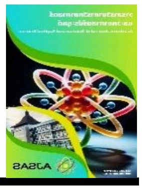
Academic Journal of Science and Applied Science 2024(1) 29-35

Faculty of Science and Technology, Uttaradit Rajabhat University

Academic Journal of Science and Applied Science

Journal homepage: https://ajsas.uru.ac.th/



Assessing greenhouse gas emissions from groundwater exploration drilling: A case study in groundwater resources office area 3, Saraburi province

Karun Chaivanich*

Department of Ordnance Engineering, Academic Division, Chulachomklao Royal Military Academy, Nakhon Nayok 26001, Thailand

ARTICLE INFO

Article History

Received: 29 March 2024
Revised: 28 June 2024
Accepted: 29 June 2024
Available online: 30 June 2024

Keywords:

Environmental impact, Greenhouse gas emissions, Groundwater Exploration, Drilling,

***Corresponding author**;
Email address:
kchaivanich@gmail.com
(K. Chaivanich)

ABSTRACT

This study employs the Life Cycle Assessment (LCA) methodology to quantify greenhouse gas emissions associated with groundwater exploration drilling in Saraburi Province, Thailand. The research focuses on a case study at the Groundwater Resources Office Area 3, specifically examining a 152-meter deep well (number 6503NO12) located at coordinates Zone 47P UTM-E 708446 and UTM-N 1591718. The investigation analyzes diesel fuel consumption from drilling machinery and air compressors to evaluate the environmental impact of drilling operations. Results indicate that drilling a 150-meter deep well generates 185.25 $kgCO_2eq$ of emissions, with a rate of 1.2187 $kgCO_2eq$ per meter drilled. The primary source of these emissions is identified as the utilization of diesel fuel in drilling equipment and compressors. These findings underscore the substantial environmental implications of groundwater well drilling, particularly regarding greenhouse gas emissions. The study's outcomes align with Thailand's national objectives to reduce greenhouse gas emissions and achieve carbon neutrality by 2065. By providing quantitative data on the environmental impact of current drilling practices, this research offers valuable insights for policymakers and stakeholders in the water management sector. The results emphasize the necessity of developing and implementing more sustainable practices and alternative energy sources in groundwater exploration activities. This study contributes to the growing body of knowledge on environmental sustainability in water resource management and provides a foundation for future research aimed at mitigating the environmental impact of groundwater extraction processes.

1. Introduction

Climate change, driven by increased greenhouse gas emissions resulting from human activity, presents a multifaceted global problem that has far-reaching effects on ecosystems, communities, and economies. It is crucial to tackle these emissions in order to restrict global warming, reduce the impact of extreme weather events, save biodiversity, ensure human health, support sustainable development, and strengthen global security [1]. Climate change presents substantial obstacles in several sectors, including agriculture, energy, and transportation, and its impacts also reach vital domains such as agriculture, health systems, and water resources [2]. To effectively tackle global warming, it is imperative to have international collaboration and legal structures in place due to the adverse effects it brings, like reduced food production, health problems, melting glaciers, and interrupted monsoon patterns. This is seen in endeavors such as the United Nations Framework Convention on Climate Change and the Paris Climate Agreement [3]. The occurrence of global warming, driven by the accumulation of greenhouse gases in the atmosphere, has attracted increasing attention due to its significant consequences for ecosystems, biodiversity, and human welfare. Out of these, the withdrawal of groundwater for farming, manufacturing, and household use stands out as a significant source of greenhouse gas emissions, highlighting the importance of conducting a comprehensive evaluation of its environmental consequences. Groundwater extraction, which is essential for supporting numerous sectors of society, has been identified as a substantial contributor to greenhouse gas emissions. This is mostly due to the utilization of fossil fuels in drilling apparatus and equipment.

The surveying of groundwater resources has become a crucial topic as civilizations globally deal with the dual concerns of guaranteeing water security and reducing environmental consequences. Groundwater is commonly seen as a reliable water supply, especially during times of drought and when surface water is scarce. Nevertheless, a thorough survey and drilling technique are essential. Groundwater drilling has the dual purpose of alleviating water scarcity and promoting sustainable growth in water-reliant industry and agriculture [4]. Groundwater drilling is essential in several areas, such as agriculture, consumption, building, and other activities [5]. However, there are widespread worries about the potential effects of groundwater drilling on groundwater systems in many places. The presence of borehole erosion highlights the importance of conducting geological surveys and vulnerability assessments to enhance drilling techniques, reduce the chances of contamination, and maximize the effective use of groundwater. Furthermore, in order to accomplish these goals, it is essential to have a thorough comprehension of the environmental trade-offs involved, as the drilling procedure might result in substantial environmental consequences, such as the release of greenhouse gases. Thus, it is of utmost importance to address these negative consequences in order to advance sustainable groundwater management and protect environmental integrity.

