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# PARAMETRIC OPTIMIZATION AND EFFICIENCY ASSESSMENT OF HORIZONTAL EARTH WATER PIPE HEAT EXCHANGER (EWPHE) IN THE CONTEXT OF BANGLADESH

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## ABSTRACT

*This study aimed to evaluate the efficiency of the Earth Water Pipe Heat Exchanger (EWPHE) system in Bangladesh through simulation and experimental work carried out at Joypurhat in Bangladesh during the coldest period of the year, January. Additionally, the study sought to establish the method for selecting optimal installation parameters of EWPHE to increase performance and efficiency. A simulation model was made in the TRNSYS (v16.0) platform to determine the optimum values of design parameters. The simulation was run by altering its operating parameters, such as the rate of water flow, length of the pipe, built materials of the pipe, and the diameter of the underground pipeline. According to the findings, pipe burial can be done to a depth of 3.5 meters to achieve optimal output. The results of comparing four distinct materials, namely GI, Steel, PVC, and HDPE, show that these materials' characteristics do not significantly affect how well the systems perform. Additionally, as the water flow rate is increased, it is shown that the EWPHE performance is declining. According to the simulation results, it is concluded that a pipe with a length of 50 meters would be sufficient in the proposed EWPHE system to reach an average temperature decrease from 35 °C to 27 °C. Subsequently, in the field experiment, the EWPHE system had an average efficacy of 55% throughout January, which is quite promising.*

**Keywords:** *EWPHE, Geothermal Energy, TRNSYS Simulation, Energy Efficiency, Space Heating & Cooling*.

## 1. INTRODUCTION

Bangladesh is rapidly developing, with many structures being constructed daily. These buildings account for the majority of energy consumption, and as a result of these advancements, energy demand is increasing rapidly. Bangladesh's primary energy source is fossil fuels, and the sources of these fuels are in jeopardy. Renewable energy should be the first priority in resolving this situation. Earth-Water Pipe Heat Exchanger (EWPHE) System is gaining popularity worldwide as a method of harnessing geothermal energy to heat and cool the ambient air in response to the weather. This system is unknown to Bangladesh. According to “SREDA 2016”, the residential sector consumes 43% of all national primary energy, 39% of which is utilized exclusively for space heating and cooling, corresponding to more than one-third of the residential sector's energy use (SREDA, 2016). The growing interest in "passive" solutions for new construction and renovations results from increasing sustainability issues (related to $CO_2$ emissions) and higher energy costs. These solutions include adding extra insulation to the roof and walls, using high-performance glass, upgrading the heating systems (using condensing boilers), and using ground-linked heat exchangers, which have received much focus already. According to data from the Ministry of Power, Energy, and Mineral Resources, Bangladesh had a significant deficit of 3056 MW in 2018 due to the total net installed electricity generation capacity being 10958 MW and the demand being 14014 MW (Moazzem & Ali, 2019). Bangladesh heavily relies on fossil fuels to generate electricity. The three main fuels for producing electricity are coal, natural gas, and Furness oil. All of these resources are non-renewable, and they will eventually run out. It is, therefore, necessary that Bangladesh adapt to using renewable sources as replacements. In developed countries, energy from renewable resources, including wind power, solar energy, hydropower, and geothermal resources, are the mainstays of the continuous production of electricity. While in Bangladesh, natural gas accounts for 62.39% of electricity production, and Furness oil for 20.49%. Renewable energy sources account for just 0.02% of the nation's electricity production. Solar energy makes up 68.96% of all renewable energy sources, while geothermal energy makes up nearly 0% (Islam, 2019). Buildings consume a substantial quantity of electricity. According to an investigation, this industry utilizes more than 40% of all energy produced, with an 8% annual growth rate (Ahmed *et al*., 2014). To achieve thermal comfort of

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interior air, buildings need over 51% of all energy consumed (Kang *et al*., 2015). 49.50 KWh of grid electricity, or 13.34% of per capita output, is used for domestic cooling and heating systems (Islam, 2019).

