Bioresource Technology 234 (2017) 297–302

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Feasibility of carbon dioxide sequestration by *Spongiochloris sp* microalgae during petroleum wastewater treatment in airlift bioreactor

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HIGHLIGHTS

- Bioremediation of hydrocarbon petroleum in airlift bioreactor coupled to CO_2 fixation.
- Hydrocabonoclastic native microbial used to degrade hydrocarbon petroleum wastewater.
- *Spongiochloris sp* microalgae reduce greenhouse effect through maximal control of CO_2.

ARTICLE INFO

Article history:
Received 9 November 2016
Received in revised form 6 March 2017
Accepted 8 March 2017
Available online 10 March 2017

Keywords:
Petroleum wastewater
Native bacterial
Microalgae
Airlift bioreactor
CO_2 fixation

ABSTRACT

The aim of this work was to study the ability of using *Hydrocabonoclastic* native microbial and *Spongiochloris sp* microalgae in airlift bioreactors couples in order to restore hydrocarbons wastewater and develop the capacity of natural systems to reduce greenhouse effect through maximal control of CO_2 gas emission in atmosphere. The kinetic parameters of CO_2 gas fixation level and conversion it into biological material by microalgae as the biodegradation process effect in hydrocarbon have been evaluated.

The result present that maximum specific growth rate μ_{max} of *Spongiochloris sp* was (0.87 ± 0.04 day^{-1}) and the biomass productivity P_{max} was attended (1.5 ± 0.3 gL^{-1} day^{-1}) with maximal CO_2 biofixation rate RCO_2 (2.9205 gL^{-1} day^{-1}). At 30 °C and pH (7.6–7.4) the bioreactor showed a good wastewater removal efficiency (99.18%) in total hydrocarbons with COD stabilized within (1.30 g/L), this result obtained suggesting that, the bioreactor applied system represented a useful strategy for maximizing CO_2 biomitigation.

1. Introduction

In the world, the continuously control of carbon dioxide emission gas is very important due to environmental, economic and social demands. Total Emissions in 2014 around 6870 Million Metric Tons of CO_2 equivalent and contributed 81% of greenhouse gas emissions in world (Wilbanks and Fernandez, 2014). At that time, The industry participated by 21% of greenhouse gas phenomena emissions (Cheah et al., 2015), the industry of hydrocarbon petroleum produced diversity sources of pollution in soil, air and water. This type of pollution caused a dangerous effect to human health and animal's life but also ecological toxicity (Fowler, 1990; Gammon et al., 2002; Das and Chandran, 2010). The abundant use of petroleum had a negative impact on the atmosphere, principally associated to the CO_2 gas production, a main anthropogenic source to global warming.

Serval techniques were regarded and approved by deferent countries to limit dioxide carbon amount gas emissions (Packer, 2009). A number of algae their growth requirements are simple; nitrogen, phosphate nutrients, trace metals, water, CO_2 and sunlight, thus it was interesting to use the microalgae for carbon dioxide adsorption as an effective key for greenhouse gas mitigation. This approach of using microalgae was predominantly owing to their photosynthetic activity factor in bio transformative carbon dioxide (CO_2), high biomass productivity, high lipid accumulation, and their valuable non fuel co-products. Although, the carbon sequestration through CO_2 biotransformation by natural phenomena during microalgae cultivation, the field of algal production for CO_2 adsorption and its transformation to biofuels, was suggested as early as (Meier, 1955) but, after industrial revolution in 2013, the carbon dioxide (CO_2), which is a major greenhouse was

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http://dx.doi.org/10.1016/j.biortech.2017.03.041
0960-8524/

increased in it aerial rate from 280 to 390 ppm (Singh and Ahluwalia, 2013).

There were many reports which confirmed that aerobic heterotrophic bacteria with cyanobacteria consortia effaces for mineralize petroleum contaminated sites (Abed, 2010; Lee et al., 2013). The bacteria biomass and algal consortia were effective in mineralization of organic and inorganic pollutants, compared to the individual microorganisms (Subashchandrabose et al., 2011). Further, the algae bacteria consortium improved the mineralization pathway, although, the most important action in toxicity lessening was affected by bacterial cell and the microalgae was played a significant, complementary activity in biodegradation process by auxiliary the growing and action of the actual degraders (Borde et al., 2003).

Under optimized conditions the current CO_2 gas was adsorbed and converted by microalgae as biological material through increased growth, the absorption of carbon dioxide was observed to be greater in organic than aqueous medium (Maheswari and Palanivelu, 2014). There were many reports on the potential and bio-economics of algal biomass to reduce greenhouse effect and they discussed a different approaches to limit the greenhouse phenomena through reducing the CO_2 gas concentration in the biosphere at a progressively elevation average, this is the primary cause of global warming (Packer, 2009; Menyah and Wolde-Rufael, 2010; Bhakta et al., 2015; Li et al., 2016).

This study focused on the adoptive and application of sustainable, environmentally microcosm design technologies that demonstrate a perspective ecosystem. It was implicating to develop the capacity of natural systems to restore organic hydrocarbons contaminant, reduce greenhouse effect through maximal control of CO_2 gas emission in atmosphere and to adapt climate change phenomena by concentrating CO_2 and transferring the organic carbon of the contaminate to biological algal material. It is important to note that the treatment of major contaminated hydrocarbon composites in industrials pilot produced important quantity CO_2 emission in atmosphere.This investigation based on green laboratory scale microcosm which a wastewater contaminated by petroleum products was studied to prove that bioremediation strategy is efficient for biodegradation of petroleum hydrocarbons coupled to CO_2 fixation and greenhouse effect reducing.

