concentration of pollutants in wastewater, but also facilitate the utilization of wastewater resources and reduce the cultivation cost of microalgae, which has good economic and environmental benefits. The concentration of pollutants in the polluted wastewater of heavy industry is relatively high, and the treatment effect of microalgae is not ideal. The algal-bacteria symbiosis system can effectively improve the removal effect of pollutants such as carbon, nitrogen and phosphorus, and improve the utilization rate of pig wastewater. Its research is of great importance. realistic meaning.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Elkahlout K , Sagir E , Alipour S , et al. Long-term stable hydrogen production from acetate using immobilized Rhodobacter capsulatus in a panel photobioreactor. International journal of hydrogen energy, 2019, 44(34):18801-18810. https://doi.org/10.1016/j.ijhydene.2018.10.133

[2] Osaka N , Hasegawa F , Kaizu Y , et al. Development of Digestion Technology for Oil Extract Residue from Microalgae. Journal of the Japan Institute of Energy, 2018, 97(5):105-113. https://doi.org/10.3775/jie.97.105

[3] J Jiménez-Llanos, M Ramírez-Carmona, L Rendón-Castrillón, et al. Sustainable biohydrogen production by Chlorella sp. microalgae: A review - ScienceDirect. International Journal of Hydrogen Energy, 2020, 45(15):8310-8328.

[4] Samuel, Soledayo, Babatola. Air pollution%Burden of diseases%Regions of World Health Organisation. Journal of public health in Africa, 2018, 9(3):813-813.

[5] Arnetz B B , Arnetz J , Harkema J R , et al. Neighborhood air pollution and household environmental health as it relates to respiratory health and healthcare utilization among elderly persons with asthma. Journal of Asthma, 2019, 57(1):1-12.

[6] Bustos G , Calvar S , Vecino X , et al. Industrial Symbiosis Between the Winery and Environmental Industry Through the Utilization of Grape Marc for Water Desalination Containing Copper(II). Water Air & Soil Pollution, 2018, 229(2):36.1-36.11.

[7] Mohammad, Hassan, Enas, et al. Metallo-Terpyridine-Modified Cellulose Nanofiber Membranes for Papermaking Wastewater Purification. Journal of inorganic and organometallic polymers and materials, 2018, 28(2):439-447. https://doi.org/10.1007/s10904-017-0685-7

[8] Bessette A P , Stuart B J , Resurreccion E P , et al. Algae-Powered Sustainable Community Design Life Cycle Assessment and Techno-Economic Analysis. ACS Sustainable Chemistry And Engineering, 2020, 8(4):1916-1922. https://doi.org/10.1021/acssuschemeng.9b06256

[9] Nakamura T , Olaizola M , Masutani S M . Recovery And Sequestration Of Co{Sub 2 From Stationary Combustion Systems By Photosynthesis Of Microalgae. Office of Scientific & Technical Information Technical Reports, 2018, 262(9):70–73.

[10] Khattab T A , Abdelrahman M S , Rehan M . Textile dyeing industry: environmental impacts and remediation. Environmental Science and Pollution Research, 2020, 27(4):1-16. https://doi.org/10.1007/s11356-019-07137-z

[11] Adnan M A , Hossain M M . Integrated drying and gasification of wet microalgae biomass to produce H_2 rich syngas - A thermodynamic approach by considering in-situ energy supply.

International Journal of Hydrogen Energy, 2019, 44(21):10361-10373. https://doi.org/10.1016/j.ijhydene.2019.02.165

[12] Cs A , Mk B , Mb B . Chlorella vulgaris microalgae strain modified with zinc chloride as a new support material for hydrogen production from NaBH 4 methanolysis using CuB, NiB, and FeB metal catalysts. International Journal of Hydrogen Energy, 2020, 45(3):1959-1968.

[13] Sadvakasova A K , Akmukhanova N R , Bolatkhan K , et al. Search for new strains of microalgae-producers of lipids from natural sources for biodiesel production. International Journal of Hydrogen Energy, 2019, 44(12):5844-5853. https://doi.org/10.1016/j.ijhydene.2019.01.093

[14] Baudry G , Macharis C , Vallee T . Can microalgae biodiesel contribute to achieve the sustainability objectives in the transport sector in France by 2030? A comparison between first, second and third generation biofuels though a range-based Multi-Actor Multi-Criteria Analysis. Energy, 2018, 155(jul.15):1032-1046.

[15] MarcoPiccini, SofiaRaikova, Allen M J , et al. A synergistic use of microalgae and macroalgae for heavy metal bioremediation and bioenergy production through hydrothermal liquefaction. Sustainable Energy & Fuels, 2018, 3(1):292-301.

[16] Jafarian S , Tavasoli A . A comparative study on the quality of bioproducts derived from catalytic pyrolysis of green microalgae Spirulina (Arthrospira) plantensis over transition metals supported on HMS-ZSM5 composite. International journal of hydrogen energy, 2018, 43(43):19902-19917. https://doi.org/10.1016/j.ijhydene.2018.08.171

[17] A K E , C E S B , D S A , et al. Long-term stable hydrogen production from acetate using immobilized Rhodobacter capsulatus in a panel photobioreactor - ScienceDirect. International Journal of Hydrogen Energy, 2019, 44(34):18801-18810.

[18] Belohlav V , Zakova T , Jirout T , et al. Effect of hydrodynamics on the formation and removal of microalgal biofilm in photobioreactors. Biosystems Engineering, 2020, 200(1):315-327. https://doi.org/10.1016/j.biosystemseng.2020.10.014

[19] Bose A , O'Shea R , Lin R , et al. Design, Commissioning, and Performance Assessment of a Lab-Scale Bubble Column Reactor for Photosynthetic Biogas Upgrading with Spirulina platensis. Industrial And Engineering Chemistry Research, 2020, 60(15):5688-5704. https://doi.org/10.1021/acs.iecr.0c05974