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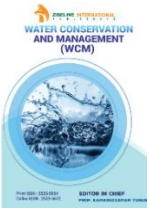

RESEARCH ARTICLE

LIFE CYCLE ASSESSMENT OF A TUBEWELL INTEGRATED WITH FILTRATION TREATMENT SYSTEM: A CASE STUDY OF A BAMBOO FARM

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ABSTRACT

A tubewell integrated with filtration treatment system (TWFTS) is proposed for construction at a bamboo plantation in Johor, Malaysia. TWFTS will be used to provide groundwater supply for irrigation. However, the environmental impacts of the TWFTS construction are unknown. Therefore, this study aims to evaluate the life cycle impact assessment of the proposed project. The objectives of this study are (i) to assess the environment impacts of proposed TWFTS using life cycle assessment and (ii) to identify environmental hotspots, opportunities for improvement, and provide recommendations for sustainable practices of TWFTS. The OpenLCA software, along with the Industrial Design & Engineering Materials database (IDEMAT) and Environmental Footprint 3.0 (EF 3.0), was used to assess the environmental impacts of the TWFTS, which consists of three phases: tubewell installation, construction of protection frame, and construction of filtration treatment system. A cradle-to-gate analysis was applied, evaluating the impacts from raw material extraction to the completion of construction. The results showed that the acidification, climate change, human toxicity (cancer), ozone depletion, and particulate matter emissions of the TWFTS were 8.5696 mol H^+ eq, 3721.9861 kg CO_2 eq, 9.44 x 10^{-7} CTUh, 1.275 x 10^{-5} kg CFC-11 eq, and 1.01 x 10^{-4} disease inc., respectively, with the construction of filtration treatment system is the primary contributor. The study also revealed that the fibre-reinforced plastic (FRP) tank, stainless steel, water pump, and poly tank are the main contributors to these environmental impacts due to their manufacturing processes. Moreover, the findings indicated that replacing the FRP tank with a poly tank can significantly reduce environmental impacts, with reductions ranging from 7.16% to 65.21%. The largest reduction (65.21%) was observed in climate change impact, primarily due to the significant greenhouse gas emissions associated with FRP manufacturing. Ultimately, this study provides a comprehensive analysis to guide the project authority toward more sustainable construction practices.

KEYWORDS

Life Cycle Assessment, OpenLCA, tubewell, filtration system, sustainable

1. INTRODUCTION

The sustainability of construction project has attracted considerable attention from both manufacturers and consumers. The growing awareness of the importance of environmental protection has prompted the quantification of environmental impacts through the use of life cycle assessment (LCA) (Samani, 2023). LCA is a technique employed to identify opportunities for improving the environmental performance of products or project, informs decision-makers in environmental strategic planning and promote marketing activities, such as ecolabelling and environmental claims (Liu et al., 2023). LCA ca be known as the process of assessing a product or project's impacts on the environment over every stage of its life, to reduce liability and increase resource efficiency (Finnveden and Potting, 2014). It can be used to identify areas of improvement. For example, identifying and providing strategies to minimize waste. The results analyzed by LCA can also be used to display a construction project's environmental impacts and benefits to their customers or users (Ferretto et al., 2024. The idea of LCA was introduced in 1960s when resources had limited accessibility and destruction of the environment had become a concern. LCA origins were conducted in packaging field, where it primarily examined energy usage and a small number of emissions. The majority conduct LCA for business purpose, which the results utilized them internally and spoke with stakeholders infrequently (Coban et al., 2024). The ISO 14040 standard served as a reference in the LCA. The ISO 14040 defines LCA is a thorough examination of the life cycle of certain goods, including their sustainability and environmental implications which primarily consists of five main steps: goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment (LCIA), interpretation of results, and identification of limitations (Mourou et al., 2025).

Several software tools can be used to conduct Life Cycle Assessment (LCA), such as Carbon Trail, SimaPro, GaBi, Ecochain, and OpenLCA. Among these, OpenLCA has attracted significant attention due to its free accessibility.

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OpenLCA is a software that had been run for more than 10 years and it is used to evaluate the life cycle assessment of a selected product or project. By using the OpenLCA, data can be imported or created with pre-existing life cycle processes and evaluation techniques. OpenLCA aids in calculating sustainability assessment or life cycle assessment quickly and accurately, display the results and export features, explain of the computation and analysis findings. Most importantly, it helps in highlight key factors at each stage of the process, by flow or effect category. Hence, the evaluation can be done by phases, and result will indicate which phase of production contribute the most environmental impact (Chen et al., 2024). OpenLCA is chosen not only because it is free of charge, but also due to its adaptability and customisation features, users may perform a variety of sustainability evaluations and modify the program to suit their unique requirements. It is noteworthy to mention that professional ecological, social, and economic life cycle evaluations may be conducted using LCA software.

Bamboo, a fast-growing and renewable resource, belongs to the Poaceae family. It can grow up to 40 meters in height in just four months, making it one of the fastest-growing woody plants. Moreover, it has become a popular alternative material due to its superior properties, such as high tensile strength and minimal environmental impact. Bamboo is widely used in various industries, including furniture and interior design, construction and architecture, textiles and fashion, the paper and pulp industry, and handicrafts (Li et al., 2024; Azuwa, 2024; Amjad, 2024; Chaudhary et al., 2024; Huang et al., 2024). According to the Food and Agriculture Organization (FAO) there are over 35 million hectares of bamboo forests and plantations, primarily cultivated in Asia, followed by South America and Africa (Food and Agriculture Organization. 2020). Generally, a manually or mechanically operated tubewell will be installed at the bamboo farm. It will provide a sustainable groundwater supply to meet the irrigation needs of the bamboo plantation, ultimately ensuring healthy crop growth throughout the year.