This study aims to assess greenhouse gas emissions from groundwater exploration drilling in Saraburi Province, Thailand, using the Life Cycle Assessment (LCA) approach. The research focuses on the environmental effects of drilling for groundwater in Saraburi Province, a crucial center for managing groundwater resources [6]. By examining this specific area, the project intends to provide insights on sustainable groundwater management techniques [7] that offer knowledge beyond local significance. The study employs the LCA approach to examine drilling procedures and groundwater management, specifically calculating the greenhouse gas emissions linked to these activities. Using data from the Groundwater Resources Office Area 3, Saraburi, this research aims to offer valuable insights that can inform environmental management initiatives and guide stakeholders towards more sustainable groundwater drilling practices, addressing the various industrial and agricultural water needs in the region.

2. Methodology

Techniques for evaluating the complete lifespan of groundwater [8] An investigation on the Groundwater Resources Office Area 3, Saraburi. Fig.1 provides specific information about the investigation

2.1 Groundwater exploration drilling processes

Test-well drilling is the act of creating holes in soil or rock, with different sizes and depths, as shown in Fig.2. The standard approach usually involves the use of a down-the-hole hammer drill, which is a drilling device that directly rotates by employing pressurized air that is sent via the drill shaft to the drill head. The drill bit set consists of a steel button bit equipped with a Tungsten carbide tip at the drill head to increase its durability [9]. The hammer component, which has a cylindrical shape, is made of steel and has an impact and rotation mechanism specifically designed for drilling groundwater in tough rock formations. Test-well drilling can be conducted using a direct circulation rotary drilling equipment, employing either pneumatic drilling or muddy water drilling.

After conducting the drilling procedure to investigate groundwater, attempts are made to determine the precise depth of the water layer within the artesian well. Following that, actions are made to ensure the safety of the groundwater well, utilizing information about the potential of the water layer. This pertains to the sequential process of digging a groundwater survey well, as seen in Fig.3.

2.2 Life Cycle Assessment (LCA)

The evaluation of greenhouse gas emissions from drilling groundwater exploration wells involves the utilization of the LCA approach. The International Organization for Standardization (ISO) defines LCA as a systematic process that evaluates the greenhouse gas emissions linked to the utilization of a product's resources over its whole life cycle, from its creation to its disposal. This methodology consists of four essential stages, as seen in Fig.4, that offer a complete structure for assessing the ecological consequences of drilling operations. Through the utilization of LCA, scientists are able to calculate the amount of greenhouse gas emissions produced over the whole lifespan of drilling groundwater exploration wells. This information can then be used to guide

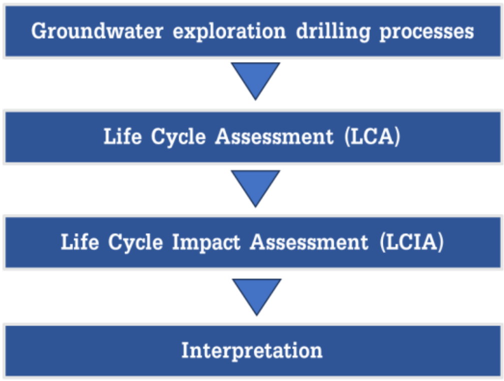


Figure 1 Methodology process.

sustainable practices and develop ways to reduce these emissions.

The life cycle assessment comprises four critical steps:

1) Goal and scopeInitially, the LCA: method necessitates a precise delineation of the objectives and extent of the investigation. When drilling groundwater exploration wells, the goal is to evaluate the environmental effects, namely the emissions of greenhouse gases, that are linked to the entire process of drilling. This entails determining the geographical location of the research region, defining the functional unit (e.g. drilling depth), and setting the system boundaries to determine which processes and inputs will be considered in the evaluation. The aim of this study is to evaluate the ecological consequences of greenhouse gas emissions linked to the process of digging groundwater exploration wells. The research specifically examines the Groundwater Resources Office Area 3 in Saraburi Province, which is situated in Village No. 5, Khok Yae Subdistrict, Nong Khae District. The results of this assessment can provide guidance for actions targeted at reducing the impact of greenhouse gas emissions that contribute to global warming. The focal element employed in this investigation is the vertical distance drilled by a 1-meter groundwater exploration well.

