The Pharmaceutical and Chemical Journal, 2024, 11(2):42-50

Available online www.tpcj.org

Research Article

ISSN: 2349-7092
CODEN(USA): PCJHBA

Designing an affordable method to separate bio-crude from liquefied wet wastes

Iqtiar Md Siddique

Department of Industrial, Manufacturing and Systems Engineering, the University of Texas at EL Paso, US.
*Email: iqtiar.siddique@gmail.com

Abstract Mankind is developing from the first invention of fire. After the industrial revolution it has increased its speed. As a result, use of energy source mainly fossil fuel has skyrocketed. However, fossil fuel is not renewable energy source. Now-a-days when most people use luxurious item it either directly or indirectly depend on fossil fuel. As example transportation medium can be used. Though the use of fossil fuel increasing its reserve is not increasing as a result it's been necessary that we search for another sources of fuel. Fecal sludge can be one of these sources of fuel. There are 8 billion people on earth by 2022. Many of them lives in under developed country where sanitation is a major problem. If fecal sludge is hydrothermally liquified we can get Bio-Crude as a product. The recent studies shows that hydrothermal liquefaction of fecal sludge can produce a significant percentage of crude. This process will solve both sanitary problem as well as problem regarding fossil fuel such as shortage of fossil fuel in future. However, separation of crude from the solution is still costly because of using solvent as normal practice. This thesis findings will help to find out a solution to separate Bio-Crude without using solvent.

Keywords bio-crude, liquefied wet wastes

1. Introduction

A total of 8 billion people populate the Earth today (Worldometers, 2023). The global population is expected to reach 9.8 billion by 2050, up from its current rate of growth of 0.84 percent as of 2022. The global population is expected to reach 9.8 billion by 2050, up from its current rate of growth of 0.84 percent as of 2022. A massive amount of fossil fuels are needed to meet the energy demands of the future, while the population keeps expanding. Some of the world's energy issues include the exhaustion of fossil fuel reserves, soaring costs, insufficient supplies, and pollution. The Global Economy estimates that 2019 gasoline consumption in Bangladesh would reach 4,000 barrels per day, a 35% increase from 2017. (Source: The U.S. Energy Information Administration). British Petroleum's statistics evaluation of world energy shows that while demand for oil is upwards of 1.6 Mb/d, the world's oil output rate is just 0.4 Mb/d. Furthermore, the burning of fossil fuels contributes to an increase in both world average temperature and emissions of greenhouse gases. Because of these issues, new forms of energy must be developed to compete with traditional fossil fuels, such as biomass-derived crude oil or biofuels. Wood scraps, energy crops, macroalgae, field crops and their waste products, municipal and animal wastes, and so on are all examples of biomass that could be used to produce fuel or chemicals [1-3].

Most of the people live in a under developed country. In these countries most common problem of regular life is sanitation problem. According to studies globally, approximately 600-700 million tons of solid waste and 250-300

million tons of FS are not managed in an environmentally safe manner [4]. There are currently 2.4 billion people without access to better sanitation facilities, and an additional 946 million people who are still using the toilet outside. And, the regions of sub-Saharan Africa and Southern Asia currently host the majority of the world's least-covered nations. (World Health Organization & United Nations Children's Fund (UNICEF), 2015). Where, Sub-Saharan Africa is expected to have a population of about 1.13 billion in 2021, whereas southern Asia will have a population of about 1.97 billion. In sum, the people living in these areas number more than half the world's total [5]. In this region, most countries are still in their developing stages. Being a developing nation, the high cost and often onerous management of its primary power

