Asian Journal of Environment & Ecology

7(4): 1-8, 2018; Article no.AJEE.44758
ISSN: 2456-690X

The Potentials of Algae from Waste and Fresh Water as a Source of Biodiesel

I. Yerima[1*] and L. Y. Fidi[2]

[1]*Department of Biological Sciences, University of Maiduguri, P.M.B. 1069, Maiduguri, Nigeria.*
[2]*Jigawa State College of Education, Gumel, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEE/2018/44758
Editor(s):
(1) Dr. Onofre S. Corpuz, CFCST-Doroluman Arakan 9417 Cotabato, Philippines.
Reviewers:
(1) Gisel Chenard Díaz, Federal University of Rio de Janeiro, Brazil.
(2) Maurilio Gustavo Nespeca, Institute of Chemistry, Universidade Estadual Paulista "Júlio de Mesquita Filho", Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/26723

Original Research Article

Received 02 August 2018
Accepted 11 October 2018
Published 20 October 2018

ABSTRACT

The demand and use for energy is increasing continuously due to industrialisation, desertification, cost of electricity, depletion of petroleum resources, human population and increasing commercial activities. The basic and traditional sources of energy has been petroleum resources, natural gas, coal, hydro and nuclear, however, the major disadvantage of using petroleum based fuel is atmospheric pollution due to greenhouse gas (GHG) emissions caused by inefficient burettes, hence inefficient indiscriminate burning of enormous amount of petroleum diesel has increased CO_2 level in the atmosphere which traps and prevent the heat from going to the outer atmosphere, thereby causing global warming. Algae were grown in waste and fresh water with NPK added to the tap water. The biodiesel was produced through the process of extraction, heating and transesterification. NaOH as a catalyst with methanol and hexane were added The result of this research revealed that 33% and 29% of was extracted from 11.5 grams 10.5 grams from the dry weight of algae from waste and fresh water respectively. It can be concluded from the result of this research that algae is a potential alternative source of biodiesel compared to oil from seeds. Biodiesel from algae is a perfect replacement or alternative to petroleum diesel. This is because algae are found everywhere, easy to cultivate in a small pond, and it is more effective than vegetable oil.

**Corresponding author: E-mail: ibrahimyerima@gmail.com, ibrahimyerima32@gmail.com;*

Keywords: Algae; biodiesel; fertilizer; waste water; hexane.

1. INTRODUCTION

1.1 Background of the Study

Due to increasing awareness of the depletion of fossil fuel resources and environmental issues. Algae can be produced using fresh water resources [1] or using saline and waste water [2], because it has a high flash point [3] it is degradable and relatively harmless to the environment if spilled [4,5]. Biodiesel became more and more attractive in the recent years due to growing awareness regarding the depletion of fossil fuels and increased harmful emissions [6], efforts are being made to develop renewable green fuels like biodiesel and bioethanol from different waste/natural resources [7]. About 30 billion (30 x 10^9) litres of fuel are utilised worldwide annually due to high demand and limitation posed by first generation biofuel [8]. These problems has forced the scientist to look for alternative sources of diesel fuel which is cheap, accessible and environmentally friendly. Petroleum diesel was identified as expensive, hazardous and a source of atmospheric pollution and greenhouse gases (GHG) emission, hence burning can cause an increase in carbon dioxide (CO_2) level thereby causing global warming [6].

The possible alternative to the petroleum diesel is biodiesel from any biological material, which is not in competition with food [9]. The production of biofuel from algae gained more attention due to the fear of using crop and food-producing plants will affect human food demand besides, algae have 20% - 80% oil content that could be converted to kerosene oil and biodiesel. The diesel produced from algae is economically easy, different species such as tribonema, ulothrix and euglena have good potential for biodiesel production, more so gene technology can be used to enhance the production of oil and diesel content [10]. The oil press technique was identified to be simple and popular extracting about 75% of oil from the algae, the hexane solvent combined with the press method extracts about 95% of the oil from algae, while the supercritical method extracts 100% of the oil [11]. The production of biodiesel from algae has the benefit of reducing carbon and nitrous oxide and other greenhouse gases emission that comes from fossil fuel [12]. The process gives off pure oxygen and water vapour. To stop or reduce CO_2 emission is to fix biomass, through the process of photosynthesis ,because microalgae possess a greater capacity to fix CO_2 compared to C4 plants [13] The greenhouse gas (GHG) emissions of carbon dioxide (CO_2) contributes up to 68% of the total emissions [6]. The most economical and environmentally friendly approach to overcoming the problem of fossil carbon dioxide emission would be to reuse the carbon dioxide through fixation in to biomass production like algae in a small pond. Carbon dioxide increases the growth of certain microalgae species it has the great capacity to fix CO_2 compared to C4 plant [12]. Microalgae can be propagated in an open race way pond or closed photo reactors. The potential use of microalgae after sequestration could include biodiesel production, fodder for livestock, production of colorant and vitamin [12].