A tubewell typically requires an electric pump to extract groundwater and distribute it through a network of pipes for agricultural irrigation. It is considered one of the most widely used methods for groundwater extraction worldwide due to its simplicity and cost-effectiveness (Adhish Kumar et al., 2024). Many rural households and agricultural farms rely on tubewells for drinking water and irrigation. Most tubewells are shallow, generally extracting water from depths of less than 50 meters (Goel et al., 2023). To ensure the quality of extracted water, a filtration system is essential. Filtration is critical for removing sediments, heavy metals, microbial contaminants, and odours, making the water suitable for irrigation, drinking, and industrial applications. Among various filtration methods, sand filtration has gained significant attention due to its effectiveness in sediment removal, low maintenance requirements, long lifespan, and ease of installation (Brar et al., 2022).

Several studies have been conducted on the LCA of irrigation system such as water pump and tubewell. The analysis investigated the greenhouse gas (GHG) emissions from natural gas-powered pumps and electric pumps used in agricultural plantations operating for 1,000 hours (Handa et al., 2019). They reported that GHG emissions from natural gas-powered pumps and electric pumps were 11.4 kg CO_2e ha^{-1} and 11.8 kg CO_2e ha^{-1}, respectively. Some a study compared the LCA of diesel-powered and electric-powered pumping systems (Pradeleix et al., 2015). Their study revealed that diesel-powered systems are more harmful to the environment than electric pumps when electricity is generated from natural gas. However, diesel-powered systems become a more favorable option when electricity is derived from coal. To conducted a gate-to-gate LCA to evaluate the environmental impacts of diesel water pumps and solar tubewells (Naseem and Imran, 2016). Their findings showed that diesel water pumps have a significantly higher global warming potential compared to solar pumps. The breakdown of contributions to the environmental impact of diesel pumps is as follows: diesel consumption (65%), fuel production (25%), transportation (5%), and generator manufacturing (5%). It can be noted that the environmental implications of the irrigation system are not thoroughly understood. The lack of such evaluations poses potential risks to the sustainability of the projects and their broader impact on the local ecosystem.

It can be noted that the aforementioned studies focus solely on pumping systems and do not comprehensively evaluate the LCA of entire irrigation and water treatment infrastructure. The impact of material selection during the construction phase has not been extensively explored by previous researchers. This gap is critical, as construction materials and processes significantly contribute to the overall environmental footprint of water management projects. Moreover, no LCA studies on tubewell and filtration systems have been conducted in Malaysia, despite the growing reliance on groundwater extraction and filtration for agricultural irrigation. The environmental impact of construction and material choices can vary significantly based on geographical factors, including climate conditions, local material availability, and energy mix. Without region-specific assessments, sustainability strategies may fail to address the unique environmental challenges of different locations.

Hence, this research aims to bridge this gap by conducting a detailed LCA to assess the environmental impacts of the proposed tubewell of the bamboo farm. In this research, a tubewell with a filtration treatment system (TWFTS) is proposed for bamboo irrigation and general use at a bamboo farm in Johor, Malaysia. The exact research location remains undisclosed. The construction of the TWFTS will be carried out in three phases: tubewell installation, construction of protective frame, and construction of filtration treatment system. The objectives of this study are (i) to assess the environment impacts (including climate change, acidification, eutrophication, fossil fuel depletion, and resource depletion) of proposed TWFTS using life cycle assessment and (ii) to identify environmental hotspots, opportunities for improvement, and provide recommendations for sustainable practices of TWFTS. At the end of the paper, a detailed comparison of the environmental impacts of these three phases will be presented.

2. MATERIALS AND METHODOLOGY

2.1 Project Information

The construction of the TWFTS will be carried out in three phases, as detailed below:

(a) Phase 1: Tubewell Installation

This phase involves deep boring to create a vertical hole with a diameter of 75 mm, reaching a depth of approximately 20 m below the surface. A PVC casing pipe (50 mm in diameter and 20 m in length) will be installed into the borehole. Subsequently, a 1 hp automatic water pump will be installed, along with a 20 mm suction pipe and a 20 mm delivery pipe connected to the storage tank.

(b) Phase 2: Construction of Protective Frame

In this phase, a 100 x 1000 x 1000 mm reinforced concrete base, aluminium C channel with zinc covering will be constructed to protect the water pump from weather conditions such as rain and extreme heat.

(c) Phase 3: Filtration and Treatment System Installation

A 100 x 1500 x 1500 mm reinforced concrete foundation will be constructed to support two poly tanks with capacities of 300 gallons and 600 gallons, along with one 300-gallon FRP tank equipped with a sprinkler for aeration. All three tanks will be connected using polypipe and various miscellaneous, including brackets, wall plugs, screws, white tape, PVC ball valves, PVC tank connectors, poly sockets, poly elbows, poly glue, cover nets, and rope. Figure 1 shows the schematic diagram of TWFTS.

