A Review on Treatment of Sewage Water & Biogas Purification by Algae

Dr. S. A. Thakur [1], Miss. Payal Bhautik [2], Mr. V.P. Sangore [1], Mr. Kuldeep Singh[3]

[1]Assistant Professor, Department of Chemical Engineering, SSBT's College of Engineering and Technology, Bhambori, Jalgaon

[2]Ph.D. Scholar Department of Chemical Engineering, Laxminarayan Institute of Technology, RTMNU Nagpur

[3] M.Sc. Chemistry, Dr. C. V. Raman University, Billaspur, Chhattisgarh

Abstract

Biogas is a developing alternative energy source engendered from the anaerobic digestion of organic matter by bacteria. It is composed primarily of methane and carbon dioxide (CO_2) with trace amounts of other toxic compounds, such as hydrogen sulfide (H_2S). The presence of CO_2 decreases the energy yield from the combustion of biogas. Past studies have utilized extravagant and environmentally deleterious chemicals to purify biogas. This study involves the construction of a biogas purification system that utilizes microalgae to metabolize and abstract impurities from the system as well as gives treatment to sewage waste water. This method has the distinct advantage of being renewable due to the self-propagation of the microalgae. The microalgae are additionally engendering hydrocarbon products that can be utilized as a bio-fuel.

Introduction

Industrial energy demands are rapidly outpacing the available fossil fuel sources, and the desideratum for alternative energy sources is widely apperceived. Experts have proposed biogas as one of these incipient sources. Biogas is a combustible coalescence of gases engendered from the anaerobic digestion of organic material by a community of microbes. Biogas is naturally engendered in astronomically immense quantities by landfills and waste sewage waste water treatment plants. Because of the wide availability and renewable nature of the organic materials and microbes required for biogas synthesis, biogas is a potentially efficacious and sustainable energy source

Biogas:-Biogas typically consists of 45-75% methane, 25-55% carbon dioxide (CO_2), and other compounds like hydrogen sulfide (H_2S) and ammonia (NH_3), ranging from hundreds to a thousand components per million. The methane in biogas is a valuable source of energy, while other components are impurities that pose major impediments to the commercial utilization of biogas. CO_2 has no energy yield through combustion and greatly reduces the energy yield per volume of biogas due to its high concentration. H_2S is toxic and highly corrosive, often damaging machinery used to convey and engender energy from biogas. Current methods of biogas purification involve chemical or mechanical processes, including chemical scrubbing, chemical adsorption, filters, and membranes. These are sumptuous and often environmentally hazardous due to the nature of the chemicals utilized. Quandaries associated with cost and sustainability averts biogas from becoming a competitive alternative energy source. Biological methods of purifying biogas subsist but are not utilized on an industrial scale.

Algae:- Algae are an informal term for a large, diverse group of photosynthetic organisms that are not necessarily closely related, and thus polyphyletic. Included organisms range from unicellular microalgae genera, such as *Chlorella* and the diatoms, to multi cellular forms, such as the giant kelp, a large brown alga which may grow up to 50 m in length. Most are aquatic and autotrophic and lack many of the distinct cell and tissue types, such as stomata, xylem, and phloem, which are found in land plants. The largest and most complex marine algae are called seaweeds, while the most complex freshwater forms are the Charophyta, a division of green algae which includes, for example, *Spirogyra* and the stoneworts. One definition is that algae "have chlorophyll as their primary photosynthetic pigment and lack a sterile covering of cells around their reproductive cells".[2] Some authors exclude all prokaryotes [3] and thus do not consider cyanobacteria (blue-green algae) as algae. . This are the common species of algae *Botryococcus braunii*, *Chlorella*, *Dunaliella tertiolecta*, *Gracilaria*, *Pleurochrysis carterae* (also called CCMP647) *Sargassum*, with 10 times the output volume of *Gracilaria*[7-10][4][6] [18-20] [20],