Algae are found in kingdom plantae, sub-kingdom thallophyta, division phycophyta (algae). Different classes of algae include cyanophyta, phaephyta, rodophyta, euglenophyta, baccilariphyta, chlorophyta. Algae are unicellular or multicellular organisms that photosynthesis, but lack features such as leave, roots, seeds and flowers of higher vascular plant. Algae have wide ranging classification falling within several groups [14] from plant through to protists (single celled organism) even bacteria (blue-green algae), they are commonly found in aquatic environment both fresh and marine environment or even dry environment where they can live in symbiotic relationship with fungus as lichen. Many algal species move themselves through water column; while others float, attach themselves to object by means of an organ called hapteron in water or terrestrial environment. It is unknown how many species of algae in Nigeria and the world at large, but there are more than 3000 species of algae that have been reported so far, It was estimated that the 36000 known species comprised only 17% of the potential total number of algal species, making the total diversity of algae approximately 200,000 species worldwide [15], the various species of algae include spirogyra, microalgae, seaweed, e.t.c [16]. Algae can be grown in the dark in fermentation tank sustained by sugar rather than photo synthetically in the open.

Table 1. The yield per acre of oil and biodiesel from algae and plants sources

Plant sources	Quality of oil (liters/acre)	Quantity of diesel/barrel (Litters)
Corn	15	-
Soya bean	48	1 (159 Litters)
Sun flower	102	-
Rep seed	127	-
Microalgae	1850 (based on actual biomass yield)	1500-2000
Microalgae	5000 (based on theoretical laboratory yield)	-

Source: Aquatic Energy 2015 [17], EcoGeek, 2008 [18]

Algae can be economically converted to solid fuel (dry and compressed), methane gas (anaerobic digestion) or liquid transportation fuel (fermentation) fuel such as ethanol and biodiesel (extraction) or used as animal feed, align extract or blue litmus ink from the plant. This research thought it wise to extract and esterify the algae oil to biodiesel to run diesel automobile, industrial machines and electricity generating plants from algae. Biodiesel is equivalent to bio fuel made from the renewable biological material such as vegetable oil or animal fats as well as algae. While there are numerous interpretation being applied to the term biodiesel, strictly speaking the term biodiesel refers to an ester or oxygenate made from oil and alcohol. Biodiesel is 100% a biological product.

Extracting or producing biodiesel from algae provide the highest net energy because converting oil into biodiesel is much less energy intensive than the method of converting fuels such as ethanol, methanol, methane etc. this characteristic has made biodiesel the favourite end product from algae. The production of biodiesel from algae has the benefits of reducing carbon and nitrous oxide (NO_2) and other greenhouse gas emission that comes from fossil fuel through industries, automobiles and other anthropogenic activities. The process gives off pure oxygen and water vapour. Light from concentrated solar panel is conducted in algae chamber via fibre optics once the algae grows to maturity it is harvested for conversion into biodiesel fuel, hence algae strain is not only useful for production of biodiesel but also waste treatment [19].

Biodiesel can be produced from vegetable oil, soybeans oil, and animal fat e.t.c. According to some estimate, the yield (per acre) of oil and hence biodiesel from algae is over 200 times the yield from the best performing vegetable oil. Below are the values of biodiesel that can be generated from plant sources;

In Louisiana (USA) algae is being harvested and turn into biodiesel by taking CO_2 from local industry and pumped into algae pond which are harvested every 3 to 5 days (Aquatic energy 2015).One acre of soya bean can produce one barrel of biodiesel in a year while algae produce between 1500 to 2000 barrels [18]. It was reported that the largest possible source of suitable oil comes from oil crop such as rape seed, palm or soya bean. In U.K. rapeseed is the largest for biodiesel production (www.esru.stracth.ac.uk). The problem associated with their production include oil quality and quantity and also the method used for their production in addition to general properties of oils taken from different natural species as well as talking of biodiesel production and utilisation [20].