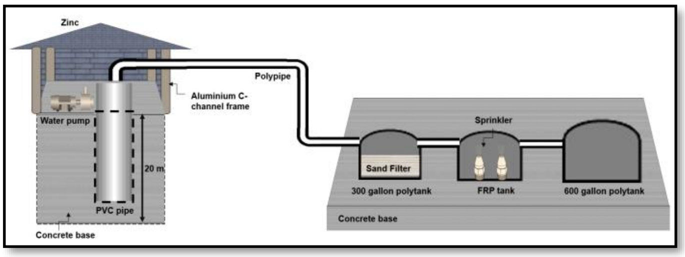

Figure 1: Schematic diagram of proposed TWFTS at bamboo farm located at Johor.

2.2 Goal and Scope

The goal and scope needed to be determined at the beginning of the investigation, prior to data collection. According to ISO 14044, the first phase is important as it establishes the precise strategy to be used (Rosenbaum, 2017). There is a wide range of alternatives to be defines in this phase, this research focusses on the goal, functional unit and system boundaries.

(a) Goal

The goals of the research are to assess the environmental impacts—including acidification, climate change, human toxicity (cancer), ozone depletion and particulate matter of proposed TWFTS at a bamboo farm in Johor using life cycle assessment, and to identify environmental hotspots, opportunities for improvement, and provide recommendations for sustainable practices.

(b) Functional Unit

A functional unit can be defined as a unit of measurement that denotes the quantity of a product or product system that is capable of delivering the desired performance in its intended application. LCA is fundamentally dependent on functional units, which facilitate objective comparisons between various products or systems that perform the same final function (Ciroth, 2017).The functional unit in this research is the construction of one complete TWFTS, which is proposed to be installed in a bamboo farm located at Johor, Malaysia. This study excludes water capacity (or volume) from the functional unit, as the main objective is to evaluate the environmental impacts of the construction phase and compare different materials used in the project's construction. Excluding capacity ensures a fair comparison.

(c) System Boundary

The boundaries of the system being studied using the LCA approach are indicated by the system boundaries. System boundary usually include inputs and outputs, which containing all flows pertaining to the extraction of raw materials, transportation, equipment, treatments, processing, usage of products, waste disposal, and emissions from the system (Osman et al., 2021). This research's system boundary is constrained to cradle-to-gate assessment, which measure the impacts over the production flow from raw materials extraction to installation but not including the footprint of product used by customers and its end-of-life disposal. Figure 2 shows a system boundary framework of proposed TWFTS.

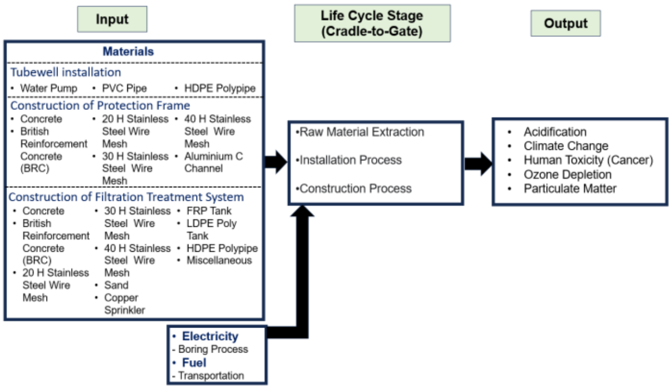

Figure 2: System boundary framework of proposed TWFTS at bamboo farm located at Johor.

2.3 Life Cycle Inventory

The estimation of the direct and indirect inputs, and output releases at each phase of a production of face mask is defined as the life-cycle inventory (LCI). It quantified the amount of energy and raw materials needed, air and waterborne emissions, solid wastes, and other discharges throughout the course of a process, activity, or product's life cycle (Köck et al., 2023). The LCI was collected based on required materials, electricity and fuel for construction of TWFTS as shown in Figure 2. The data collection was conducted through an interview session with the engineer involved in the construction of the proposed TWFTS. The LCI data is presented in Table 1.

Table 1: LCI of proposed TWFTS

Phase	Components	Amount
1	Water Pump	45 kg
	Transportation	100 km
	PVC Pipe	7.73 kg
	Boring Process	1 kwh
	Polypipe	0.168 kg
2	Stainless Steel	60.44 kg
	Transportation	40 km
	Concrete	0.1 m³
	BRC	30.57 kg
	Aluminium Frame	3 kg
3	FRP Tank	120 kg
	Stainless Steel	89.64 kg
	Polytank	180 kg
	Transportation	80 km
	Concrete	0.225 m³
	BRC	48.9 kg
	Sprinkle	0.8 kg
	Sand Filter	300 kg
	Polypine	0.1 kg
	Miscellaneous	2 kg

***The materials were converted to mass due to software limitations. The conversion was based on the volume and density of each material. Small components were measured using a scale.*

2.4 Life Cycle Impact Assessment

To conduct life cycle impact assessment, an OpenLCA software version 2.2.0 was used. In addition, Industrial Design & Engineering Materials database (IDEMAT) and Environmental Footprint 3.0 (EF 3.0) was used for life cycle impact assessment

2.5 Life Cycle Interpretation

This research aims to conduct life cycle assessment on three phases of construction of TWFTS mainly focus on five impact categories, which include acidification, climate change, human toxicity (cancer), ozone depletion and particulate matter. These five impact categories were selected due to their significance in the environmental impacts of tube well construction and filtration treatment systems. By interpreting findings and results, decision makers will gain a better understanding to the environmental and health effects linked to each alternative. These alternatives include the location (local or global) and the relative importance of each impact category, as well as the relationship of each alternative proposed through the LCA study.