This unit functions as a standardized metric for assessing the environmental consequences linked to drilling operations. This research includes the complete life cycle of digging groundwater exploration wells, from the initial gate to the final gate. The objective is to detect and evaluate environmental effects, with a special emphasis on greenhouse gas emissions. The analysis is performed from start to finish, focusing exclusively on the procedure of digging a well to explore groundwater.

2) Life Cycle Inventory Analysis (LCI): The second step is gathering data on all inputs (such as raw materials, energy, and water) and outputs (such as emissions and waste) linked to each phase of the drilling process. This encompasses the gathering of data on the composition of materials utilized in drilling equipment, the amount of energy consumed during drilling operations and the emissions produced as a result of drilling activities. The data gathered during this phase are utilized to create a thorough inventory of the environmental consequences linked to the digging of groundwater exploration wells. The life cycle inventory analysis entails the gathering of data on the use of resources, such as raw materials and energy inputs, and the estimation of their amounts. Emission factors (EF) are subsequently employed to translate these inputs into outputs associated with the product. The complete procedure throughout the life cycle is recorded, catching different gasses released. The data gathering method is essential for compiling the inventory and establishing the parameters of the research. Gathering data on energy and resource use is necessary for accounting for every step involved in drilling groundwater exploration wells. The study incorporates both primary data, which is gained directly, and secondary data, which is collected by researchers. These records are then utilized to assess the life cycle of digging groundwater exploration wells.

3) Life Cycle Impact Assessment (LCIA): After compiling the inventory of inputs and outputs, the following stage is to evaluate the probable environmental consequences of these activities. This entails utilizing impact assessment methodologies to measure the scale and importance of different environmental pressures, such as emissions of greenhouse gases.

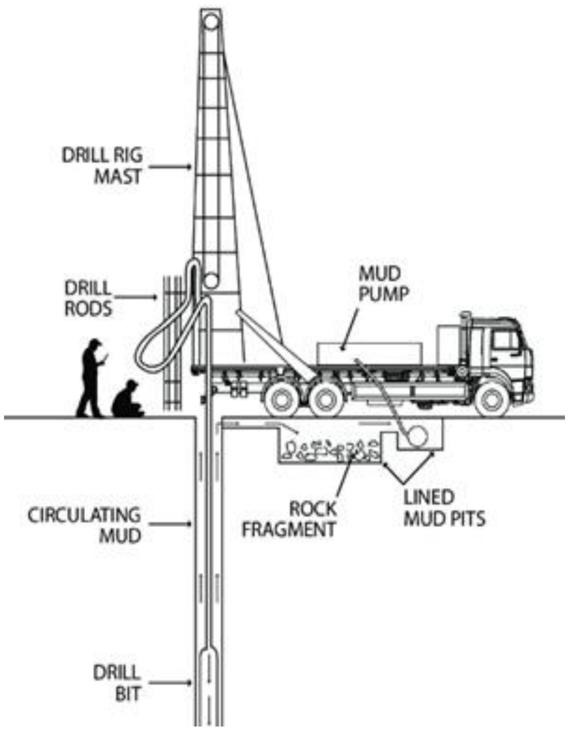


Figure 2 Groundwater exploration drilling. [10].

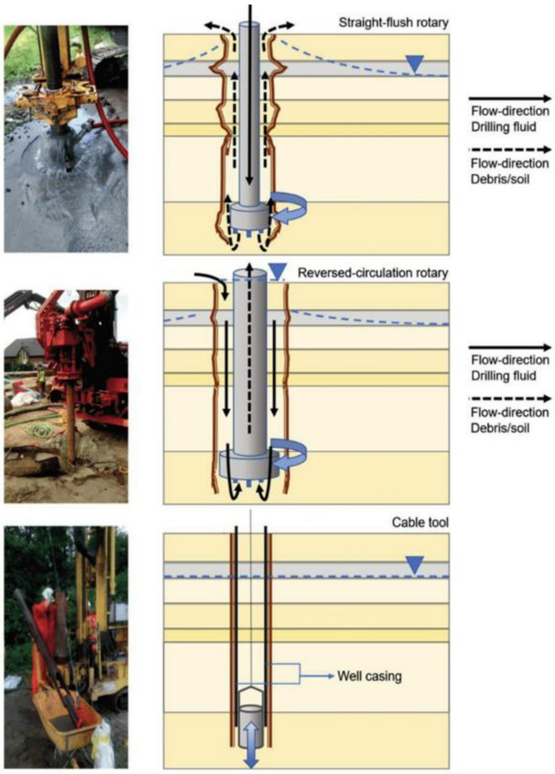


Figure 3 Methods for drilling to explore groundwaterresources. [11]

