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**REVIEW ARTICLE**

# Evaluation of Industrial Waste-water and exhaust gases for co-usage in Micro-algal growth and Biodiesel production: A review

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***Abstract***

Continued utilization of petroleum sourced powers results in fossil fuel exhaustion and contribution of these fuels to the increment of carbon dioxide in the earth prompts extreme harmful ecological effects. Fluid and vaporous effluents created are connected with every single anthropogenic activity. Micro-algal bio-fuel is the most potential option of fossil fuel and waste treatment. There is not any economically attainable algal-fuel innovation. To make algal bio-fuel fuel commercial, cumulating cheap raw materials and compelling down streaming of product with consummate utilization of biomass ought to be applied. Coupling utilization of waste-water and flue gasses to algal development decrease production cost as well as give waste-water therapy and reduces air contamination. Therefore this review focuses on potential of waste-water, flue gasses as a nutrient source for micro-algae production to develop algal bio-fuel generation technology in future course. Utilization of waste-water, leads to cost reduction of algal biofuels production and waste remediation.



## INTRODUCTION

As standard of living of human being is advancing each day, energy need also increasing simultaneously, from start of day till night and even while sleeping, energy is required. Main driving forces of present scenario are electricity and transportation which are directly linked to fossil fuels like coal and petroleum. Hence for maintenance of its driving forces then there is immediate requirement of Renewable fuel in huge amount. There are numerous sources of renewable energy like tidal energy, solar power and wind energy, etc. but all of these renewable sources of energy have some or other issues that need to be solved. Most potent renewable source of energy is Bio-fuel i.e., fuel generated through living cells or biomass. Bio-fuel has potential to sustain world's energy need and economic requirements, but there is need of proper technology development to make it commercially feasible. Model estimates from Pacific Northwest National Laboratory reported that algal biodiesel have the capacity to meet as much as 17% of the transportation fuel demand **(Wigmosta *et al.*, 2011)**.Biodiesel delivered from oil yields is a potential renewable and carbon impartial different option for petroleum fuels. Unfortunately, biodiesel from plant oil, waste cooking oil and animal fat are not capable to satisfy even a little fraction of the current vitality prerequisites for transport energizes. From past studies, microalgae seem, by all accounts, to be the main source of renewable biodiesel that is fit for taking care of the worldwide demand for transport fuels. Like plants, microalgae use daylight to produce oils but they do so more efficiently than crop plants.Oil producing efficiency of many microalgae very much exceed the oil production capacity of the best producing oil crops **(Chisti, 2007)**.