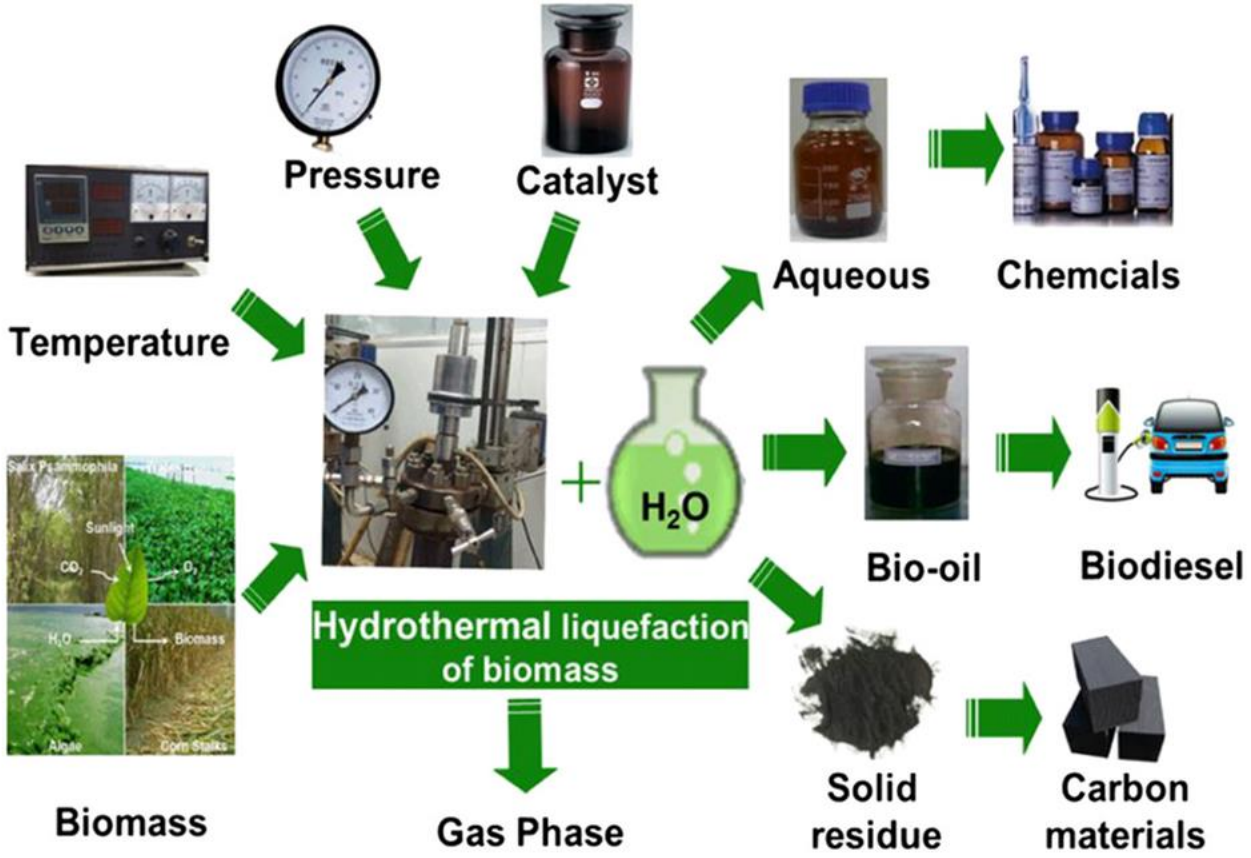

Figure 1: Hydrothermal Liquefaction Process

source—crude oil—makes it worthwhile to explore whether or not these wastes may be converted into a useful form of energy. To solve the waste management and oil supply problems simultaneously, a streamlined, low-cost, and effective process to turn this material into bio-fuel is required.

Many different kinds of waste can be found, including: Food scraps, paper, plastic, glass, and metal are all examples of the solid waste generated in homes and cities. Concrete, bricks, and wood are all examples of solid waste generated in the industrial and construction sectors. Wastewater, sewage, and various forms of liquid waste from homes, businesses, and other establishments are all classified under this category. Chemicals, batteries, electrical equipment, and medical waste are all examples of hazardous waste that can be harmful to both humans and the environment. Food scraps, grass clippings, and other biodegradable items are all examples of organic waste. Electronic garbage, or "e-waste," refers to obsolete or broken electrical gadgets. With the sanitation crisis and oil scarcity in mind, our primary concern will be with both solid and liquid waste. The percentage of water in solid waste is quite low (15-40%) [6]. Powerful facilities that convert garbage into useful energy are already in operation in both Sweden and Brazil [7]. However, sewage sludge has an extremely high moisture content, rendering this method ineffective. So, we shall be concentrating on liquid waste, more specifically human sludge.