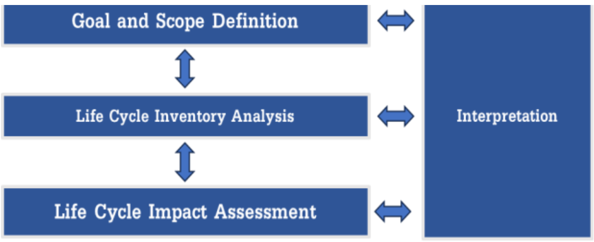


Figure 4 Life cycle assessment process.

4) Interpretation The last stage in the Life Cycle Assessment (LCA): procedure involves analyzing the outcomes of the evaluation and formulating conclusions derived from the findings. This entails the identification of locations with high levels of activity and places that require attention throughout the drilling process. It also involves assessing the pros and cons of various environmental consequences and suggesting ways to enhance the environmental efficiency of drilling groundwater exploration wells. During the interpretation phase, sensitivity analysis is conducted to evaluate the reliability of the results and to identify potential sources of ambiguity in the evaluation.

3. Results and discussion

The process of digging a groundwater exploration well is depicted visually in Fig.5 and stated concisely in Table 1. This study measures the amount of greenhouse gas emissions by evaluating the entire process of digging groundwater exploration wells. The investigation specifically examines the Groundwater Resources Office Area 3, Saraburi, which is located at coordinates Zone 47P UTM-E 708446 and UTM-N 1591718. More precisely, we assess well number 6503NO12, which has been drilled to a depth of 152 meters. The geological features of this well are provided in Table 2. Table 3 provides a summary of the greenhouse gas emissions associated with digging groundwater exploration wells.

Table 2 presents a thorough summary of the soil strata found when digging groundwater exploration wells. Each row in the data represents a unique soil layer, including information on the depth range across which the layer spans. As an illustration, the initial row signifies that the soil layer consisting of brown stone combined with gravel is found at a depth ranging from 0 meters to 15 meters. Similarly, the next rows include data on the depth intervals of each consecutive soil layer encountered throughout the drilling procedure. This data assists in comprehending the geological attributes of the drilling location, so permitting additional examination of the drilling procedure and its ecological consequences.

Table 3 provides a classification of greenhouse gas emissions resulting from the drilling of groundwater exploration wells. More precisely, the emissions originate from the use of diesel fuel by the direct rotary drilling machine and the air compressor. The emissions from the drilling machine amount to 42.987 $kgCO_2eq$, while the emissions from the air compressor amount to 142.262 $kgCO_2eq$. The cumulative greenhouse gas emissions linked to these activities are 185.25 $kgCO_2eq$. Comprehending these emissions is vital for evaluating the ecological consequences of drilling operations. Equipped with this knowledge, individuals with a vested interest may create and execute enduring strategies to release of greenhouse gases, therefore guaranteeing environmental and social accountability in the sector.

Figure 5 The drilling a groundwater exploration processes.

Table 1 Compiling a roster of groundwater survey boreholes, categorized by each meter of depth.

No.	Detail	Unit	Volume	EF	References
1	diesel consumption from a direct rotary drilling machine	Lite	805	0.0475	[8]
2	diesel consumption from air compressors	Lite	2,995	0.0475	[8]
	Total		3,800		

Table 2 Soil layers.

No.	Order list of soil layers	From (m)	To (m)
1	brown stone mixed with gravel	0	15
2	brown stone	15	45
3	light green stones	45	60
4	dark green stones	60	90
5	light green stones	90	120
6	green-brown stones	12	149
7	brown stone	149	152

Table 3 Drilling groundwater exploration wells contributes to the release of greenhouse gases.