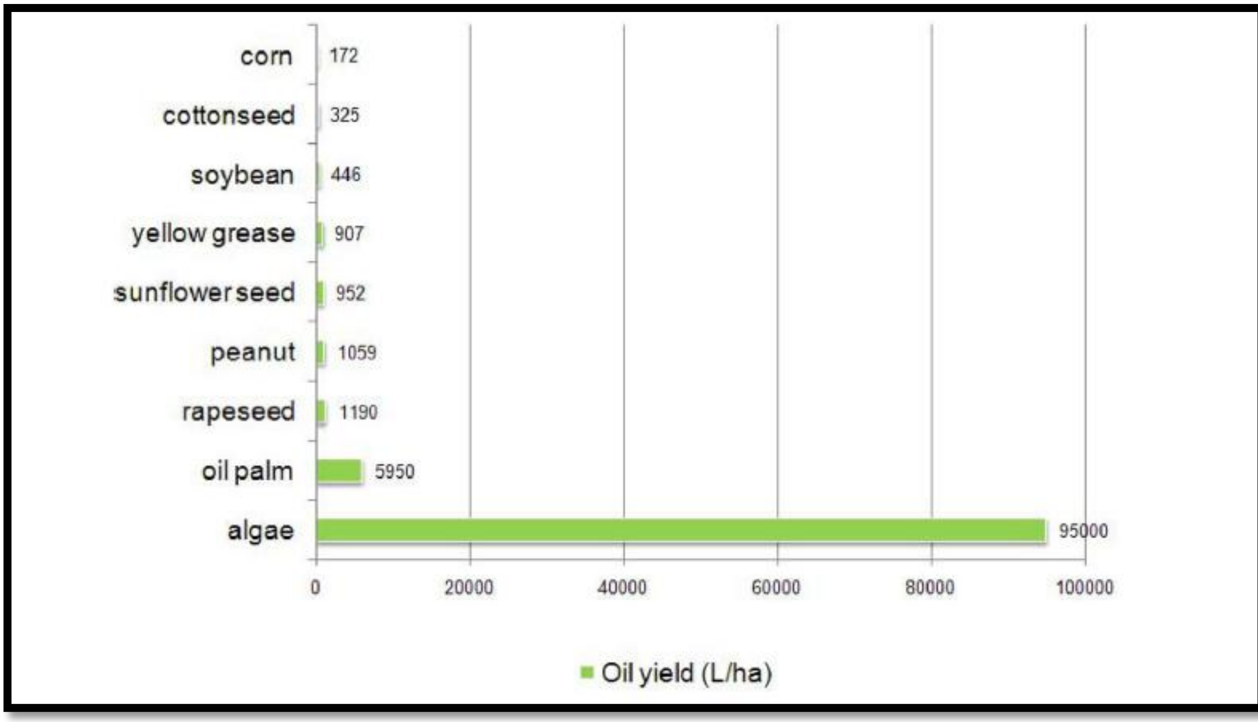


Figure 1 Oil Yields of various Feedstocks for Biofuel **(Trends, 2007)**

Figure 1 depicts capacity of algae as oil producing organism is very much higher than other currently available oil producing crops.

The potential of algae-based bio-fuels to replace petroleum fuels and mitigate greenhouse gas production through micro-algal photosynthesis has long been recognized. Various species of micro-algae can produce up-to 70-75 % lipid, which can be easily converted into bio-fuels. Oil content of some micro-algae is shown in Table 1

Table 1 : Oil contents of some microalgae **(Demirbas & Demirbas, 2011, Gouveia & Oliveira, 2009)**

| **Microalgae** | **Oil content (wt. % of dry basis)** |
|---|---|
| *Botryococcus braunii* | 25-75 |
| Chlorella emersonii | 63 |
| Chlorella protothecoides | 23/55 |
| Chlorella sorokiana | 22 |
| Chlorella minutissima | 57 |
| *Chlorella sp.* | 28-32 |
| Chlorella vulgaris | 14–40/56 |
| *Crypthecodinium cohnii* | 20 |
| *Cylindrotheca sp.* | 16-37 |
| *Dunaliella primolecta* | 23 |
| Dunaliella bioculata | 8 |
| *Isochrysis sp.* | 25-33 |
| Dunaliella salina | 14–20 |
| *Monallanthus salina* | >20 |
| *Nannochloris sp.* | 20-35 |
| *Nannochloropsis sp.* | 31-68 |

| | |
|---|---|
| *Neochloris oleoabundans* | 35-54 |
| *Nitzschia sp.* | 45-47 |
| *Phaeodactylum tricornutum* | 20-30 |
| *Schizochytrium sp.* | 50-77 |
| Scenedesmus obliquus | 11–22/35–55 |
| Scenedesmus dimorphus | 6–7/16–40 |
| Spirulina maxima | 4–9 |
| *Tetraselmis sueica* | 15-23 |

On the basis of specific growth conditions like Temperature, pH, aeration and suitable medium lipid content of micro-algae varies. Suitable species should be selected for growth in presence of waste-water and exhaust gases. Any species will not withstand with the toxicity of Industrial Waste-water. Even though there is huge potential in micro-algae biofuels system but currently there are no commercial algae to-fuel technologies that can overcome techno-economic barricade and address serious sustainability issues. Most Critical issue in large scale production of algae bio-fuel is cost effectiveness of technology. Large-scale commercial production of algae, however,is potentially more costly than traditional crop production. Algae cultivation requires significant quantities of energy and water and the use of off-site generated carbon dioxide. Harvesting is one of most energy consuming step of the algal biomass production, which can account for as much as 30% of the total cost of production (**Wiley *et al.*, 2009, Barbosa, 2003, Bare *et al.*, 1975)**. Additionally nutrients and water supply are among the most essential variables in algal production **(Ferrell & Sarisky-Reed, 2010, Stephens *et al.*, 2010**). There should be adequate economic viability in any technology so that it can be utilized overall industrially. To increase economic viability production expense should be least for which all resources should be used up to full extent. So using Industrial wastewater as nutrient medium for growth of microalgae can be a best option to reduce production cost because wastewater contains lots of essential nutrient required by microalgae which are just wash off into water bodies without any utilization. Additionally, algae biofuel production can be coupled with wastewater treatment, $CO_2$ of exhaust gases mitigation, and the production of value added products. It consists of a micro algal biomass production step that needs light, carbon dioxide, water and inorganic foods. In the biomass-recovery phase, the cells suspended in the broth are filtered from the water and residual nutrients, which are then processed to the biomass-generation phase. The recovered biomass is utilized for pulling up the algal oil that is further converted to biodiesel in a separate operation. Some of the spent biomass can be employed as animal feed and for recovering other possible high value products that might be present in the biomass. Most of the biomass undergo anaerobic digestion, which produces beggars to get electricity. Wastewaters from the anaerobic digester use as a nutrient-rich fertilizer and as irrigation water. Most of the force brought forth from the biogas is consumed inside the biomass-production procedure and whatever excess energy is traded to the gridiron. Additionally, CO2 emissions from the power generation stage are fed into the biomass production. Merely it is likewise hinted that the spent biomass could be deviated to a fermentation process to make bioethanol. In fact, a team of Danish researchers at the National Institute of Environmental Research (NERI) analyzed the production of bio-ethanol by microalgae. Results showed that this green algae produces 700 times more biomass per hectare than a conventional wheat field **(Fargione *et al.*, 2008).**