3. RESULT AND DISCUSSION

3.1 Acidification

Figure 3 shows the impact of TWFTS on acidification. As shown in Figure 3, the construction of the filtration treatment system (5.7985 mol H$^+$ eq) has the highest impact on acidification compared to tubewell installation (1.4778 mol H$^+$ eq) and the construction of the protection frame (1.2933 mol H$^+$ eq). Overall, this project contributes a total of 8.5696 mol H$^+$ eq to acidification. The major contributors to acidification are the FRP tank (2.7063 mol H$^+$ eq), followed by stainless steel (2.4988 mol H$^+$ eq), water pump (1.1419 mol H$^+$ eq), and poly tank (1.0210 mol H$^+$ eq), among others. This can be attributed to the production process of FRP composites, which involves various additives and catalysts. For example, the use of sulfuric acid in the solvolysis process to reclaim carbon fibers from epoxy composites can release acidic byproducts, contributing to environmental acidification (Elser and Buchmeiser, 2024; Kumar and Krishnan, 2020). Furthermore, the manufacturing of stainless steel emits sulfur dioxide (SO_2), a major precursor to acid rain, further contributing to acidification. Additionally, it is worth noting that polypipe, aluminum frames, miscellaneous, and sand filters have a negligible effect on acidification.

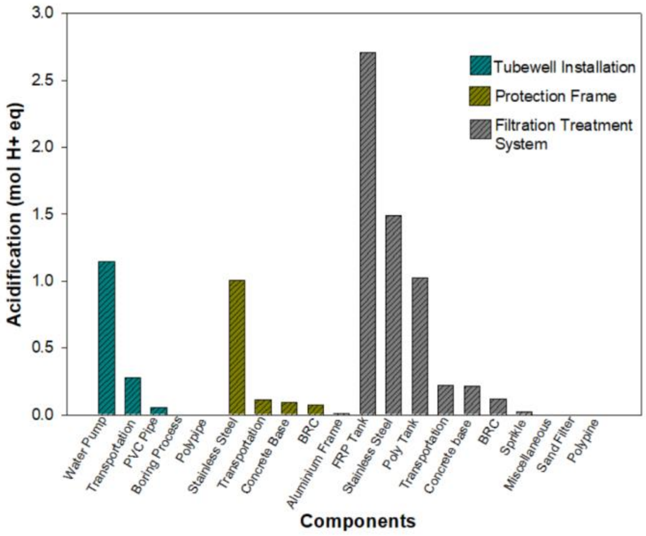

Figure 3: LCA Results on acidification impact of propossed TWFTS.

3.2 Climate Change

On the other hand, Figure 4 presents the impact of TWFTS on climate change. Similar to acidification, the construction of the filtration treatment system has the highest impact on climate change (3,236.6077 kg CO$_2$ eq), followed by tubewell installation (257.1578 kg CO$_2$ eq) and the construction of the protection frame (228.2206 kg CO$_2$ eq). The filtration treatment system alone contributes approximately 87% of the total emissions from the project. Once again, the FRP tank is the major contributor, accounting for 2,534.3456 kg CO$_2$ eq, which represents 68% of the total emissions. This is primarily due to the materials and chemicals used in its manufacturing process, as well as the high energy consumption required for production, which results in significant CO$_2$ emissions from fossil fuel use. Additionally, FRP is made using polymer resins, which release CO$_2$, methane (CH_4), and other greenhouse gases during the extraction and processing of petrochemicals (Qureshi, 2022; Ziemińska-Stolarska et al., 2024). The second largest contributor is the poly tank, mainly composed of high-density polyethylene (HDPE), which accounts for 322.2 kg CO$_2$ eq. Similar to the FRP tank, its environmental impact is due to the use of polymer resins in production. Other significant contributors include stainless steel, the water pump, and transportation. In contrast, the impact of the boring process, sprinkler system, sand filter, miscellaneous components, and polypipes on climate change is negligible.

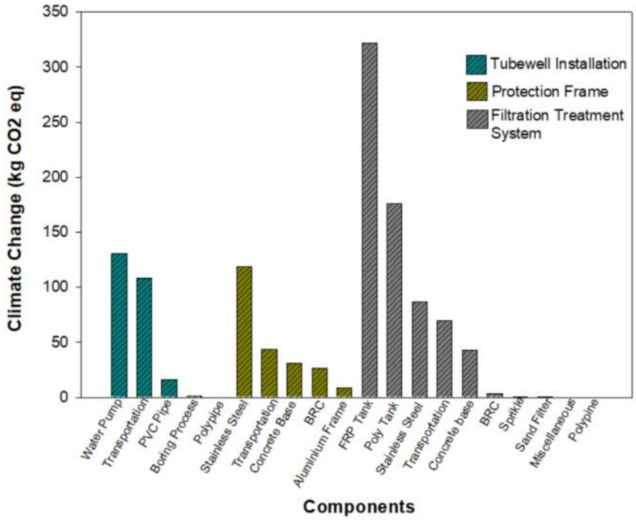

Figure 4: LCA Results on climate change impact of propossed TWFTS.