2. MATERIALS AND METHODS

2.1 Materials

The materials and method involves the use of the following equipment and substances for the growth, extraction and trans esterification of oil from algae to produce biodiesel.

Basin
Thermometer
Measuring cylinder 100mls
NPK fertiliser 250g
Mortar and pestle
Drying oven
Electronic precision balance (model 700, U.S. PAT.NO.2729.439).
Glass Petri dishes
Conical flask 100mls
Beaker 250mls
Thermostatic shaker
Gasoline
Hexane 40ml
Ether solution 40ml
NaOH 0.30g
28ml Methanol
Filter paper 12.0cm/funnel
Water

2.2 Methods

2.2.1 Method of growing algae

15 litres of waste water and tap water was collected from the drainage of the female's hostel University of Maiduguri in a basin and kept in the open for adequate sunlight in the experimental garden of the Department, of Biological Sciences, University of Maiduguri. Dibenedetto [21] reported that aquatic biomass has long been cultivated in salty water or fresh waste. Stewart and Hesami [22] reported that the capture of CO_2 produced by combustion of fossil fuel used in electric generation can be achieved by amine scrubbing of the flue gases. This process may be costly and can be replaced by an option such as incomplete membrane separation, molecular sieves or desicant absorbtion. 250 g of NPK fertiliser was weighed on the electronic precision balance (Model 700, U.S. PAT.NO.2729.439) and added to the tap water, with 60g of algae was added as inoculants (seed) to the tap water and allowed for some time to grow. Pitman et al [23] suggested that waste water is a nutrient source, but cannot feed the algae directly unless it is processed by bacteria through anaerobic digestion or it can kill the algae, It was further suggested that ,the organic fertiliser from biogas digester can be used to grow algae but must be cleaned and sterilised. After then, 10 litters of water were added at regular interval to sustain minimum amount of water and moisture required for growth. Stecker [24] reported that to produce one litre of algal biofuel manufacturers must use 3315 to 3650 litres of water or up to 123 billion litres for 39 billion litres of algal fuel A thermometer was mounted to measure the daily temperature of the water.

2.2.2 Method of producing biodiesel from algae

Various methods such as transesterification, blending, cracking, microemulsification and pyrolysis have been developed to convert oils from biological sources into biodiesel that is comparable to diesel fuel. Trans esterification, by a number of consecutive reversible reactions is the most common method: triglycerides are converted stepwise to diglycerides, monoglycerides, and finally glycerol with the liberation of fatty acids methyl ester as biodiesel [25]. The method or processes involved in the production of biodiesel from algae include the following stages.

2.2.3 Extraction of algal oil

Two Petri dishes containing 50g of fresh algae was grounded in a mortar with a pestle and placed in an oven at a temperature 160^{o}c for 10 minutes to dehydrate. 40mls each of hexane and ether solution were added to the grounded and dehydrated algae to bring out oil from the cells of the algae. Al-Iwayzy et al. [26] reported that the lipid extracted was heated to 48°C at the same time NaoH was added to 11mils of methanol and hexane. The mixture was kept in a beaker and allowed to stand and settle for 22 hours. The mixture was filtered using filter paper and funnel into a conical flask. The biomass was collected and weighed; the sample was heated to evaporate hexane and ether solution from the extracted oil. The oil from nuts and seeds is extracted mechanically using presses or expelled, which can also be used for microalgae. The algal biomass should be dried before the process. The cells are broken down with a press to leach out the oil. About 75% of oil can be removed through this method and no special skills are required [27].

2.2.4 Transesterification

A 0.30 g of NaOH was dissolved in 28mls of methanol and stirred properly for 20 minutes; the mixture was used as the catalyst of the reaction. The catalyst was poured into the algal oil in a conical flask where the solution was put into the thermostatic shaker and was shaken for 3 hours with the solution kept for 16 hours to stand and settle. The oil can be obtained by various chemical methods such as transesterification acid catalysed methonolysis etc [20]. Here the biodiesel and sediments were seen clearly and stratified. Biodiesel was separated using filter paper and funnel separator, where the biodiesel was washed by cold water bath and air dried by fanning and then stored in a bottle.