Scope of this study: Every day, less of the world's crude oil—basically a fossil fuel that takes a long time to convert to crude—is extracted. Quite the opposite, usage is rising rather than falling. If this thesis research succeeds in locating an alternative source of oil and developing a process that not only speeds up production but also lowers costs, then the situation will improve significantly. This study will result in a method of waste-to-energy conversion that is sustainable, cost-effective, and gentle on the natural world.

Literature Review

In recent years the population is rising rapidly. As a result, cities and urban areas are also increasing. There are 8 billion people in our planet present day. The growth rate is also very high which is 1.1% per year (Population Growth - Wikipedia, 2022). As a result of modernization and fast growth of cities all around the world people are more trending to live in cities. Today 56% of world's population live in cities [8]. But it is becoming more and more hard and concerning to provide a good life style as well as a good waste management system to all of the people. In 2020, the world was estimated to generate 2.24 billion tons of solid waste [8]. It is predicted that by 2050, the amount of municipal solid waste produced worldwide will have risen by around 70%, reaching 3.4 billion metric tons (cycles & Text, 2023). This vast amount of solid waste is not very easy to collect and manage.

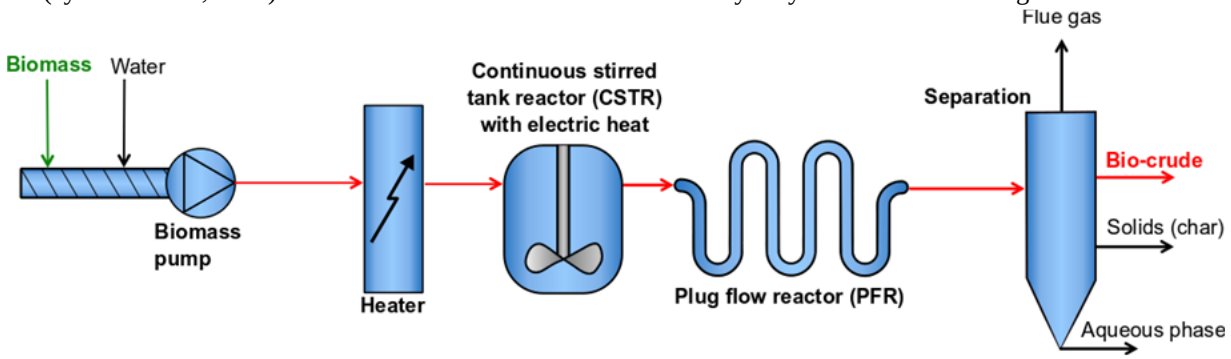

Figure 2: HTL reactor process diagram

Due to shortening of resource and manpower all the waste cannot be collected and managed properly. Only around 50% of total waste can be collected when most of them around 15% is used in landfill. These collected waste is mostly solid waste. But there is another type of waste which is sludge. In most part of the world sludge is not collected and managed officially of systematically which cause a to of problem. There are currently 2.4 billion people without access to better sanitation facilities, and an additional 946 million people who are still using the toilet outside. And, the regions of sub-Saharan Africa and Southern Asia currently host the majority of the world's least-covered nations (World Health Organization & United Nations Children's Fund (UNICEF), 2015). People who have access to sanitation system mainly use on site sanitation system. As an example, pit toilet and this allow the sludge to be managed on site. But it also causes a lot of health issues. These wastes can infiltrate ground water level and contaminate ground water. Which will cause a lot health disease. Around 485,000 deaths are caused by diarrheal diseases each year [9].

