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Review article

Phyco-remediation of industrial waste-water and flue gases with algal-diesel engenderment from micro-algae: A review

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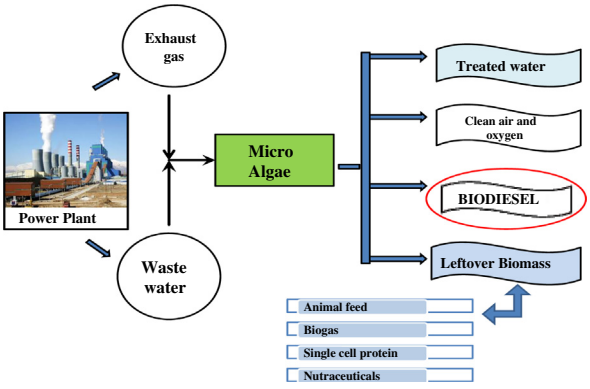
GRAPHICAL ABSTRACT



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ABSTRACT

Micro-algal bio-fuel is the most potential alternative of fossil fuel. There is not any commercially feasible algal-fuel technology available till now. Therefore, to make algal bio-fuel commercial, cumulating cheap raw materials and compelling down streaming of product with consummate utilization of biomass ought have to be applied. Coupling utilization of waste-water and flue gasses to algal development decreases production cost as well as give waste-water treatment and reduces air pollution. Therefore, this review focuses on potential outcome of consolidating waste-water, flue gasses with micro-algae production and to develop algal bio-fuel generation technology in the future course of study. This technology will address three major problems of the world viz. Energy depletion, global warming and water pollution. Hence, with the help of *in-situ* single process, three main aims of algal-fuel generation, remediation of industrial waste-water and flue gases may be achieved.

Contents

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1. Introduction

In the present era our world is suffering through various economic and environmental problems among which conventional energy depletion, global warming and water pollution are of more concern. These problems are affecting the whole society in different ways. Even though many alternatives to fossil fuels are available, but they have some limitations due to which major focus has been developed worldwide on renewable bio-fuel production. Bio-diesel can be a suitable answer to these problems, which does not contribute to net carbon dioxide (CO_2) accumulation in the atmosphere. Biofuel can as well support energy requirement of present era and produces lower levels of harmful gas emissions compared to conventional petroleum diesel [1]. Among different source of bio-diesel, micro-algae are most potent feedstock for production of bio-energy, algae with 50% lipid content and a dry biomass productivity of 50 g/m^2/day can potentially produce 10,000 gallons oil/acre/year [2]. By comparison to soybean it produces only 48 gallons oil/acre/year. This data indicates the importance of micro-algae in the large scale production of bio-diesel [3]. Another benefit of micro-algae is that it does not require arable land or fresh water; it can grow in saline water, domestic and industrial waste-water utilizing the excess nutrient present in it and accumulating heavy metals which can also help in reduction of water pollution. It is well known that due to global expansion of human population and advanced living standards of people, a high-level of water and air pollution is caused worldwide. Municipal, domestic, agricultural, and industrial sources generates waste water as the end product [4]. The recent reports of Central Pollution Control Board [CPCB (Central Pollution Control Board), 2011], New Delhi, India, revealed that waste-water generation in the nation is around 40 billion liters per day. Largely from urban areas only 20–30% of the generated waste-water is subjected to treatment. In most developing nations, waste-water of municipal, agricultural, and industrial activities are released into the surroundings without having enough treatment steps [5]. Waste-water contain many nutrients, excess of these nutrient loads in surrounding water bodies causes eutrophication or algal blooms often because of anthropogenic waste production [6]. One promising approach to achieve cost and energy drops during bio-fuel production is to integrate algal cultivation within existing industrial or waste treatment activity and mitigation of flue gases. For example, co-location of an algal process with power plants or waste-water treatment facilities would allow to use feedstock, waste streams and industrial flue gases [7]. This type of industrial symbiosis can result in greatly lessened economic and environmental cost, while also performing valuable remediation services [8]. Many studies have been done which shows that traditional feedstock for algal cultivation can be replaced with various waste drawn alternatives [9]. One suitable source of feedstock is the waste-water industry, which already use mixed algal consortia within conventional treatment processes [10]. This is because the nutrients needed for algal growth (such as compounds of nitrogen, phosphorous, trace metals and vitamins) can be sourced directly from secondary or tertiary waste-water [11,12]. Even under highly unfavorable growth conditions, algae can thrive and produce valuable by-products such as lipids (oils), carbohydrates, proteins, and various feedstock's that can be converted into bio-fuels and other useful materials [13]. If algae, waste-water and exhaust gases are combined in a consolidated system for remediation as well as bio-fuel production then it will drastically reduce the overall production cost of bio-product and also provide remediation credit [14]. There is a sudden need of algae fuel technology to fulfill world energy requirements, which can be achieved by using waste-water as a commercial media and industrial flue gases as carbon dioxide source [15].

This integration can offer an environment friendly and economically viable means for sustainable algal bio-fuel production since enormous amounts of water and nutrient (for example, nitrogen and phosphorus) can be recycled for algal growth in waste-water based algal cultivation system [16,17]. Micro-algae bio-fuel systems are capable of producing clean fuels while removing the food versus fuel and forest versus fuel concerns associated with first generation bio-fuels and lingo-cellulosic processes based on wood feedstock [18]. Despite being so promising and useful, the techno-economics of present micro algal bio-fuel production systems is not that effective to compete with petroleum-based conventional fuels as cost of production is higher [19]. Composition of micro-algae fatty acid is shown in Table 1. Different concentration of fatty acids has been extracted by using different extraction methods.

Micro-algal biodiesel has all properties compared to conventional diesel with minor differences. Comparison of properties of biodiesel from micro-algal oil and diesel fuel and ASTM biodiesel standard are shown in Table 2 [21].

There is an urgent requirement of taking an important measure to reduce the overall cost of production of bio-fuel. Cost reduction should be done at each step of bio-fuel production.

Objective of this article is to study the difference between the present micro-algae bio-diesel production techniques and the micro-algae grown in presence of waste-water and flue gas and to analyze the benefits of using waste-water and flue gas for microalgal bio-diesel production. On the basis of overall cost, pollution reduction credit and quality and quantity of bio-diesel production, utilization of waste-water and flue gas is far more beneficial than commercial media and pure carbon-dioxide.

There are various merits and demerits of using waste-water and flue gas for growth of micro-algae which needs critical analysis for the development of economically feasible technology.

2. Waste-water as a growth medium for algal growth

Waste-water is an excellent medium for algal growth, with carbon dioxide addition. Waste-water usage eliminates the need of fresh water, saves nutrient cost since nutrients are in abundance