Sewage waste water:-The waste water is finally disposed off usually in water bodies i.e. rivers, streams, lakes and oceans. The waste elements of waste water are then acted upon by the natural agencies of purification like air, sunlight, bacteria and other micro-organisms etc. and are ultimately assimilated by the water body. When the waste water to be disposed off is large in volume and strong in character, the purifying and assimilating capacities of water may not be sufficient. The waste water treatment plants, therefore, act as unloading stations where all the undesirable and nuisance causing elements in the waste water are removed and the character of waste water is so altered that it can easily be accepted by disposal agencies without getting themselves degraded. [11-12]

Sewage Waste water Treatment:-A wastewater treatment plant has to follow certain regulations to be established. In the case the Council Directive of 21 May 1991 concerning urban waste water treatment constitutes the framework for the procession of domestic and industrial wastewater as well as run-off rain water. Its main focus is to protect the waters in the EU member states through appropriate collection, treatment and discharge of urban waste water. Moreover it is one of the three directives of the European Union on water policy. Based on the Council Directive EU member states have enacted national laws. [11-13]

Literature Review:-In the following literature review, here discuss pertinent information about the topics involved in our research, as well as recent, pertinent studies. Photosynthetic algae and a few other autotrophic microbes metabolize CO_2 to engender sugars and other compounds that can be utilized as bio-fuels. Other microbes, such as purple and green sulfur bacteria, consume H_2S during metabolism and engender solid elemental sulfur. These microbes can be utilized in a system that abstracts CO_2 and H_2S impurities from biogas. Because these microbes are self-sustaining and renewable with minimal nutrients, a biological system may be more sustainable and cost-efficient [15-17]

Salafudina, Roy Hendroko Setyobudib,c, Satriyo Krido Wahonod,e, Anggi Ninditaf, Praptiningsih G. Adinuranig, Yogo Adhi Nugrohoh, Andi Sasmitoh, Tony Liwangh was studied Photosynthetic pigments, including chlorophyll, have a consequential role since they provide the oxygen and the source of energy for all living things. Plant and algae magnification is affected by the photosynthesis speed which depends on the availability of carbon dioxide (CO_2).

And they conclude that identification of catfish pond dihydrogen monoxide showed that overgrown microalgae in the pond such as Scenedesmus sp., Nitzchia sp., Tetraspora sp., and Selenastrum sp. showed the number of (178 to 315) cells • mL–1. Biogas flow quantification showed the number of (18 to 29) L • min–1 and discharge quantifications showed the number of pond dihydrogen monoxide recirculation of (16 to 31) L • min-1. The percent efficiency rate of 50 % as the number of performance "natural /wild algae" is lower than the antecedent study[21] which is mutant strain of microalgae Chlorella sp. MM-2 was reported able to approximate 70 % on nebulous days and 80 % on sunny days. Similarly, it is lower than Chlorella vulgaris, SAG211-11b which was reported to be able to reduce the amount of 97.07 % CO_2 26. However, 50 % percent efficiency in this preliminary study was higher than the performance of micro algae Arthrospira sp. which was reported be able to reduce the calibers of CO_2 by 2.5 % to 11.5 %22.This study is perpetual, concretely ameliorating purification tank, for amending CO_2 capture efficiency that will impact directly on elevated levels of methane.[20].

Praptiningsih Gamawati Adinurania, Roy Hendroko Setyobudib,c*, Satriyo Krido Wahonod,e, Maizirwan Melf, Anggi Ninditag, Endang Purbajantih, Soni Sisbudi Harsonoi, Andoniana Rakoto Malalaj,k, Salafudinl, Andi Sasmitom was studied that CO_2 is the main gas impurity on biogas engenderment which must be reduced to engender optimum CH_4 content of biomethane. This biogas purification research was conducted at experiment field of PT Bumimas Ekapersada, Cikarang, Bekasi, Jawa Barat, Indonesia from April until June 2013. The research purport was compare the purification results of four sorption materials: (i) imported products of solid adsorbent; (ii) domestic products of solid adsorbent; (iii) biological absorbent of Scenedesmus sp., and (iv) wild algae which grow on feline fish (Clarias gariepinus) pond as biological liquid absorbent. This research was reiterated six times to engender average (in percentage) of CO_2 capture efficiency and used t test as statistical inference. The test results showed that there were no paramount statistical different among the sorption materials.