A convenient and cheap source of nutrients is municipal, industrial and agricultural wastewaters. Nutrient removal is an important aspect of wastewater treatment because rich nutrient streams discharged into natural water bodies can result in eutrophication. Furthermore, centrate (a nutrient-rich effluent stream from the anaerobic digestion process) is generally recycled to the head of the wastewater treatment plant and can increase the cost and destabilize the overall treatment process due to phosphorus accumulation. Since algae are known to grow in wastewater, a possible synergistic solution is to co-locate and integrate algal production with treatment of nutrient-rich wastewater and utilization of $CO_2$ from power plant flue gas **(Dalrymple *et al.*, 2013)**. Utilization of wastewater as a medium it will help in reduction of eutrophication and microalgae helps in phyco-remediation of wastewater. Another way to enhance growth of algae is addition of inorganic carbon which can be supplemented from exhaust gases of industries which otherwise cause air pollution through green house gas emission and finally leads to global warming.

To evaluate potential of Industrial waste-water and Exhaust gases to be used in place of nutrients for algal growth, there is a need of proper study of various pros and cons of this technology.

**Utilization of industrial waste-water as source of nutrients**

Among different resources found on the earth water is most vital one, and are severly affected by anthropogenic activities and by industry. Human beings and industries lead to sever pollution, which is a serious concern around the world. Advance urbanization, population explosion, rapid industrialization and technological advancements in agriculture have increased water pollution and led to the gradual depletion of its quality. A large quantity of wastewater disposed of at sea or on land has caused environmental issues which have led to environmental pollution, economic losses and toxic chemical release caused by the wastewater and its impact on agriculture. However, waste water which include nutrients and organic material has probable advantages for agricultural purposes **(Al-Dulaimi *et al.*, 2014)**. Shortages in fresh water supplies, today affects more than 1 billion people worldwide. Phytoremediation strategies, based on the capabilities of aquatic plants to reuse nutrients gives an striking solution for the bioremediation of water pollution and correspond to one of the most internationally researched issues. The subsequent application of the biomass from the remediation for the production of fuels and petrochemicals offers an eco-friendly and economic viable solution for water pollution problems and production of value-added products. Microalgae can be efficiently used to take away major amount of nutrients because they require elevated amounts of nitrogen and phosphorus for protein (45–60% of microalgae dry weight), nucleic acid, and phospholipid synthesis(**Rawat *et al.*, 2011)**. Dual application of duckweed and azolla plants for wastewater treatment and renewable fuels and petrochemicals production. Rapid industrialization results in the production of large amounts of waste which is usually discharged into the nearby water bodies. Despite appropriate legislation the contamination of the aquatic ecosystem is on rise consequently the inhabiting flora and fauna will become the victim of anthropogenic pollution. For algal biofuels to achieve their full potential, then algal cultivation must be inexpensive allowing for the economical mass production of feedstock. A convenient and cheap source of nutrients is municipal, industrial and agricultural wastewaters. Nutrient removal is an essential feature of wastewater treatment because rich nutrient streams discharged into natural water bodies can result in eutrophication. Furthermore, centrate (a nutrient-rich effluent stream from the anaerobic digestion process) is generally reused to the head of the wastewater treatment plant and can amplify the cost and destabilize the whole treatment process due to phosphorus accumulation. Since algae are known to grow in wastewater, a possible synergistic solution is to co-locate and integrate algal production with treatment of nutrient-rich wastewater and utilization of $CO_2$ from power plant flue gas. This approach basically reduces the cost of algal production, while prevent eutrophication and mitigating $CO_2$ emissions **(Gouveia, 2011, Pittman *et al.*, 2011, Campbell *et al.*, 2011, Sturm & Lamer, 2011)**. Large-scale marketable production of algae, however, is potentially more costly than conventional crop production. Algae cultivation requires significant quantities of energy and water and the use of off-site generated carbon dioxide. One energy intensive process, for example, is the harvesting of the algal biomass, which can account for as much as 30% of the total cost of production **(Wiley et al., 2009, Bare et al., 1975, Barbosa, 2003, Shelef *et al.*, 1984).** There are various toxic materials are also present in wastewater like heavy metals , which can be chelate by chelating capacity of microalgae. But for growth and remediation proper pre study is required. If indigenous species are employed for remediation and biodiesel production then it will be more beneficial.