One of the main reasons faecal sludges is not treated properly is poverty. Most of the people on earth live in Asia and Africa and here many countries can be considered poor according to the per capita income. As an example, according to the World Bank's 2021 data, the average annual income per person in Burundi is just over $20 per month. So, they can't afford to maintain FS management service and their resources. Human feces contain 63 to 83 percent water by weight [10]. When added with other water sources such as flushing water it can increase more than 90%.

Though they can be used to produce bio gas, solid fuels, fertilizer a huge part is dumped in the environment without any prior treatment endangering the health of human and other living organism in addition to polluting the environment. Now a days there are many ways to manage this sludge without a lot of cost. HTL is one of those. Hydrothermal Liquefaction (HTL) is a promising technology. It can convert wet biomass to biofuel at high

temperature (180-375 ℃) and high pressure (4-30 MPa) [11]. It can help in two ways one is reducing the amount of faecal sludge and an effective way to manage it and the other is providing a new source of oil.

3. Hydrothermal Liquifaction

Hydrothermal liquefaction (HTL) is a thermochemical conversion process that involves heating organic material, such as biomass, sewage sludge, or algae, in the presence of water under high temperature and pressure conditions. The process breaks down the complex organic molecules into simpler compounds, producing a bio-oil-like substance that can be further refined into fuels or other value-added products. HTL has several advantages over other thermochemical processes, including its ability to handle wet feedstocks, its potential for carbon capture and utilization, and the production of a liquid product that is easily transportable and can be used in existing infrastructure. The technology has applications in various sectors, including waste management, bioenergy production, and carbon capture and utilization [12]

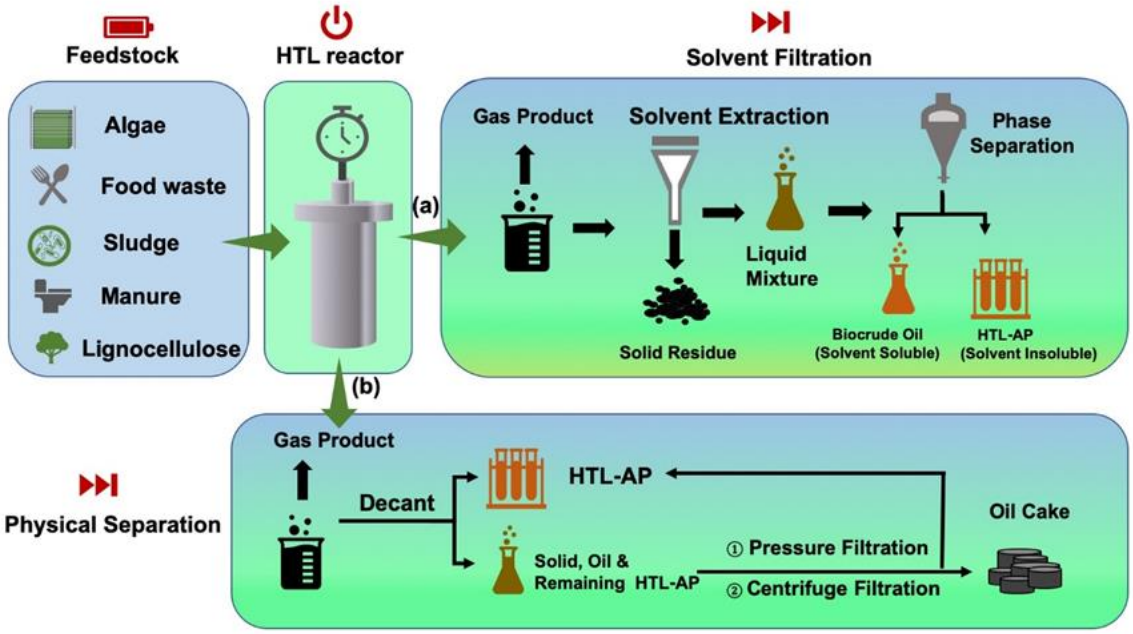

Figure 3: HTL Process [13]