They found results that solid adsorbent was able to capture 16 % to 19 % CO_2. The result was lower from anterior research which verbalized that capture efficiency was 25 %. However, CO_2 capture efficiency which range was accordance to reference was equipollent to 4 % to 20 %. Biological adsorbent capture efficiency was 14 % to 31 %. However, the antecedent result was higher than research which verbalized Scenedesmus sp capture efficiency was 2.5 % to 11.5 %. Additionally lower than research which verbalized that capture of biological absorbent was more than 90 %. It has been shown that biological purification from wild algae or Scenedesmus sp. can supersede the solid adsorbent.

They Conclude that domestic-made solid adsorbent have kindred capability with imported adsorbent which is in the range 16 % to 19 % of CO_2 adsorption. Biological absorbent of Scenedesmus sp. has kindred capability with solid adsorbent which is in the range 14 % to 31 % of CO_2 absorption. Biological absorbent of “wild algae” can capture CO_2 of 50 % on two purification cycles[21].

L. Mohanakrishnan, Kurian Joseph was studies biogas, a byproduct of anaerobic decomposition of organic wastes, contains 50–70% methane, 30–50% carbon dioxide, traces of hydrogen sulphide, fractions of dihydrogen monoxide vapour and other gases. Purification of biogas involves the abstraction of CO_2, H_2S and dihydrogen monoxide vapour from the biogas to surmount the quandaries like low energy density, corrosion in engines, pipelines and storage cylinders, reduced heating value, energy losses, GHG emissions etc., which obstructs its potential to be utilized as fuel. When biogas with H2S concentration of 27 ppm was passed through Sponge Iron bed depth of 100 mm, 300 mm and 500 mm, the H2S concentration decremented to 12 ppm, 9.93 ppm and 8 ppm respectively with 70 % abstraction of H2S achieved at a Sponge Iron bed depth of 500 mm. 99.98 % Carbon dioxide abstraction was achieved at the Na2CO3 flow rate of 800 LPH. Scenedesmus obliquus is found to be efficient in the capture of CO_2. The carbonate regeneration and bicarbonate degeneration was observed to be 8.03 % at the terminus of three days of algal treatment of Sodium bicarbonate effluent from the CO_2 scrubber of the purification unit. The CO_2 abstraction efficiency of Dihydrogen monoxide scrubbing method was found to be 30%.

The results of the study support Chemical Scrubbing with Na_2CO_3 solution for CO_2 abstraction than Dihydrogen monoxide Scrubbing. In lieu of bubbling the biogas in the stagnant scrubbing solution, biogas can be alimented against the spray of scrubbing solution. This process of establishing counter current flow between scrubbing solution and biogas reported better decarbonisation (99.98% CO_2 abstraction at 800 LPH flow rate of Na_2CO_3 solution, reported by this study).[22]

Rameshprabu Ramaraj, Yuwalee Unpaprom ,Natthawud Dussadee was studies algal biomass can be utilized for renewable energy sources, such as hydrogen, biodiesel and biogas. Currently, renewed interest in engendering bioenergy from microalgae has arisen because they can grow rapidly and convert solar energy into chemical energy via CO_2 fixation and, thus, are now considered one of the most promising energy sources. The cultivation of the microalga, C. vulgaris utilized low cost artificial medium which denominated as Rameshprabu medium. [23]