3. RESULTS AND DISUSSION

From the result presented in the table below (Table 2) oil was generated from both algae grown on waste water and tap water and subsequently used in biodiesel production. Bhakta and Ohnishi, [27] reported that tremendous biomass growth of aquatic weeds in nutrients enriched aquatic environments up taking various pollutants has received considerable interest in applying as a potential feedstock for producing sustainable biofuel. This is compared to other crops like corn and soya bean algae produces more oil with other fuels like bio-oil, biodiesel, bioalcohol, biohydrogen and biogas which can be obtained after the liquid feed extraction [28]. Algal biomass contains carbohydrate, protein and lipid/natural oil. The bulk of the natural oil is in the form of tricylglycerol which is the right kind of oil for producing diesel [12]. In addition to the fuels algae has long been cultivated as a source of industrial chemicals like agar, alginінate, carragenans and fucerellans or as food for human and animal feed [29] The lipid content of microalgae on a dry cellular weight basis usually varies between 20 and 40%, a lipid content as high as 85% has been reported for selected microalgal strain [21]. The vegetable oil content of algae can vary with growing conditons and species, but has been known to exceed 70% of the dry weight of algal biomass [30]. The loss in weight during the process of dehydration and extraction amounting to 3.8g and3.0g which could be attributed to volatile substances. About 33% and 29% of oil was extracted from 11.5g and 10.3g dry weight of algae grown on waste water and tap water respectively, while Vijayaraghavan and Hemanathan [24] obtained a lipid content ranging from 41% to 49%, Murthy, [31] obtained 101,249.2 litres/ha/yr. The dry weight constitutes 43% and 45% of the fresh of algae plant from waste and tap water respectively.

Some species of algae have the ability to produce up to 60% of their dry weight in the form of oil. The 26% of the total biomass constitute the left over biomass after extraction of oil. This can be compressed into solid biofuel or digested anaerobically to produce biogas (methane). The main obstacle to the commercial production of biodiesel is its cost and feasibility characteristics, they can be grown in fresh water or synthesised using ocean water or waste water, they are degradable and relatively harmless to the environment if spilled [32]. The differences in weight of 3.7g (15%) and 3.9g (17%) between fresh weight and by products could be attributed to volatile substances. Direct transesterification was unsuitable for wet biomass as indicated by [33,24]. Hence it is ideal to dry algae before extraction. Direct extraction could be affected by the hydration level of the oil due to wetness, because the oil is hydrophilic.

American Society for Testing Material (ASTM) [34] published new biodiesel blend specification as seen in table below (Table 3). To assess the potential of biodiesel, the properties of the diesel such as density, viscosity and Ph. [35]. were determined and comparison were made with the algal biodiesel, fossil diesel and ASTM biodiesel standard and it shows that the fuel properties of algal biodiesel is comparable to ASTM biodiesel standard and fossil diesel [34,36], therefore algal biodiesel (0.884Kgl^{-1}) is a potential diesel better than fossil diesel (0.838Kgl^{-1}).The biodiesel was described to be environmentally friendly.

Table 2. Table showing fresh and dry weight of extracted oil and residue of algae

Treatments	Fresh weight (g)	Dry weight (g)	Extracted oil (g)	Biomass (g)
Waste water	25.5	11.5	3.8	6.5
%		56%	33%	26%
Tap water	23.0	10.3	3.0	5.8
%		55%	29.1%	23.2%

Table 3. Table showing some properties of algal biodiesel, fossil diesel and ASTM biodiesel standard

Properties	Algal biodiesel	Fossil diesel	ASTM biodiesel standard
Density Kgl^{-1}	0.884	0.838	0.84-0.90
Viscosity (mm^2s^{-1}cp at 40°C)	4.4	1.9-4.1	3.5-5.0
PH	7.2	7-9	7-9

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

It can be concluded that an algae as a third generation biofuel is a potential source of biodiesel and an economical choice for biodiesel production because of its availability and low cost and as a third generation fuel. Algal biodiesel is technically feasible because algae is easy to cultivate and harvest without much stress or space, high oil yields and reduced pressure on cultivable land. Algal biodiesel stability is relatively better than seed based biodiesel [37].