Hydrothermal liquefaction (HTL) is a promising technology for the conversion of faecal sludge into biofuels and other value-added products. HTL involves heating the sludge to high temperatures and pressures in the presence of water, which breaks down the organic matter into a liquid oil-like substance. This process can significantly reduce the volume and weight of the sludge, while producing a renewable energy source that can be used in transportation or heating. HTL has the added benefit of destroying pathogens and other contaminants in the sludge, making it safe for reuse. While still in the research and development phase, HTL has the potential to provide a sustainable and efficient solution for faecal sludge management [14-16].

From above figure it is indicated that by HTL faecal sludge and other organic waste can be converted into oil. The yield percentage by hydrothermal liquefaction (HTL) can vary depending on several factors, such as the type of feedstock, the operating conditions, and the reactor design. Generally, HTL has been found to have a high conversion efficiency, with reported yields ranging from 50% to 80%. For example, in a study it is shown that, the yield of bio-oil from HTL of algae was found to be 58.8% [17], with the remaining solid residue having potential applications as a fertilizer or soil amendment. Similarly, a study shows that the HTL of sewage sludge resulted in a bio-oil yield of 63.5%, with the potential for the solid residue to be used as a soil conditioner.

Hydrothermal liquefaction (HTL) has several advantages over other bioenergy and waste management technologies, including:

Figure 4: Distillation process

Versatility: HTL can handle a wide range of feedstocks, including biomass, sewage sludge, algae, and other organic wastes. This versatility makes it a valuable technology for waste management and bioenergy production.
High conversion efficiency: HTL has a high conversion efficiency, with reported yields of bio-oil ranging from 50% to 80%. This means that a significant amount of the energy content of the feedstock can be recovered as bio-oil.
Carbon capture and utilization: HTL can be used for carbon capture and utilization by using carbon dioxide as a reactant in the process. This can help to reduce greenhouse gas emissions and mitigate climate change.
Production of value-added products: The bio-oil produced by HTL can be further refined into transportation fuels, chemicals, and other value-added products. This creates opportunities for new markets and revenue streams.
Reduction in waste volume: HTL can reduce the volume of waste materials, such as sewage sludge, by up to 80%. This can reduce the need for landfill space and lower disposal costs.
Water recycling: HTL can recycle water from the feedstock, which can be reused for other processes or for irrigation purposes.
While hydrothermal liquefaction (HTL) has several advantages, it also has some disadvantages that must be considered. These include:
High energy requirements: HTL requires high temperatures and pressures, which can require significant energy inputs. This can reduce the overall efficiency and economic viability of the process.
Corrosion and fouling: The high temperatures and pressures used in HTL can cause corrosion and fouling in the reactor, which can reduce the lifespan of the equipment and increase maintenance costs.
Water usage: HTL requires significant amounts of water to operate, which can be a concern in water-scarce regions.
Upstream processing: The feedstock for HTL must be pre-treated to remove contaminants and increase the energy content. This upstream processing can add to the overall costs and complexity of the process.

Bio-oil stability: The bio-oil produced by HTL is typically unstable and requires further processing to improve its stability and properties. This additional processing can add to the overall costs and complexity of the process.
Residue disposal: HTL produces solid residues that must be disposed of or used in other applications. The disposal of these residues can be costly and may require additional treatment.
Overall, while HTL has the potential to be a valuable technology for waste management and bioenergy production, it also has some disadvantages that must be considered when evaluating its feasibility for a particular application [16-18].

Results and discussion:

A-Factor, C-Factor

A-Factor and C-Factor has been calculated following equation 8 & 9 and presented below.