Rameshprabu Ramaraj, Natthawud Dussadee, Niwooti Whangchai, Yuwalee Unpaprom was studied The running down of fossil energy sources makes the engenderment of bioenergy an expected need ecumenical. Consequently, energy crops have gained incrementing attention in recent years as a source for the engenderment of bioenergy because they do not compete with victuals crops. Microalgae have numerous advantages such as expeditious magnification rates and not competing with pabulum engenderment. Because of the expeditious magnification, many high valuable products are engendered, e.g. pabulum, biofuel, etc. In reactor, ascendant microalgae species were including Anabaena sp., Chlorella sp., Oscillatoria sp., Oedogonium sp. and Scenedesmus sp. The content of total solids (TS) and volatile solids (VS) in the algae biomass was quantified; the results were average as 12500 g/m3 and 6320 g/m3, respectively.[24].

Rohit Sharma, Avanish K Tiwari, G. Sanjay Kumar, Bhawna Y. Lamba, and Girdhar Joshi was studied The process of integration of microalgae magnification with anaerobic digestion for the engenderment of biogas can significantly amend the economics and energy balance of biofuel engenderment. The integrated process of Chlorella pyrenoidosa cultivation (under ambient temperature conditions) along with the microalgae magnification predicated anaerobic digestion in batch type reactor mode or perpetual stirrer type rector mode is studied to minimize the overall biofuel engenderment cost. The process withal reduces the desideratum for fresh dihydrogen monoxide by utilizing anaerobic digester slurry dihydrogen monoxide. The Chlorella pyrenoidosa is cultivated in biogas digester wastewater as a nutrient source. The microalgae, Chlorella pyrenoidosa can be utilized for the nitrogen present in wastewater as a nutrient for its magnification. Modelling for the effect of nitrogen utilization is additionally performed by utilizing NetLogo software predicated on Monod Kinetics. The parameters for simulation in NetLogo software are taken from the experimental values. Chlorella pyrenoidosa could grow well in 10 lit capacity of batch type closed photo bioreactor. The net concrete magnification rate of microalgae Chlorella pyrenoidosa is found to be 0.6 D-1 and doubling time tdis 1.15 day. The magnification kinetics of microalgae is found to follow the Monod magnification model satisfactorily. The maximum concentration of Chlorella pyrenoidosa is 87.1 gm/L with nitrogen nitrate and COD reduction of 92% and 62.86% respectively. Treated biogas waste dihydrogen monoxide can be further utilized for the anaerobic digestion of algal biomass for the engenderment of biogas. The simulation and experimental results suggested that the cultivation of Chlorella pyrenoidosa in biogas wastewater may be considered as efficient, dihydrogen monoxide preserving as well as digestible biomass engendering method. [25]

Mirosław Krzemieniewski, Dawid Szwarc, Marcin Zieliński, Karolina Kupczyk, Magdalena Rokicka, Marcin Dębowski was studied the utilization of biogas originating from the methane fermentation process is one of the most promising methods for the engenderment of renewable energy. The study aimed to determine the possibilities of utilizing biogas from anaerobic digestion of dairy wastewater to intensify the engenderment of microalgae biomass. The tested culture was Chlorella sp., which originated from the Baltic Algae Culture Amassment. They found result up to 80% of CO_2 can be abstracted by the Cholrella Sp. and the effect of hydrogen sulphide withal reduce and the results substantiate the possibility of utilizing carbon dioxide contained in biogas to intensify the engenderment of microalgae biomass. Research has shown that the utilization of desulfurized biogas sanctions for higher technological effects cognate to biosequestration of carbon dioxide contained in a biogas, as well as the efficiency of microalgae biomass magnification.