**Exhaust gases as a inorganic Carbon source**

If large-scale intensive algal cultivation is to become a truth then sustainable and economic $CO_2$ sources must be found out. The dissolution of atmospheric carbon into water is partial by the high surface tension of water and relatively low $CO_2$ content of the atmosphere and this leads to carbon limitation in rigorous algal culture systems (**Van Den Hende *et al.*, 2012)**. As the addition of additional $CO_2$ can double yield, it is a important step towards achieving the high biomass requirements for development of future bio-energy ventures **(Cole *et al.*, 2014)**, yet the high cost of commercial carbon sources is a huge barrier to economic viable microalgal biofuels **(Rickman *et al.*, 2013)**. A technology which overcomes these two key barriers is to integrate algal culture with industries that produce waste water and waste inorganic carbon ($CO_2$). It has been well known, for example, that algae can be cultivated in nutrient and organic-rich waste water from agriculture, aquaculture **(Mulbry & Wilkie, 2001**) and municipal waste water (**Park *et al.*, 2011)** to remediate surplus nutrients from effluents(**Roberts *et al.*, 2013)**. Generally, atmospheric $co_2$ is not a sufficient source for sustaining highest algal growth. On the other hand, the high concentrations of $co_2$ in industrial exhaust gases have unfavorable effects on algal physiology. Consequently, both cultivation conditions (such as nutrients and light) and the control of the flue gas flow into the photo-bioreactors are significant to build up an competent "flue gas to algae" system**(He *et al.*, 2013)**.

**Studies on algal wastewater culture**

The production of different species of microalgae in consortium with other micro-organisms from wastewaters may represent an substitute process, for reduction in cost , for producing bio-fuels. Gouveia study was to evaluate the influence of pre-ultraviolet disinfection (Gouveia) in the production of lipids from biomass formed in high rate ponds. Two high rate algal ponds were evaluated: a pond that contains domestic sewage without disinfection and the other receiving domestic sewage earlier disinfected by UV radiation (uvHRAP). The UV disinfection did not lead to important alteration in fatty acid profile and total lipid productivities, although it increased algal biomass concentration and productivity as well as lipid content. Moreover, the overall biomass concentrations and productivities decreased with the UV disinfection, mostly as a consequence of a loss in bacterial load. Study concludes that uvHRAP disinfection may represent a potential strategy to support the cleaner and safer production of algal biomass when cultivated in consortium with other micro-organisms. Mainly regarding the use of wastewater as culture medium, together with a cheaper production of lipids for biodiesel, pre-disinfection may represent an advancement since removal expenses could be considerably trimmed due to the increase in lipid content (**Assemany *et al.*, 2015)**. The anaerobically digested swine lagoon wastewater (ASW) The concentrations of NH4+–N and $PO_4$ in the ASW were 680.7 mg/l and 145.7 mg/l, respectively(Wrede *et al.*, 2014).$NH_4^+$-N in wastewater is the key factor for micro-algal biomass and lipid production (**Chiu *et al.*, 2015)**. It is conceivable that locating large scale algae plants which take advantage of available high nutrient wastewater and industrial sources of CO2 and waste-heat can produce biodiesel for half the $8.03/gal price derived above. At the approximate price of $4/gal algae derived biodiesel would be competitive with other biodiesel feedstocks and petroleum derived diesel **(Menetrez, 2012)**.

Open ponds for algae production are comparatively (compared to PBRs) simple in creation and operation. There are three configuration categories: unmixed, circular, and raceway. Unmixed ponds are not handy, cannot be supplied with $CO_2$ efficiently, and are of low output **(Lundquist *et al.*, 2010).**

## Conclusions

In present era due to increase in technological advancements and urbanizations, a large amount of energy is required to support all above needs. There is a huge requirement of alternate energy. Biological source of energy is one of most potent alternative renewable energy which can sustain whole world energy need. Among biological source microalgae is best as it has various desired quantities. Cost effectiveness issue can be reduced by utilization of industrial wastewater as a nutrient source and exhaust gas as a inorganic carbon source. The harmful effect of waste-water and exhaust gas is well known, which can also reduced by coupling technology of remediation and biodiesel production using suitable strain of microalgae with optimize growth parameters. Co-utilization of exhaust gases and wastewater can leads to triple benefits, firstly energy production in terms of biodiesel, secondly air pollution reduction through carbon dioxide sequestration and lastly water pollution reduction as well as waste utilization. This technology is both environment friendly and economic viable.

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