Table.1: A- Factor & C-Factor from FTIR spectra of Bio-Crude and Bio-Char

Sample Type	Peak height(Absorbance%)				Parameters	
	293cm^{-1}	**2860cm^{-1}**	**1705cm^{-1}**	**1630cm^{-1}**	**A-factor**	**C-factor**
6000 RPM	0.75348	0.62458	0.31637	0.58746	0.70112	0.35003
9000 RPM	2.35493	2.35456	1.84570	1.98463	0.70353	0.48186
12000 RPM	2.65478	2.4157	1.56478	1.95648	0.72158	0.44438

T_{fluid}, T_{burial}, VR (%)

T ℃ fluid and T ℃ burial has been calculated following equation 10 & 11 respectively.

Table.2: Paleotemperature from FTIR spectra of Bio-Crude and Bio-Char

Sample Type	Vitrinite Reflectance (VR%)	Kerogen Type	Maturation Scheme	T fluids	T burial
6000 rpm	0.68	II	Early mature	102.86	104.38
9000 rpm	0.48	II	Premature	58.32	76.29
12000 rpm	0.55	II	Premature	75.72	87.27

Table.3: Bio-Crude characteristics

Sample Type	SG	API Gravity	Barrels of biocrude per metric ton
6000 rpm	1.33	-25.10	4.73
9000 rpm	1.47	-35.54	4.327
12000 rpm	1.44	-33.33	4.36