Geothermal energy is a form of energy conversion that harnesses heat energy from deep below the Earth to create electrical power. Humans can recover and use geothermal heat energy, which is accessible over the whole surface of the planet (Lund, 2023). Around 1.4x106 terawatt-years, or 4.5x106 exajoules, is the estimated amount of energy that can be harvested and used on the surface, which is nearly three times the annual global use of all energy sources (Lund, 2023). The amount of energy that can be extracted from geothermal sources varies depending on the extraction method and depth. Typically, energy needs to be transported to the surface using a fluid (or steam) in order to extract heat. The current study attempts to evaluate an EWPHE system's effectiveness. An earth-water heat exchanger method collects thermal energy from beneath the surface by pumping water through it through pipes. The heat pump raises or drops the temperature, and the residence is heated or cooled using energy from the heat. Although they need power to function, the idea is that they use less electricity than they do with heat. The pump functions in a central heating system similarly to a boiler. However, it captures ambient heat from the ground instead of burning fuel to produce heat. An EWPHE system comprises a heat exchanger (a loop of subsurface pipes) and a pump. A fluid—typically a mixture of antifreeze with water—flows through the system's pipes to transport heat energy from the ground to the surface air. During summertime, heat is transmitted from the heated air to the pipe loop known as the heat exchanger and further into the fluid. The heat is dispersed to the earth's surface as it travels through the pipes. In the winter, the pump operates in reverse. The thermal energy that is essentially stored in the comparatively warm surface raises the temperature of the water. After receiving this energy, the heat pump uses it to warm the air inside the structure (Kaushal, 2017). EWPHE offers a number of advantages over more traditional heating and cooling systems. They use between 25% and 50% less power than similar traditional air-conditioning and heating systems, which results in reduced carbon production. When compared to air-source heat pumps, the energy reductions resulting from (which transport energy between the inside and the outside air) can equal a 44 percent reduction in the production of greenhouse gases. Additionally, compared with standard air conditioners and electrically powered heating systems (which convert electricity into heat), EWPHEs can emit up to 72% fewer greenhouse gases into the atmosphere (Lund, 2023).

Based on the geothermal working principle, it can be observed that the thermal state of the subsurface, namely at a depth of at least 3 meters, displays a rather stable behavior across the year, closely approximating the mean air temperature (A.S.H.R.A.E, 2001) The ambient or air temperature of Bangladesh's northern regions, such as Joypurhat and Dinajpur, can reach roughly 39°C and 9°C, respectively, during the peak of summer and winter. Geothermal heating and cooling may be considered a good substitute for traditional HVAC systems in such locations (Ryherd & Lawrence, 2009). Iranian architects used wind farms and subterranean air passages to cool indirectly from around 3000 BC. (Bahadori, 1978). Since then, scientists have worked to advance geothermal energy technology, resulting in the development of the EAHE system. For air conditioning, a number of investigators have used earth air heat exchangers (EAHE) (Bisoniya *et al*., 2013; Vaz *et al*., 2011; Zhao *et al*., 2019). A model for EAHE has been proposed and empirically confirmed by Bansal et al. (Bansal et al., 2010). Jakhar *et al*. (2015) investigated the EAHE system's efficiency with photovoltaic heating air ducts for heating during the cold season. They came to the conclusion that adding a solar air heating duct boosted the system's Coefficient of Performance up to 4.57. The issue with EAHE is that plenty of surface area is required to convey energy effectively because of the air's poor thermal conductivity and inadequate energy-carrying ability. Because water has a large capacity for heat transmission, it can be used as a cooling medium in EWPHE, reducing the necessary surface area. Joen et al. provided a statistical method for contrasting the efficacy of EAPHE with EWPHE (T'Joen *et al*., 2012). Their calculations show that in the case of EWPHE, the soil resistance is more important, and tubes with lower diameters are required for efficient energy exchange. Chel et al. examined the overall efficiency of a combined method consisting of an air-to-air heat exchanger (AAHE), and an EWPHE, an earth-water heat exchanger (Chel *et al*., 2015). They discovered that the integrated system as a whole could cut the building's annual heating use by 72%.

This study utilizes the TRNSYS program for simulation purposes, facilitating the subsequent evaluation of efficiency. TRNSYS is a simulation software that is mostly utilized for modeling thermal systems characterized by transient behavior. It is known for accurately simulating such systems, yielding results that align well with acceptable error margins (Jani *et al*., 2019). TRNSYS is selected as the preferred simulation software in this context because of its exceptional versatility and capacity for customization. TRNSYS software version 16, renowned as a global authority in the domain of dynamic modeling of buildings and systems, offers the capability of conducting dynamic thermal simulations specifically tailored for buildings (Zaidan *et al*., 2018). The program enables the integration of all building features and HVAC equipment to facilitate a comprehensive analysis of the thermal performance of the building. Based on factors such as its geographical placement, the specific construction materials employed, the overall architectural scheme, and the chosen energy strategy, among others. The TRNSYS program is primarily designed for engineering offices, gas and electricity makers, and suppliers. However, it has also received significant recognition from researchers (Garrido *et al*., 2019). The program known as TRNSYS has been developed by the Scientific and Technical Centre for Building (CSTB) for the purpose of numerically simulating the thermal behavior of buildings and their associated equipment. TRNSYS is a valuable tool for researching systems that exhibit significant temporal variations in their thermal behavior. TRNSYS enables several functionalities, such as precise energy load calculations, a thorough evaluation of building thermal performance, conduction of sensitivity analyses, and optimization of energy system design (Dols *et al*., 2015).

In this study, an attempt was made to optimize the parameters of an EWPHE system using TRNSYS simulation and then to use the optimized parameters for field work and efficiency calculations to propose an optimum method concerning different variables to install the EAHE system for the low-rise buildings of Bangladesh. The mentioned EWPHE system's effectiveness depends on various parameters, such as water mass flow rate, pipe length, pipe burial depth, pipe diameter, built material, etc. By adjusting these parameters, it is possible to vary the EWPHE outlet temperature. This study examines the effect of varying these parameters on EWPHE outlet temperature. In addition, fieldwork was conducted in Joypurhat, Bangladesh, using the optimized parameters. The results of simulations and fieldwork indicate that the suggested system performs better than conventional heating and cooling systems by providing sufficient temperature rise and decline according to the season.