3.3 Human Toxicity (Cancer)

Tubewell installation has the highest impact on human toxicity (cancer) compared to the construction of filtration treatment system and protection frame. As shown in Figure 5, the human toxicity (cancer) values for tubewell installation, filtration treatment system, and protection frame are 5.4665×10^{-7} CTUh, 3.4051×10^{-7} CTUh, and 5.7269×10^{-8} CTUh, respectively. Tubewell installation contributes 57.88% of the overall impact, primarily due to the use of water pumps, which account for 5.3607×10^{-7} CTUh. Water pumps, particularly older models or low-quality variants, contain materials such as chromium and molybdenum, which can leach into the water supply and pose carcinogenic risks when consumed over time (skari et al., 2024). Additionally, materials used in the construction of filtration treatment system and protection frame, such as FRP tanks, stainless steel, and BRC (Bamboo Reinforced Concrete), also contribute significantly to human toxicity (cancer).

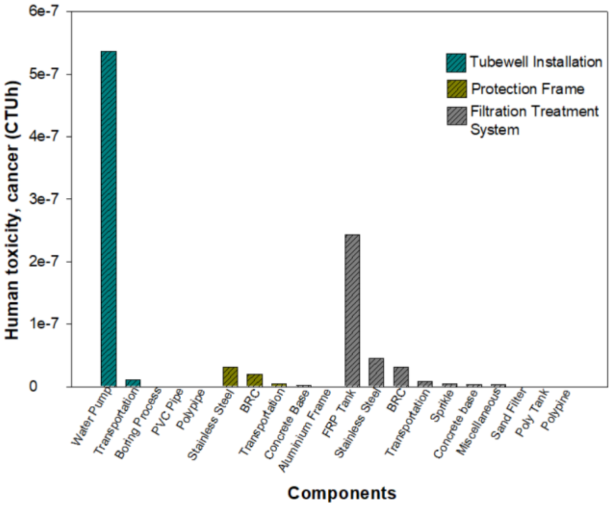

Figure 5: LCA Results on human toxicity (cancer) impact of propossed TWFTS.

3.4 Ozone Depletion

Figure 6 illustrates the impact of TWFTS on ozone depletion. The total ozone depletion impact is 1.28×10^{-5} kg CFC-11 eq. It is evident that the construction of the filtration treatment system has the highest contribution at 8.7316×10^{-6} kg CFC-11 eq, followed by the construction of the protection frame (3.5338×10^{-6} kg CFC-11 eq) and tubewell installation (4.8575×10^{-7} kg CFC-11 eq). Unlike acidification, climate change, and human toxicity (cancer), where other factors play a dominant role, the primary contributor to ozone depletion is the concrete base, accounting for 41.41% of the overall project impact. In addition to concrete, stainless steel is another major contributor, making up 36.76%, followed by the FRP tank, which contributes 17.04%. The high ozone depletion potential of concrete is mainly attributed to cement production, which emits chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and nitrogen oxides (NOx) (Partonia et al., 2024; Küfeoğlu et al., 2024. Similarly, stainless steel production has a significant impact due to its high energy consumption and NOx emissions, as it involves the burning of coal, natural gas, and petroleum coke to meet its high energy demands. Additionally, CFCs and HCFCs are released from cooling systems and older industrial equipment used in stainless steel manufacturing (Jouhara et al., 2024).

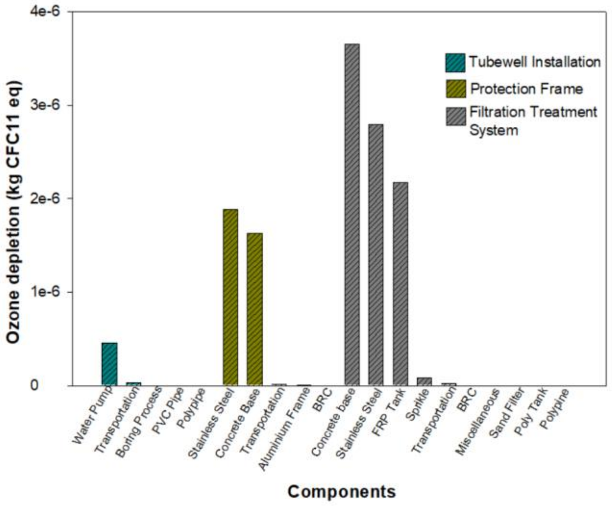

Figure 6: LCA Results on ozone depletion impact of propossed TWFTS.

3.5 Particulate Matter

On the other hand, Figure 7 illustrates the impact of the TWFTS project at the bamboo farm on particulate matter emissions. Similar to other environmental impact indicators, the construction of the filtration treatment system has the highest impact on particulate matter emissions. The reported particulate matter emissions for the filtration system, tubewell installation, and protection frame are 8.0518×10^{-5} disease inc., 1.3128×10^{-5} disease inc., and 7.4151×10^{-6} disease inc., respectively. Unlike other environmental impact indicators, the poly tank has the highest contribution to particulate matter emissions, accounting for 4.5862×10^{-5} disease inc., followed by the FRP tank (2.2524×10^{-5} disease inc.), stainless steel (1.37×10^{-5} disease inc.), and water pump (8.9824×10^{-6} disease inc.). The poly tank is primarily made of low-density polyethylene (LDPE). LDPE production involves the burning of fossil fuels, which releases particulate matter (PM_{10} and $PM_{2.5}$), sulfur oxides (SOx), and nitrogen oxides (NOx) into the atmosphere. Additionally, during the polymerization of ethylene into LDPE, catalysts, solvents, and additives are used, which can release volatile organic compounds (VOCs) and particulate matter precursors into the air (Jouhara et al., 2024).