4.2 Recommendation

This research, therefore, recommend further research to be carried out on types of algae and quantity of biodiesel produced for possible use in large quantity by various machines to either supplement or replace the traditional fuel used in industries or homes for coooking due to the numerous advantage and importance of algae to the human environment. It was reported that high value strains oil rich algae in waste water can simultaneously remove more than 90% of nitrates and more than 50% of phosphorous from the waste water. Because waste water treatment plants and their facilities have no cost effective means of removing large volume of nitrates or phosphorous from treated water [38]. In addition to other advantages mentioned earlier, algae grows 20 to 30 times faster than food crops and contains up to 30 times more fuel than equivalent amount of other biofuel sources such as soya bean, canola, jatropha or even palm oil. Studies shows that they can also produce up to 60% of their biomass in the form of oil or carbohydrates. Algae can yield up to 94000 litres/ha/year of biofuel compared to corn which yield about 560 litres annually [8]. The utilisation of waste and ocean water is strongly advocated due to the continuing depletion of fresh water resources. Strains of algae can remove 90% of nickel and zinc from industrial waste water in relatively short period of time [39].

ACKNOWLEDGEMENT

We wish to acknowledge the Department of Biological Sciences University of Maiduguri, Maiduguri Borno State, Nigeria for the space and all the facilities used in this research. The research would not have been successful without the cooperation of the technical staff of the Department, we are great full for that.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jia Y, Xu M, Zhang X, Hu Q, Sommerfeld M, Chen Y. Life-cycle analysis in biodiesel product from microalgae: Water footprint and nutrient balance. Bio Resources Technology. 2010;10.1016.
2. Clayton BC. First algal biodiesel plant goes online compounds in the green alga *Tetraspora* sp. CU2551. Plant Physiol. Biochem. 2008;70:7–13.
3. Dinh LTT, Guo Y, Mannan MS. Sustainability evaluation of biodiesel production using multicriteria decision – Making Environmental Progress and Sustainable Energy. 2009;28:38-46.
4. Demirbas A, Fatih Demirbas M. Importance of algae oil as a source of energy conversion and management. 2011;52(1):163-170.
5. Demirbas AA. In expressions of oil and fats feedstock for production of biodiesel. Energy Education Science and Technology Part A: Energy Science and Research. 2009;23:1-13.
6. Ho SH, et al. Perspectives on microalgal CO2-emission mitigation systems; 2011. Available:http://www.crcribase.com/isbn/9780849314674 (Accessed June 2011)
7. Chacraborty R, Chatterjee S, Mukhopadhyay P, Barman S. Progress in waste biomass derived catalyst for production of biodiesel and bioethanol: A review. Proceedia Environmental Sciences. 2016;35:546–554. Available:www.sciencedirect.com
8. Ullah K, Ahmad M, Vinod S, Sharma K, Penjmei Lu, Harvey A, Zafar M, Sultana S, Anyawu CN. Algal biomass as a global source of transport fuel: Overview and development perspective. Progress in Natural Science. 2014;24(4):329-339.
9. Mata TM, Martins AA, Caetano NS. Microalgae for biodiesel production and other applications: A review. Renewable and Sustainable Energy; 2010.
10. Murthy GS. Theoretical estimation of the potential of algal biomass for biofuel

production and carbon sequestration in Ethiopia. International journal of Renewable Energy Research. 2013;3(3): 560–570.