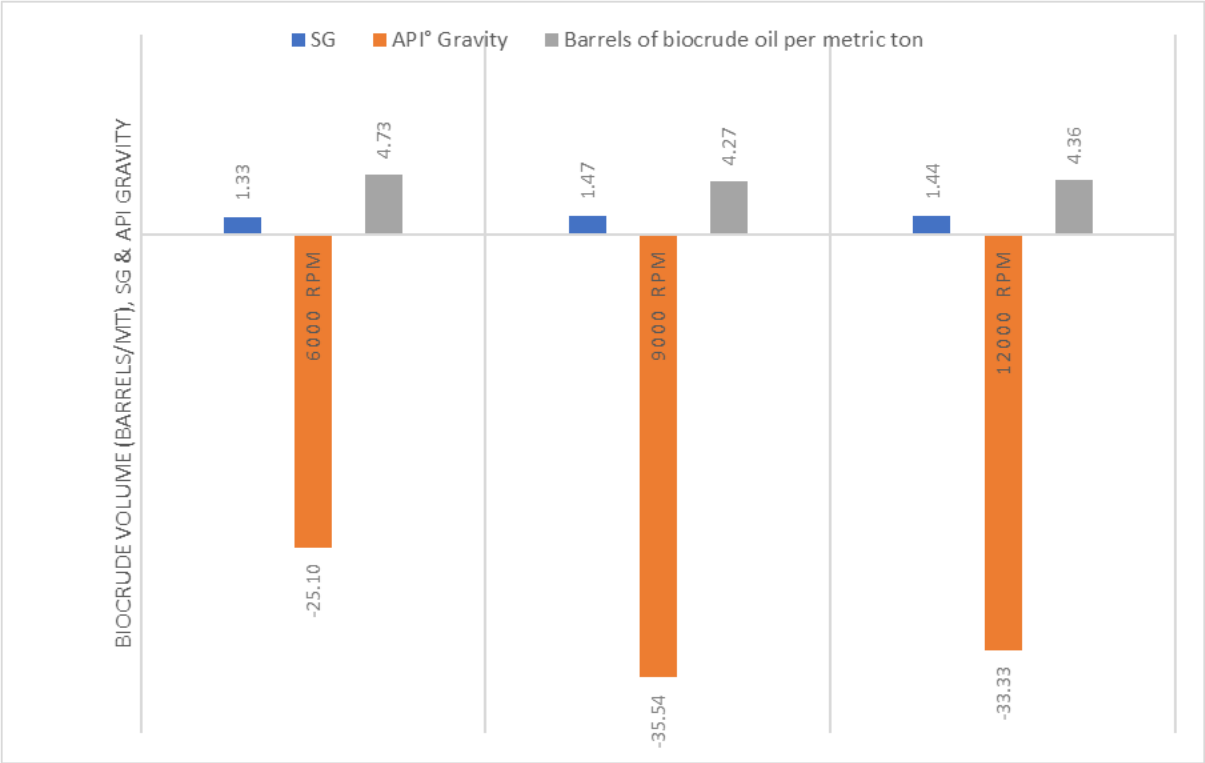

Figure 4: Biocrude volume, SG and API gravity chart

According to above figure, SG of separated Bio-Crude range is 1.33 to 1.47. Where, 1.33 is for 6000 rpm and 1.47 is for 9000 rpm. In terms of API° gravity maximum is -25.10 and minimum is -35.54 respectively for 6000 rpm and 9000 rpm. Here projected Bio-Crude amount from per metric ton of faecal sludge in terms of barrels are also presented. From the projection it can be said that at 6000 rpm the projected volume is 4.73 barrels, at 9000 rpm it is 4.27 barrels and at 12000 rpm it is 4.36 barrels. So, in this case amount of Bio-Crude at 6000 rpm is highest [19].

Conclusion

Hygiene and sanitation are now global concerns. Sustainable Development Goals (SDG) adopted by the United Nations General Assembly in 2015 sets two goals in this sector. One is no 3. Good health and Well-being. Second is no. 6 Clean Water and Sanitation. As a large no of people lives under poverty line in the world. They do not have a well sanitation system which is a huge setback for these two goals. Another goal of SDG's is affordable and clean energy. now price of crude oil is very high. Which is out of a lot's affordable limit. No 13 says climate action. When there is no well-established sanitation system it not only effects the regular life but also effects the climate. And 15th goal of SDG is life on land. It depends on a lot of elements. Two of them are sanitation and energy source.

From the tests done in this research we can conclude that Bio-Crude obtained at 6000 rpm SG is lowest and API° gravity is highest. According to SG and API° gravity this Bio-Crude is easy to transport and store. But it also indicates lower energy content and higher emission. Besides at 6000 rpm AP is not fully separated from Bio-Crude. So, this speed not applicable for real life or large-scale production of Bio-Crude. As for 9000 rpm & 12000 rpm AP is fully separated from Bio-Crude and according to SG & API° gravity though 9000 rpm indicates better than 12000 rpm but the amount of Bio-Crude is less than 12000 rpm. So, my conclusion is for real life use and large-scale industrial production 12000 rpm is suitable and acceptable speed. If this research work can be implicated in the real life, then a lot of people can have access to low-cost fuel as well as a good sanitation system which will also provide a good environment

References

[1]. Bazdar, E., Roshandel, R., Yaghmaei, S., & Mardanpour, M. M. (2018). The effect of different light intensities and light/dark regimes on the performance of photosynthetic microalgae microbial fuel cell. Bioresource Technology, 261, 350–360. https://doi.org/10.1016/j.biortech.2018.04.026

[2]. Bhosale, A. C., & Rengaswamy, R. (2019). Interfacial contact resistance in polymer electrolyte membrane fuel cells: Recent developments and challenges. Renewable and Sustainable Energy Reviews, 115, 109351. https://doi.org/10.1016/j.rser.2019.109351

[3]. Bilgili, F., Kuşkaya, S., Toğuç, N., Muğaloğlu, E., Koçak, E., Bulut, Ü., & Bağlıtaş, H. H. (2019). A revisited renewable consumption-growth nexus: A continuous wavelet approach through disaggregated data. Renewable and Sustainable Energy Reviews, 107, 1–19. https://doi.org/10.1016/j.rser.2019.02.017

[4]. Characterization of Niger Delta Crude Oil by Infrared Spectroscopy. (n.d.). https://doi.org/10.3923/jas.2005.906.909

[5]. cycles, T. text provides general information S. assumes no liability for the information given being complete or correct D. to varying update, & Text, S. C. D. M. up-to-D. D. T. R. in the. (2023). Topic: Waste generation worldwide. Statista. https://www.statista.com/topics/4983/waste-generation-worldwide/