Source	Greenhouse Gas Emissions ($kgco_2eq$)
Diesel fuel consumption (Direct rotary drilling machine)	42.987
Diesel consumption from air compressor	142.262
Total	**185.25**

In the Office of Groundwater Resources Area 3, Saraburi, the drilling of groundwater exploration wells results in the emission of greenhouse gases. Specifically, each meter of depth drilled emits 1.2187 $kgCO_2eq$, and a well that is 150 meters deep emits 185.25 $kgCO_2eq$. The main source of these pollutants is the utilization of diesel fuel in drilling equipment and compressors. A research conducted by Jia, G (2002) [12] investigated the influence of groundwater on greenhouse gas emissions. The study found that drilled wells, especially in hydrocarbon-rich basins such as the Musi catchment in India, had notable emissions compared to those in South Australia. In addition, the act of pumping groundwater can result in the release of methane, which is a powerful greenhouse gas, into the atmosphere [13]. Biodiesel has emerged as a feasible approach to alleviate these environmental consequences. Studies have shown that biodiesel has the potential to decrease greenhouse gas emissions by as much as 86% when compared to petroleum diesel [14]. The use of waste cooking oil and non-food crops, such as algae, for biodiesel production has the potential to decrease waste and provide a sustainable fuel supply [15]. An alternative solution to address the drawbacks of biodiesel combustion is the incorporation of biodiesel into gasoline in engines, which leads to a decrease in carbon and hydrocarbon emissions [16]. In addition, life cycle analysis indicates that biodiesel derived from particular soybean types can effectively reduce greenhouse gas emissions. High-fat soybeans can yield significant savings by substituting a larger amount of fossil diesel [17]. Biodiesel adoption shows potential in mitigating environmental effect and addressing climate change by providing a viable solution to reduce greenhouse gas emissions linked to groundwater exploration and pumping operations.

This studyaims to clarify the environmental consequences of groundwater well drilling activities, enabling strategic planning and the adoption of actions to alleviate negative effects in accordance with Thailand's strategy to decrease greenhouse gas emissions. Thailand is committed to reaching a state where it emits no more greenhouse gases than it removes from the atmosphere, known as net-zero greenhouse gas emissions. Additionally, Thailand has set a goal to become a nation that has a balance between the amount of carbon dioxide it emits and the amount it removes from the atmosphere, known as carbon neutrality, by the year 2065 (2608). The National Energy Plan supports the ambitious goal by prioritizing key initiatives such as increasing the use of renewable energy, adopting electric vehicle technology, improving energy efficiency through technological advancements and innovation, and restructuring the energy industry to promote sustainable energy practices. Thailand may enhance its dedication to environmental sustainability and support worldwide endeavors to battle climate change by comprehending and mitigating the environmental consequences of groundwater drilling.

4. Conclusion

This study successfully assessed greenhouse gas emissions from groundwater exploration drilling in Saraburi Province, Thailand, using the Life Cycle Assessment (LCA) approach. The research achieved its primary objective by quantifying emissions associated with drilling operations, revealing that a 150-meter deep well generates 185.25 $kgCO_2eq$ of emissions, with a rate of 1.2187 $kgCO_2eq$ per meter drilled. The benefits of this study are multifaceted. Firstly, it provides a detailed understanding of the environmental impact of groundwater drilling practices, specifically in terms of greenhouse gas emissions. This knowledge is crucial for developing more sustainable water management strategies. Secondly, the study offers a methodological framework using LCA that can be applied to similar assessments in other regions, contributing to the broader field of environmental impact assessment in water resource management. The impact of this research extends beyond its immediate findings. By aligning with Thailand's national objectives to reduce greenhouse gas emissions and achieve carbon neutrality by 2065, the study serves as a valuable resource for policymakers and stakeholders in the water management sector. It highlights the urgent need for more sustainable practices and alternative energy sources in groundwater exploration activities. Furthermore, the research provides a scientific basis for informed decision-making in balancing water resource needs with environmental conservation efforts. In conclusion, this study not only meets its objectives in assessing greenhouse gas emissions from groundwater drilling but also provides significant benefits in terms of environmental understanding and methodological approaches. Its impact lies in its potential to influence policy, drive sustainability initiatives, and contribute to Thailand's broader environmental goals, ultimately promoting more responsible and sustainable groundwater management practices.

Acknowledgement

The researcher expresses profound appreciation to the Groundwater Resources Office, Area 3, Saraburi, for their generous provision of essential information and insightful remarks for the entirety of this study. Furthermore, we express our sincere gratitude to the experts who generously examined and provided valuable ideas to improve the original chapter on "Manual for Surveying and Preparing Reports on Hydrogeology and Drilling Artesian Wells" (2018) by the Royal Irrigation Department. Your contributions have played a crucial role in enhancing the quality and depth of this study.