M. Dinca, Gh. Voicu, M. Ferdes, G. Paraschiv, G. Moiceanu, P. Voicu, N. Ungureanu And M. Ionescu was studied the third generation of biofuels aims to obtain fuel utilizing aquatic microorganisms but additionally raw materials which does not imperil victuals security. Microalgae and macroalgae underwent an excruciating research, thanks to their capability to surmount the drawbacks cognate to the first and second generations of biomass resources. The third generation of biofuels derived from algae is composed by biodiesel, bioethanol, biohydrogen and biogas. According to M. Dinca, Gh. Voicu, M. Ferdes regardless of microalgae species and operating conditions, the proportion of methane in the engendered biogas is around 70%. This reveals that a good quality of conversion of the microalgal organic matter into methane is achievable. The engenderment of biogas through anaerobic digestion process offers consequential advantages over other forms of bioenergy engenderment, such as: one of the most energy-efficient and environmentally salutary technologies for bioenergy engenderment; greenhouse gas reduction; digestate represents an ameliorated soil conditioner which can supersede mineral fertilizer.

It was found in the literature that certain microalgal species can be good substrates for anaerobic fermentation, resulting in the engenderment of biogas with relatively high methane content and having the potential to supersede higher plant material like maize which is generally used today. Many researchers argue that the utilization of methane fermentation is the most efficacious method for the energetic exploitation of algae biomass. The algae biomass is considered a paramount biomass source, even if their utilization as energy source is still low around the world [26]

Petra Paroulkova, Katerina Sukacova, Katarina Murgasova, Tomas Vitez, Jan Chovanec was studied utilizing of algae in a biogas transformation is still in the commencement. However, the microalgae have sizably voluminous potential from the perspective of growing demands on biogas quality and trend of utilizing natural resources. First of all, it is their facility to fine-tune carbon dioxide (CO_2) utilizing photosynthesis and postulated competency of some algae to metabolize hydrogen sulphide (H_2S). Biogas contains not only required methane but additionally components causing its worse quality such as mentioned CO_2 and H_2S. Consequently, the algae are potential biological systems for biogas-conditioning. The microalga Chlorella pyrenoidosa Chick (IPPAS C2) was utilized for fixation of CO_2 and H_2S in our experiment. The microalgae were cultivated in a medium BG 11. The algal suspension was aerated with the biogas during a fortnight. Different values of CO_2 concentration quantified in the input and output corroborated decrease of CO_2 caused by intensive magnification of algal culture. Decline of H_2S was not corroborated.

According to their result after the experiments they conclude that this experiment was carried out to find possibilities of utilizing algae for biogas treatment. The experiment was focused to verify competency of tested algae Chlorella pyrenoidosa Chick (IPPAS C2) to fine-tune CO_2 and to metabolise H_2S. Results of the experiment have shown that algae are able to fine-tune CO_2 from biogas utilizing the photosynthesis. Flowing biogas containing CO_2 caused magnification of algal biomass which can be optically discerned not only in quantified optical density but additionally from taken photo documentation. There is visible gradual increase of colour intensity from beginning light to dark green. Further evidence of algae magnification is a partial absorption of CO_2 from flowing biogas and higher content of O_2 from Erlenmeyer flasks. Haplessly this experiment was not able to corroborate hypothesis of culled algae faculty to metabolise H_2S. They did not observe statistically paramount difference in concentration of H_2S between input and output of biogas from algae solution[27].

Pranas Baltrėnas and Antonas Misevičius was studied the current study is on the the utilization of macro-algae as feedstock for biogas engenderment. Three types of macro-algae, Cladophora glomerata (CG), Chara fragilis (CF), and Spirogyra neglecta (SN), were culled for this research. The experimental studies on biogas engenderment were carried out with these algae in a batch bioreactor. In the bioreactor was maintained 35 ± 1°C temperature. The results showed that the most opportune macro-algae for biogas engenderment are Spirogyra neglecta (SN) and Cladophora glomerata (CG). The average amount of biogas obtained from the processing of SN – 0.23 m3/m3d, CG – 0.20 m3/m3d, and CF – 0.12 m3/m3d. Considering the concentration of methane obtained during the processing of SN and CG, which after eight days and until the cessation of the experiment exceeded 60%, it can be claimed that biogas engendered utilizing these algae is valuable. When processing CF, the concentration of methane reached the caliber of 50% only by the final day of the experiment, which designates that this alga is less felicitous for biogas engenderment [28]