11. Newman S. How algae biodiesel works; 18 June 2008. Available:https://science.howstuffworks.com
12. Bhola V, Swalaha F, Kumar RR, Singh M, Bux F. Overview of the potential of microalgae for CO_2 sequestration. Int. J. Environ. Sci. Technol. 2014;11:2103–2118.
13. Bhakta JN, Ohnisi K. Biofuel potential of aquatic weeds. Int. J. Env. Tech Sci. 2015; 1:15–20.
14. Stockenreiter M, Haupt F, Graber AK, Seppälä J, Spilling K, Tamminen T, Stibor H. Functional group richness: Implications of biodiversity for light use and lipid yield in microalgae. In press. J. Phycol; 2013.
15. Wersal RM, Madsen JD. Aquatic plants, their uses and risks. A Review of the Global Status of Aquatic Plants; 2013. Available:https://www.Ippc.Int.largerfile.Ippc
16. Pokoo-Aikins G, et al. Design and analysis of biodiesel production from algae Grown through carbon sequestration. Clean Technologies and Environmental Policy. 2009;12(3):239-254.
17. Aquatic Energy; 2015. Available:http://www.acquaticenergy.org
18. ECOGeek; 2008. Available:http://www.ecogeek.org/content/veiw/1269/
19. Chen CY, Durbin EG. Effect of PH on growth and carbon uptake of marine phytoplankton mar. Ecol- Prog. Ser. 1994; 109:83-94.
20. Sreenath J, Pai A. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences; 17 March, 2018. Available:https://wwwresearchgate.net.17 March 2018.
21. Dibenedetto A. The potential of aquatic biomass for CO_2 – enhanced fixation and energy production; 21 March, 2011. Available:https//doi.org
22. Stewart C, Hesami M. A Study of methods poof carbon dioxide capture and sequestration – the sustainability of a photosynthetic bioreactor approach. Energy Conversion and Management. 2005;46:403–420. Available:www.sciencedirect.com
23. Pitman JK, Dean AP, Osundeko O. The potentials of sustainable algal biofuel production using waste water resources. Bioresources Technology. 2011;102(1): 17-25.
24. Vijayaraghavan K, Henianathan. Biodiesel production from fresh water algae. energy and fuel. 2009;23(11):5448–5453.
25. Takisawa K, Kanemoto K, Kartikawati M, Kitamura Y. Overview of biodiesel production from microalgae. Journal of Development in Sustainable Agriculture. 2014;9:120-128.
26. El-Iwayzy SH, Yusaf T, Raed A, Juboori AM. Biofuels from Fresh Water Microalgae *Chlorella vulgaris* (FWM – CV) for diesel engine. Energies. 2014;7:1825–1851.
27. Behera S, Singh R, Arora R, Sharma NK, Shukla M, Kumar S. Scope of algae as third generation biofuels. Bioeng. Biotechnol. 2014;2:90.
28. Fernandez AFG, Gonzalez CV, Sevilla F, Mohind JM, Grima E. Convertion of carbon dioxide into biomass by microalgae: How realistic a contribution may it be to significant carbon dioxide removal. Applied Miccrobiology and Biotechnology. 2012; 96(3):577-586. For species succession. Aquat. Microb. Ecol. 2002;28:279–288.
29. Barsanti L, Gualtieri P. Algae, CRC Press; 2005. Available:http://www.crcribase.com/isbn/9780849314674 (Accessed June 2011)
30. Baliga R, Powers SE. Sustainable algae biodiesel production in cold climates. International Journal of Chemical Engineering; 2010. Article 1D.102179, 13 pages. Available:https://dx.doi.org
31. Rao AR, Dayananda C, Sarada R, Shamala TR, Ravishankar GA. Effect of salinity on growth of Green alga *Botryococcus braunii* and its constituents. Bioresour. Technol. 2007;98:560–564.
32. Abishek MP, Patel J, Rajan AP. Algal oil: A sustainable renewable fuel for future. Biotechnology Research International; 2014. Article ID. 272814, 8 pages. Available:https://dr.doi.org
33. Michael D. Giury. Phycological Society of America Dol. 2012;111. Available:http://www.mihael.guiry@algaebase.org

34. Jaaskelamen H. Biodiesel standard properties. Dieselnet.com ASTM Publication; 2009.
Available:https://www.dieselnet.com.org
35. Hansen PJ. Effect of high pH on the growth and survival of marine phytoplankton: Implications for species succession. Aquat. Microb. Ecol. 2002; 28:279-288.
36. The Biodiesel Standard; 2006.
Available:http://www.biodiesel.org/resource/fuelfactsheets/standard_and_war_anties.shtm
37. Kheira AAA, Atta NMM. Response of *Jatropha curcas* to water deficit; yield, water use efficiency and oil seed characteristics. Biomass and Bio Energy. 2008;33(102008):1343-1350.
38. Battacharjee M, Siemann E. Low algal diversity systems are a promising methods for biodiversity production in waste water fed open reactor. Algae; 2015.
39. Chang AMY, Wong YS, Tam NFY. Performance of different microalgal species in removing nickel and zinc from industrial waste. Chemosphere. 2000; 41(1-2):251-7.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/26723