2. Material and methods

2.1. Wastewater sample

Contaminated wastewater samples used in the experiments were obtained from a petrochemical industry, sampling zone situated in the north of Tunisia, the zone was previously polluted owing to petroleum storage tanks, principally diesel hydrocarbons. All the collected samples were stored at 4 °C after collection until required for further analysis. Wastewater used in this study, was characterized through standard protocols (APHA et al., 1998).

2.2. The microcosm description

The biodegradation process of petroleum wastewater compounds was established in green microcosm (Fig. 1). The pilot plant was designed and built in the Laboratory. Essentially, this system consisted of two glass's reactors, the first was airlift biological reactor which contained wastewater that was treated with native bacterial microbial and the second was airlift photo bioreactor, which contained a *Spongiochloris sp* green microalgae culture that was stimulated by NPK (20/20/20) ratio nutrient and it was exposed under light source during the treatment period.

A master flex air pump poly-tetra-fluoro-ethylene (PTFE) tubing was used to aspirate the CO_2 gas that was produced during the degradation of the contaminated wastewater in reactor 1 and injected into the liquid phase of the reactor 2 which contained the photosynthesis process.

At the same time, another pump aspirated the O_2 gas that was produced during algal cultivation in reactor (2) and injected into the liquid phase of the reactor (1) which contained the bioremediation process. The aeration rate was fixed on 0.4 vvm for the two pumps, the gases that were transferred between the two reactors were provided by aspiration and injection operation through a porous diffuser. Each reactor capacity was working with a total volume of 4 L for continuous experiments and the temperature was maintained at 30 °C with a Cryostat. The monitoring of each reactor was carried out by serval analysis. A Sterile syringe was used for each reactor sampling taken.

2.3. Analysis

2.3.1. Wastewater analysis

The bioreactor system was evaluated through deferent analytical analysis, all physicochemical, biological and characterization analysis of petroleum wastewater used for experiment to be studied were achieved agreeing to the AFNOR norms (AFNOR, 1987) and (AFNOR, 1979) also the standard protocols (APHA et al., 1998) were used.

The hydrocarbon wastewater was characterized by a pH of 8.3 ± 0.2, an Electric conductivity (EC) of 626 µS/cm, a redox potential (ORP) of -152 mV, a total suspended solids (TSS) of 497 ± 73 mg/l, with a total volatile solids (TVS) of 321 ± 55 mg/l, a Total Organic Carbon (TOC) of 123 ± 8.4 mg/l, a Total Nitrogen (TN) of 63.5 ± 2.0 mg/l, a Nitrate Nitrogen (NO3-1) of 1.06 ± 0.14 mg/l, an Ammonium Nitrogen (NH4 + 1) of 40.4 ± 4.4 mg/l, a Nitrite Nitrogen (NO2-1) of 0.21 ± 0.03 mg/l, an ortho-phosphates (OP) of 11.1 ± 1.3 mg/l, a Total Phosphorus (TP) of 17 ± 3.2 mg/l, a total phenol of 14 ± 0.04 mg/l, a Chemical Oxygen Demand (COD) of 285 ± 16.1 with a Biological Oxygen Demand (BOD5) of 0.95–0.63 g/l, an Oil and greases of 0.16–0.10 g/l and Total petroleum hydrocarbons (TPH) of 188.37 ± 6.14 mg/l.

2.3.2. Measurement of growth

In this experiments a green microalgae *Spongiochloris sp* was used (Bchir et al., 2011). The initial cell concentration was approximately, 10^8 cell mL^{-1} and it was cultivated at 20 ± 2 °C. To study the CO_2 fixation and biomass algal production optimal effect, the photo reactor exposed under a dark: light cycle of 18:6 h. [6]. During the treatment, a microalgae biomass was evaluated according to Becker method(Aslan and Kapdan, 2006).

The maximum biomass productivity P_{max} ($gL^{-1}day^{-1}$) was estimated according to(Anjos et al., 2013)as follow in Eq. (1). The specific growth rate μ_{max}(day^{-1})was determined depending on (Abreu et al., 2012) as explained in Eq. (2). The maximal carbon dioxide bio-fixation rate, $RC0_2$ ($g\,L^{-1}day^{-1}$) was estimated according to (Tang et al., 2011) as described in Eq. (3).

$$P_{max} = (B_T - B_0)/(T_f - T_0) \quad (1)$$

B_t and B_0 explain the biomass concentration ($g\,L^{-1}$) at the end and initial days of the treatment (T_f), (T_0), respectively.

$$\mu_{max} = (\ln C_2 - \ln C_1)/(T_2 - T_1) \quad (2)$$

C_1 and C_2 are the concentration of cells in exponential growth phase (T_1), (T_2), respectively.

$$RCO_2 = Cc\ P_{max}(MCO_2/M_C) \quad (3)$$

MCO_2 and M_C are the molar mass of CO_2 and C ($g\,mol^{-1}$), respectively.