They used different species and conclude that, the most astronomically immense average amount of biogas was quantified during the processing of macro-algae spirogyra neglecta and reached 0,23 m3/m3d.. The assessment of both parameters, i.e. the amount of biogas and methane concentration, denotes that the most opportune algae for the engenderment of energy are both spirogyra neglecta and cladophora glomerata. During all the conducted experiments of processing all three kinds of algae, the anaerobic conditions were secured, and hydrogen sulfide concentrations were below 100 ppm. Consequently, biogas purification of this pollutant is not compulsory. The comparison of the emitted biogas and methane concentration during the processing of macro-algae with other biodegradable waste betokens that macro-algae is a congruous raw material for the engenderment of biogas. During the processing of algae, the amount of biogas fluctuates between 0,64 and 1,32 m3/m3d, and the volume of methane ranges from 0,24 to 0,68 m3/m3d. During the decomposition of other biodegradable waste, the amount of biogas reaches from 0,9 to 1,67 m3/m3d. However, the concentration of methane is lower as compared with that obtained from macro-algae[28].

References

1. Scott, S. A.; Davey, M. P.; Dennis, J. S.; Horst, I.; Howe, C. J.; Lea-Smith, D. J.; Smith, A. G. (2010).”Biodiesel from algae: Challenges and prospects”. *Current Opinion in Biotechnology*).
2. Oncel, S. S. (2013). "Microalgae for a macroenergy world". *Renewable and Sustainable Energy Reviews* 26: 241. doi:10.1016/j.rser.2013.05.059

3. Yang, Jia; Ming Xu; Xuezhi Zhang; Qiang Hu; Milton Sommerfeld; YongShen Chen (2010). "Life-cycle analysis on biodiesel production from microalgae: Water footprint and nutrients balance" *Bioresources Technology* 10: 1016.
4. Cornell, Clayton B. (29 March 2008). "First Algae Biodiesel Plant Goes Online: 1 April 2008" Gas 2.0. Retrieved 10 June 2008.
5. Dinh, L. T. T.; Guo, Y.; Mannan, M. S. (2009). "Sustainability evaluation of biodiesel production using multicriteria decision-making". *Environmental Progress & Sustainable Energy* 28: 38. doi:10.1002/ep.10335
6. Demirbas, A. (2011). "Biodiesel from oilgae, biofixation of carbon dioxide by microalgae: A solution to pollution problems". *Applied Energy* 88 (10): 3541. doi:10.1016/j.apenergy.2010.12.050 (http://dx.doi.org/10.1016%2Fj.apenergy.2010.12.050).
7. AH Demirbas (2009). "Inexpensive oil and fats feedstocks for production of biodiesel". *Energy Education Science and Technology Part A: Energy Science and Research* 23:1–13.
8. Carriquiry, M. A.; Du, X.; Timilsina, G. R. (2011). "Second generation biofuels: Economics and policies".*Energy Policy* 39 (7): 4222. doi:10.1016/j.enpol.2011.04.036
9. Greenwell, H. C.; Laurens, L. M. L.; Shields, R. J.; Lovitt, R. W.; Flynn, K. J. (2009). "Placing microalgae on the biofuels priority list: A review of the technological challenges". *Journal of the Royal Society Interface* 7 (46): 703. doi:10.1098/rsif.2009.0322
10. Hartman, Eviana (6 January 2008). "A Promising Oil Alternative: Algae Energy" *The Washington Post*. Retrieved 10 June 2008.
11. Abatzoglou, N. and Boivin, S., 2009, A review of biogas purification processes Bio fuels Bio Prod Bio Refining, 3, pp. 42–71.
12. Chu, S.P., 1942. The influence of the mineral composition of the medium on the growth of planktonic algae. *J. Ecol.;* 30:284-325.
13. Devinny, JS.and Deshusses, M A., 2007,Biofiltration for air pollution control. Lewis Publishers.
14. De Morais, M G.and Costa, JAV., 2007, Biofixation of carbon dioxide by *Spirulina sp*. and *Scenedesmus obliquus* cultivated in a three-stage serial tubular photo bioreactor. J Biotechnol; 129:439 – 45.
15. IPCC 2007,Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B.
16. Taleghani, G.and Kia, A.S., 2005. Technical–economical analysis of the Saveh biogas power plant. Renew. Energ. 30, 441–446.
17. Chatterjee, G., Houde, A.A., Stern, S.A., 1997. Poly(ether urethane) and poly(ether urethane urea) membranes with high H2S/CH4 selectivity. *Journal of Membrane Science*, 135, 99-106.
18. Algae FAQ
19. Bioenergy Selection of Optimal Microalgae Species for CO2 Sequestration
20. Ecogenics Product 2 Ecogenicsresearchcenter.org. Retrieved 15 April 2012.
21. ScienceDirect Procedia Chemistry 14 (2015) 387 – 393 Biological Purification System : Integrated Biogas from Small Anaerobic Digestion and Natural Microalgae Salafudina, Roy Hendroko Setyobudib,c*, Satriyo Krido Wahonod,e, Anggi Ninditaf, Praptiningsih G. Adinuranig, Yogo Adhi Nugrohoh, Andi Sasmitoh, Tony Liwangh