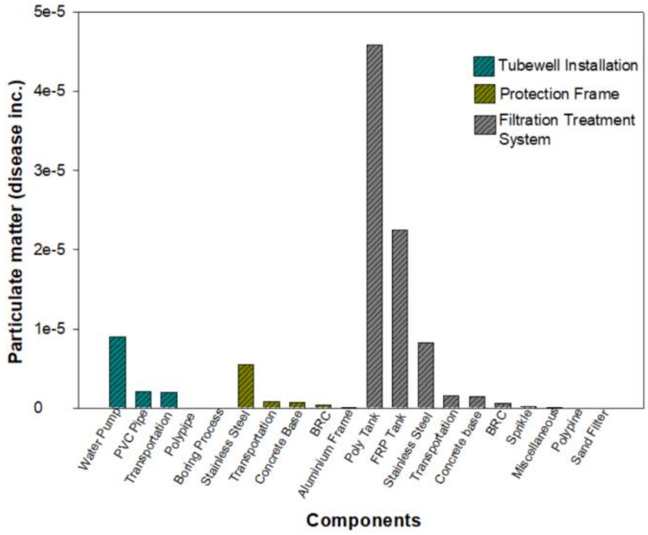

Figure 7: LCA Results on particulate matter impact of propossed TWFTS.

3.6 Sensitivity Analysis

Based on the LCA results, it is evident that the FRP tank is the main contributor to acidification, climate change, human toxicity (cancer), ozone depletion, and particulate matter emissions. This is primarily due to its energy-intensive manufacturing processes, as discussed earlier. According to the project leader of the TWFTS, the FRP tank was chosen to make the filtration process visible to visitors, allowing them to observe and understand the system for educational purposes. However, the FRP tank can be replaced with a poly tank, which offers a lower cost but does not provide the visibility for visitors.

Table 2 shows the comparison of LCA results before and after replacing FRP tank with poly tank. On the other hand, Figure 8 illustrates comparison of contribution percentage. The results show a significant reduction across all environmental indicators. Acidification, climate change, human toxicity, ozone depletion, and particulate matter emissions were reduced by 27.61 %, 65.21 %, 25.71 %, 17.04 %, and 7.16 %, respectively. Among these, climate change impact shows the greatest reduction of 65.21%, primarily due to the high greenhouse gas emissions associated with FRP manufacturing as mentioned previously. Therefore, replacing the FRP tank with a poly tank results in a substantial environmental benefit.

Interestingly, despite the poly tank being a major contributor to particulate matter emissions, the overall particulate matter emissions still decrease by 7.16 % after the replacement. This can be explained by the fact that while the particulate emissions from the poly tank increased from 4.5862 x 10-5 disease inc. to 6.1149 x 10-5 disease inc. due to the additional poly tank. Additionally, the complete elimination of the FRP tank, which previously contributed 2.2524 x 10-5 disease inc., results in an overall reduction in particulate emissions. Apart from the FRP tank, stainless steel is also a major contributor to all environmental impact indicators. However, there is no suitable alternative material that can replace it while maintaining the necessary durability and functionality.

Table 2: Comparison of LCA results before and after replacing FRP tank with poly tank

Environmental Impacts	Proposed TWFTS	FRP Replacement	Reduction (%)
Acidification (mol H^+ eq)	8.5696	6.2036	27.61
Climate Change (kg CO_2 eq)	3721.9861	1295.04047	65.21
Human Toxicity (cancer) (CTUh)	9.444 x 10^{-7}	7.01647 x 10^{-7}	25.71
Ozone Depletion (kg CFC-11 eq)	1.275 x 10^{-5}	1.0578 x 10^{-5}	17.04
Particulate Matter (disease inc.)	1.01 x 10^{-4}	9.38248 x 10^{-5}	7.16

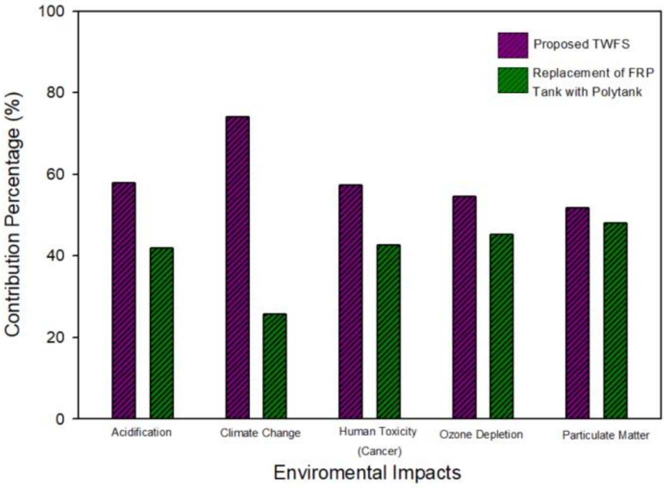

Figure 8: Comparison of contribution percentage before and after replacing FRP tank with poly tank.

4. CONCLUSIONS

In conclusion, this study evaluated the environmental impacts of the proposed TWFTS located at a bamboo farm in Johor, Malaysia, focusing primarily on the construction phase. The simulation results indicated that the filtration treatment system (Phase 3) is the primary contributor to acidification, climate change, ozone depletion, and particulate matter emissions, while tubewell installation has the highest impact on human toxicity (cancer). Notably, the FRP tank, stainless steel, water pump, and poly tank were identified as the most significant contributors to the environmental impacts.