References

[1] Nukusheva, A., Ilyassova, G., Rustembekova, D., Zhamiyeva, R., & Arenova, L. (2021). Global warming problem faced by the international community: International legal aspect. International Environmental Agreements: Politics, Law and Economics, *Springer*, 21(2), 219-233. http://10.1007/s10784-020-09500-9

[2] Chirescu, A. D. (2022). Using renewable energy sources as an alternative to adapt to climate change. null–null. https://doi.org/10.24818/cafee/2021/10/04

[3] Kulakhmetova, G. (2022). The problem of global warming and climate change. Prospects and Key Tendencies of Science in Contemporary World, 15, null–null. https://doi.org/10.32743/spainconf.2022.1.15.332424.

[4] Khan, A. N., Kim, B. W., Rizwan, A., Ahmad, R., Iqbal, N., Kim, K., & Kim, D. H. (2023). A new method for determination of optimal borehole drilling location considering drilling cost minimization and sustainable groundwater management. ACS Omega, 8(12), 10806-10821.http://doi.org/10.1021/acsomega.2c06854

[5] Ferreira-Gomes, L. M. (2023). Drilling boreholes in sulphureous groundwater areas: Elements of some case studies in Portugal. In IOP Conference Series: Earth and Environmental Science (Vol. 1124, No. 1, p. 012106). IOP Publishing.

[6] Acharya, S., George, B., Aye, L., Nair, S., Nawarathna, B., & Malano, H. (2015). Life cycle energy and greenhouse gas emission analysis of roundwater‑based irrigation systems. Irrigation and Drainage, 64(3), 408-418.

[7] Cho, J. S. (2011). Life cycle assessment on pump and treatment remediation of contaminated groundwater. Journal of Korean Society of Environmental Engineers, 33(6), 405-412.http://doi.org/10.4491/KSEE.2011.33.6.405

[8] Ollila, A. (2019). Challenging the greenhouse effect specification and the climate sensitivity of the IPCC. Physical Science International Journal, 22(2), 1-19. http://doi.org/10.9734/psij/2019/v22i230127

[9] Chansorn, R. (2019). Evaluation of landslide occurrence using hydrological model in Huai Nam Phung Subbasin, Thailand. [Doctoral dissertation, Chulalongkorn University]. ttps://digital.car.chula.ac.th/cgi/viewcontent.cgi?article=9549&context=chulaetd

[10] Guevara, S. E., Agudelo, W. M., Rueda, D., García, N., Becerra, C., Figueredo, Y., & Plata, A. (2010). Seismic and lithological near surface characteristics of an area in north-east Colombia. CT&F-Ciencia, Tecnología y Futuro, 4(1), 7-21.

[11] van Lopik, J. H. (2020). Design of recharge and abstraction well systems in heterogeneous aquifers: Modeling and experimental studies [Doctoral dissertation, Utrecht University Dept. of Earth Sciences]. https://www.researchgate.net/publication/344456321_Design_of_recharge_and_abstraction_well_systems_in_heterogeneous_aquifers_modeling_and_experimental_studies

[12] Ferdush, J., & Paul, V. (2021). A review on the possible factors influencing soil inorganic carbon under elevated CO_2. Catena, 204, 105434. https://doi.org/10.1016/j.catena.2021.105434

[13] Morais, T. A., Ladd, B., Fleming, N. A., & Ryan, M. C. (2022). Free‑phase gas detection in groundwater wells via water pressure and continuous field parameters. Groundwater, 60(2), 262-274.

[14] Dubey, N. S. K., Godara, N. E. R. K., Dar, N. E. G. A., Sharma, N. E. S., & Kawal, N. E. S. (2023). A study of biodiesel as opportunities for environmental improvement. International Journal of Advanced Research in Science, Communication and Technology, 465–470. https://doi.org/10.48175/ijarsct-9238

[15] Khan, N. F., & Rehman, I. U. (2023). Impacts of the biofuel industry on the environment. In Environmental

Sustainability of Biofuels (pp. 87-97). Elsevier. http://doi.org/10.1016/B978-0-323-91159-700020-5

[16] Zandie, M., Ng, H. K., Gan, S., Said, M. F. M., & Cheng, X. (2022). The viability of using gasoline-integrated biodiesel–diesel mixtures in engines as a solution to greenhouse gas emissions: A review. Clean Energy, 6(6), 848-868. https://pureadmin.qub.ac.uk/ws/portalfiles/portal/425500017/zkac056.pdf

[17] Li, Y., Xu, H., Northrup, D., & Wang, M. (2023). Effects of soybean varieties on life-cycle greenhouse gas emissions of biodiesel and renewable diesel. Biofuels, Bioproducts and Biorefining, 17(3), 449-462. http://doi.org /10.1002/bbb.2462