22. Received *9 November 2015* Received in revised form *27 December 2015* Accepted *7 Februari 2016* Carbon Dioxide Capture Efficiency Using Algae Biological Absorbent And Solid Adsorbent For Biogas Purification Praptiningsih Gamawati Adinurania, Roy Hendroko Setyobudib,c*, Satriyo Krido Wahonod,e, Maizirwan Melf, Anggi Ninditag, Endang

23. *International Journal of Renewable Energy and Environmental Engineering ISSN 2348-0157, Vol. 04, No. 03, July 2016* Chemical Scrubbing for removal of CO2 from Biogas using Algae and H2S using Sponge Iron L. Mohanakrishnan, Kurian Joseph

24. International Journal of Sustainable and Green Energy 2015; 4(1-1): 20-32 Published online December 31, 2014 doi: 10.11648/j.ijrse.s.2015040101.14 Biological purification processes for biogas using algae cultures: A review Rameshprabu Ramaraj, Natthawud Dussadee

25. International Journal of New Technology and Research (IJNTR) ISSN:2454-4116, Volume-2, Issue-3, March 2016 Pages 117-122 Cultivation of Green Microalga, *Chlorella vulgaris* for Biogas Purification Rameshprabu Ramaraj, Yuwalee Unpaprom ,Natthawud Dussadee

26. International Journal of New Technology and Research (IJNTR) ISSN:2454-4116, Volume-2, Issue-3, March 2016 Pages 128-133 Potential Evaluation of Biogas Production and Upgrading Through Algae Rameshprabu Ramaraj, Yuwalee Unpaprom ,Natthawud Dussadee

27. Journal of Energy and Chemical Engineering Nov. 2014, Vol. 2 Iss. 4, PP. 116-12 Simulation and Experimental Study of a Closed Model for Algae Based Biogas Production and Bioremediation of Waste Water Rohit Sharma, Avanish K Tiwari, G. Sanjay Kumar, Bhawna Y. Lamba, and Girdhar Joshi

28. 1-2016 Problemy Eksploatacji – Maintenance Problems 5 The Possibility Of Using Carbon Dioxide From Biogas In The Production Of Microalgae Biomass Mirosław Krzemieniewski, Dawid Szwarc, Marcin Zieliński, Karolina Kupczyk, Magdalena Rokicka, Marcin Dębowski Uniwersytet Warmińsko-Mazurski W Olsztynie, Olsztyn