Additionally, a sensitivity analysis was conducted to compare the environmental impacts of replacing the FRP tank with a poly tank, as the FRP tank was found to be the main contributor to these environmental burdens. The results showed a reduction of 7.16% to 65.21% across various environmental indicators, with the most significant improvement observed in climate change impact (a reduction of 65.21%), primarily due to the high greenhouse gas emissions associated with FRP manufacturing. Although the poly tank contributed more to particulate matter emissions, the overall environmental impact still decreased due to the elimination of the FRP tank.

This study provides valuable insights for decision-makers regarding material selection and the reduction of environmental impacts in the construction of TWFTS. However, the analysis follows a cradle-to-gate approach, focusing solely on the construction phase. Future research should adopt a cradle-to-grave assessment to evaluate the long-term environmental impacts, including the usage and disposal phases.

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REFERENCES

Adhish Kumar, S., Navneet, G., Arun Kumar, A., And Tanvi, K., 2024. From Tubewell To Tap_ The Persistent Challenge Of Safe Drinking Water In Rural India, International Journal Of Health Systems And Implementation Research, Vol. 8, No. 2, Pp. 17–29.

Amjad, A. I., 2024. Bamboo Fibre: A Sustainable Solution For Textile Manufacturing, May 01, 2024, Elsevier B.V. Doi: 10.1016/J.Bamboo.2024.100088.

Askari, M., Soleimani, H., Nalosi, K. B., Saeedi, R., Abolli, S., Ghani, M., And Alimohammadi, M., 2024.Bottled Water Safety Evaluation: A Comprehensive Health Risk Assessment Of Oral Exposure To Heavy Metals Through Deterministic And Probabilistic Approaches By Monte Carlo Simulation," Food And Chemical Toxicology, Vol. 185, Pp. 114492, 2024, Doi: Https://Doi.Org/10.1016/J.Fct.2024.114492.

Azuwa, S. B., 2024. A Review On Experimental Observation On Structural Performance Of Bamboo Reinforced Concrete Beam, Jan. 30, Elsevier Ltd. Doi: 10.1016/J.Heliyon.2024.E24628.

Brar, K. K., Raza, H., Magdouli, S., And Brar, S. K., 2022. Role And Importance Of Filtration System In Modular Drinking Water Treatment System," In Modular Treatment Approach For Drinking Water And Wastewater, S. Kaur Brar, P. Kumar, And A. Cuprys, Eds., Elsevier, Pp. 239–265. Doi: Https://Doi.Org/10.1016/B978-0-323-85421-4.00013-9.

Chaudhary, U., Malik, S., Rana, V., And Joshi, G., 2024. Bamboo In The Pulp, Paper And Allied Industries, Elsevier B.V. Doi: 10.1016/J.Bamboo.2024.100069.

Chen, Z., Chen, L., Zhou, X., Huang, L., Sandanayake, M., And Yap, P. S., 2024. Recent Technological Advancements In BIM And LCA Integration For Sustainable Construction: A Review, Feb. 01, 2024, Multidisciplinary Digital Publishing Institute (MDPI). Doi: 10.3390/Su16031340.

Ciroth, A., 2017. Goal And Scope Connection To The Interpretation Phase, In Goal And Scope Definition In Life Cycle Assessment, M. A. Curran, Ed., Dordrecht: Springer Netherlands, Pp. 161–167. Doi: 10.1007/978-94-024-0855-3_5.

Coban, K., Ekici, S., And Karakoc, T. H., 2024. Life Cycle Analysis (LCA): A Retrospective Overview, In Life Cycle Assessment In Aviation: Theory And Applications, T. H. Karakoc, S. Ekici, And A. Dalkiran, Eds., Cham: Springer Nature Switzerland, 2024, Pp. 1–9. Doi: 10.1007/978-3-031-52772-2_1.

Elser, I., And Buchmeiser, M. R., 2024. Toward Sustainable Fiber-Reinforced Polymer Composites, Macromol Mater Eng, Sep. 2024, Doi: 10.1002/Mame.202400013.

Ferretto, L., Lucertini, G., And Brigolin, D., 2024. LCA For Territorial Metabolism Analysis: An Application To Organic Waste Management Planning, J Clean Prod, Vol. 441, Pp. 141051, Doi: Https://Doi.Org/10.1016/J.Jclepro.2024.141051.

Finnveden, G., And Potting, J., 2014. Life Cycle Assessment, Third Edit., Vol. 2. Elsevier, 2014. Doi: 10.1016/B978-0-12-386454-3.00627-8.

Food And Agriculture Organization. 2020. Putting Bamboo On The Map.

Goel, V., Chan, B., Ziade, M., Yunus, M., Ali, M. T., Khan, M. A. F., Emch, M., 2023. Deep Tubewell Use Is Associated With Increased Household Microbial Contamination In Rural Bangladesh: Results From A Prospective Cohort Study Among Households In Rural Bangladesh," Environmental Pollution, Vol. 324, May 2023, Doi: 10.1016/J.Envpol.2023.121401.

Handa, D., Frazier, R. S., Taghvaeian, S., And Warren, J. G., 2019. The Efficiencies, Environmental Impacts And Economics Of Energy Consumption For Groundwater-Based Irrigation In Oklahoma, Agriculture (Switzerland), Vol. 9, No. 2, 2019, Doi: 10.3390/Agriculture9020027.