[6]. Dandamudi, K. P. R., Muhammed Luboowa, K., Laideson, M., Murdock, T., Seger, M., McGowen, J., Lammers, P. J., & Deng, S. (2020). Hydrothermal liquefaction of Cyanidioschyzon merolae and Salicornia bigelovii Torr.: The interaction effect on product distribution and chemistry. Fuel, 277, 118146. https://doi.org/10.1016/j.fuel.2020.118146

[7]. David H. McNeil, H. G. S., & Bosak, T. (2015). Raman spectroscopic analysis of carbonaceous matter and silica in the test walls of recent and fossil agglutinated foraminifera. AAPG Bulletin, 99(6), 1081–1097. https://doi.org/10.1306/12191414093

[8]. Feng, H., Zhang, B., He, Z., Wang, S., Salih, O., & Wang, Q. (2018). Study on co-liquefaction of Spirulina and Spartina alterniflora in ethanol-water co-solvent for bio-oil. Energy, 155, 1093–1101. https://doi.org/10.1016/j.energy.2018.02.146

[9]. Ganz, H. H., & Kalkreuth, W. (1991). IR classification of kerogen type, thermal maturation, hydrocarbon potential and lithological characteristics. Journal of Southeast Asian Earth Sciences, 5(1), 19–28. https://doi.org/10.1016/0743-9547(91)90007-K

[10]. Griffiths, P. R., & de HASETH, J. A. (2007). Fourier Transform Infrared Spectrometry.

[11]. Hasan, M., Khalekuzzaman, Md., Alamgir, M., Datta, P., & Kabir, S. B. (2022). A new energy-positive technological approach for wastewater treatment and bioenergy generation using a photo anoxic baffled reactor (PABR). International Journal of Environmental Science and Technology, 19(2), 995–1006. https://doi.org/10.1007/s13762-021-03168-

[12]. Hossain, M. R., Khalekuzzaman, M., Kabir, S. B., Islam, M. B., & Bari, Q. H. (2022). Enhancing faecal sludge derived biocrude quality and productivity using peat biomass through co-hydrothermal liquefaction. Journal of Cleaner Production, 335, 130371. https://doi.org/10.1016/j.jclepro.2022.130371

[13]. Islam, Md. B., Khalekuzzaman, M., Kabir, S. B., Hossain, Md. R., & Alam, Md. A. (2022). Substituting microalgal biomass with faecal sludge for high-quality biocrude production through co-liquefaction: A sustainable biorefinery approach. Fuel Processing Technology, 225, 107063. https://doi.org/10.1016/j.fuproc.2021.107063

[14]. Kaza, S., Yao, L. C., Bhada-Tata, P., & Van Woerden, F. (2018). What a Waste 2.0. Washington, DC: World Bank. https://doi.org/10.1596/978-1-4648-1329-0

[15]. Li, R., Ma, Z., Yang, T., Li, B., Wei, L., & Sun, Y. (2018). Sub–supercritical liquefaction of municipal wet sewage sludge to produce bio-oil: Effect of different organic–water mixed solvents. The Journal of Supercritical Fluids, 138, 115–123. https://doi.org/10.1016/j.supflu.2018.04.011

[16]. Opel, A., Bashar, M. K., & Ahmed, M. F. (2012). Faecal sludge management in Bangladesh: An issue that needs urgent attention.

[17]. Parikh, J., Channiwala, S. A., & Ghosal, G. K. (2007). A correlation for calculating elemental composition from proximate analysis of biomass materials. Fuel, 86(12), 1710–1719. https://doi.org/10.1016/j.fuel.2006.12.029

[18]. Population growth—Wikipedia. (2022). https://en.wikipedia.org/wiki/Population_growth

[19]. Standard Practice for Proximate Analysis of Coal and Coke. (n.d.). Retrieved March 7, 2023, from https://www.astm.org/d3172-13.html.