Huang, X., Chen, X., Xian, Y., And Jiang, F., 2024. The Material Sources, Pharmacological Activities Of Bamboo Polysaccharides And Influencing Factors: A Review, Apr. 01, 2024, Elsevier B.V. Doi: 10.1016/J.Indcrop.2024.118037.

Jouhara, H., Żabnieńska-Góra, A., Delpech, B., Olabi, V., El Samad, T., And Sayma, A., 2024. High-Temperature Heat Pumps: Fundamentals, Modelling Approaches And Applications," Energy, Vol. 303, Pp. 131882, Doi: Https://Doi.Org/10.1016/J.Energy.2024.131882.

Jouhara, H., Żabnieńska-Góra, A., Delpech, B., Olabi, V., El Samad, T., And Sayma, A., 2024. A Review Of Weathering Studies In Plastics And Biocomposites—Effects On Mechanical Properties And Emissions Of Volatile Organic Compounds (Vocs), Multidisciplinary Digital Publishing Institute (MDPI). Doi: 10.3390/Polym16081103.

Köck, B., Friedl, A., Serna Loaiza, S., Wukovits, W., And Mihalyi-Schneider, B., 2023. Automation Of Life Cycle Assessment—A Critical Review Of Developments In The Field Of Life Cycle Inventory Analysis, MDPI. Doi: 10.3390/Su15065531.

Küfeoğlu, S., 2024. Industrial Process Emissions, In Net Zero: Decarbonizing The Global Economies, S. Küfeoğlu, Ed., Cham: Springer Nature Switzerland, 2024, Pp. 341–414. Doi: 10.1007/978-3-031-70322-5_7.

Kumar, S., And Krishnan, S., 2020. Recycling Of Carbon Fiber With Epoxy Composites By Chemical Recycling For Future Perspective: A Review, Chemical Papers, Vol. 74, No. 11, Pp. 3785–3807, 2020, Doi: 10.1007/S11696-020-01198-Y.

Li, H., Liu, S., Yang, F., He, S., Jing, H., Zou, X., And Sheng, Y., 2024. Review Of Utilization Of Bamboo Fiber In Asphalt Modification: Insights Into Preparation, Performance, Reinforcement, And Challenges, Aug. 25, 2024, Elsevier Ltd. Doi: 10.1016/J.Jclepro.2024.143010.

Liu, F., Shafique, M., And Luo, X., 2023. Literature Review On Life Cycle Assessment Of Transportation Alternative Fuels, Nov. 01, 2023, Elsevier B.V. Doi: 10.1016/J.Eti.2023.103343.

Mourou, C., Bonoli, A., Zamorano, M., And Martín-Morales, M., 2025. Environmental Impact Of Roof Tiles Using Recycled Waste Glass Coatings: A Life Cycle Assessment Approach, Build Environ, Vol. 270, P. 112481, 2025, Doi:

Https://Doi.Org/10.1016/J.Buildenv.2024.112481.

Naseem, Z., And Imran, S., 2016. Assessing The Viability Of Solar Water Pumps Economically, Socially And Environmentally In Soan Valley, Punjab," Vol. 10, No. 6, 2016, Doi: Doi.Org/10.5281/Zenodo.1126525.

Osman, A. I., Mehta, N., Elgarahy, A. M., Al-Hinai, A., Al-Muhtaseb, A. H., And Rooney, D. W., 2021. Conversion Of Biomass To Biofuels And Life Cycle Assessment: A Review, Environ Chem Lett, Vol. 19, No. 6, Pp. 4075–4118, 2021, Doi: 10.1007/S10311-021-01273-0.

Partonia, P., Heidarian, S., Sharifi, M., Dezvareh, G., And Khodadadi Darban, A., 2024. Evaluation Of Environmental Impacts Of Cleanroom Construction With A Life Cycle Analysis Approach Based On Energy And Material Consumption," Sci Rep, Vol. 14, No. 1, P. 31929, 2024, Doi: 10.1038/S41598-024-83449-6.

Pradeleix, L., Roux, P., Bouarfa, S., Jaouani, B., Lili-Chabaane, Z., And Bellon-Maurel, V., 2015. Environmental Impacts Of Contrasted Groundwater Pumping Systems Assessed By Life Cycle Assessment Methodology: Contribution To The Water-Energy Nexus Study," Irrigation And Drainage, Vol. 64, No. 1, Pp. 124–138, Doi: 10.1002/Ird.1865.

Qureshi, J., 2022. A Review Of Recycling Methods For Fibre Reinforced Polymer Composites, Dec. 01, 2022, MDPI. Doi: 10.3390/Su142416855.

Rosenbaum, R. K., 2017. Selection Of Impact Categories, Category Indicators And Characterization Models In Goal And Scope Definition," In Goal And Scope Definition In Life Cycle Assessment, M. A. Curran, Ed., Dordrecht: Springer Netherlands, Pp. 63–122. Doi: 10.1007/978-94-024-0855-3_2.

Samani, P., 2023. Synergies And Gaps Between Circularity Assessment And Life Cycle Assessment (LCA), Dec. 10, 2023, Elsevier B.V. Doi: 10.1016/J.Scitotenv.2023.166611.

Ziemińska-Stolarska, A., Sobulska, M., Pietrzak, M., And Zbiciński, I., 2024. A Review Of End-Of-Life Scenarios For Fibre-Reinforced Polymer Materials, Aug. 01, 2024, Multidisciplinary Digital Publishing Institute (MDPI). Doi: 10.3390/En17153713.

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