## 2. TRNSYS SIMULATION DETAILS

The renewable energy systems are modeled using TRNSYS, a transient simulation system tool, to estimate transient variation (Klein, 1988). Using this application's built-in Meteonorm files to simulate meteorological conditions, a numerical simulation of the EWPHE was performed. The design of the model incorporates system components. The desired system's parameters and time-dependent inputs produce time-dependent outputs. Using a flowchart, various Type-designated components can be connected to one another. Here, the output of one element serves as the input for multiple other elements. The EWPHE design was used in the current configuration to calculate the time-varying transitory outcome.

The simulation utilized the distinct TRNSYS model elements (Types) listed below:

- Element 77 - Simple model for ground temperature
- Element 952 - EWPHE System
- Element 3 - Changing flow rate impeller
- Element 15 - Meteonorm information
- Element 65 – Output

Table 1 displays the thermal and physical attributes of the operated model in the simulation.

**Table 1:** Thermal and Physical variables used in the simulation.

| Parameters | Values |
|---|---|
| Heat conductivity of water (W/m K) | 0.55 |
| Specific heat of water (J/kg K) | 4200 |
| Density of water (kg/m$^3$) | 1000 |
| Heat conductivity of steel pipe (W/m K) | 54 |
| Heat conductivity of Galvanized Iron or (GI) pipe (W/m K) | 16.2 |
| Heat conductivity of High-Density Polyethylene or (HDPE) pipe (W/m K) | 0.40 |
| Heat conductivity of Poly Vinyl Chloride or (PVC) pipe (W/m K) | 0.19 |

## 3. NUMERICAL CALCULATIONS OF HEAT EXCHANGER EFFECTIVENESS

The total heat transfer and efficiency of the system were calculated using the collected field data under the following assumptions:

- The average temperature of the topmost layer of the earth is equal to the ambient air temperature, which is also equal to the inlet water temperature.
- The pipe that is utilized in EWPHE displays a notably thin thickness, resulting in a negligible impact on the heat resistance of the pipe material.
- The temperature distribution along the surface (wall) of the pipe was found to be uniform in the axial direction and was judged to be like Joypurhat's undisturbed ground temperature (23.6 °C). Since the pipe's interior wall is ineffective at resisting heat, it was thought to be smooth.
- The convective heat transfer coefficient for water moving in a tube range from 500-1200 W/m$^2$-K. A constant value of 1000 was selected for subsequent calculations. (Edge, 2023)

The total heat transferred to the water when it flows through buried pipes ($Q_h$) can be calculated as follows (Bisoniya, 2015):

$$Q_h = \dot{m}C_p(T_{out} - T_{in}) \tag{1}$$

Where $\dot{m}$ represents the water mass flow rate in kilograms per second or (kg/s), and $C_p$ denotes the specific heat of the water in joules per kilogram-kelvin or (J/kg-K). $T_{out}$ refers to the temperature of the air at the pipe outlet, which is measured in degrees Celsius. Conversely, $T_{in}$ represents the air temperature at the pipe's inlet, also measured in the same unit as previous.

The efficiency ($\varepsilon$) of EWPHE for winter heating application can thus be described as (Bisoniya, 2015):

$$\boldsymbol{\varepsilon} = \frac{\boldsymbol{T}_{out} - \boldsymbol{T}_{in}}{\boldsymbol{T}_{ETU} - \boldsymbol{T}_{in}} = \mathbf{1} - \boldsymbol{e}^{-\left(\frac{\boldsymbol{hA}}{\dot{\boldsymbol{m}}\boldsymbol{C}_p}\right)} \tag{2}$$

Where $h$ represents the coefficient of convective heat transfer in units of watts per square meter per Kelvin or (W/m$^2$-K), $T_{ETU}$ is the undisturbed temperature of earth and $A$ is the internal surface area of the pipe in meter square (m$^2$).

## 4. RESEARCH METHODOLOGY

This part explains the procedure for varying the measurements of the underground pipe's design parameters. Figure 1 shows the overall process of methodology. The effectiveness of the design attributes was simulated and evaluated using TRNSYS. The conditions for the simulation were obtained from Joypurhat, Bangladesh, and the simulation was conducted for 10 hours, the length of a typical daytime period. The variation in temperature throughout depth was calculated over the duration of a year. Four pipe materials were subjected to parametric simulation: Galvanized Iron, steel, PVC, and high-density polyethylene pipe. Simulating various pipe materials with constant flow rates, lengths, and diameters determined that the temperature variation between the three materials is only 0.7 °C. Because it is the most affordable of the three materials, a pipe made of HDPE was selected for further performance evaluation in simulation. For an HDPE pipe, the water flow rate and discharge temperature vary for every scenario, while the pipe's diameter and length are held constant. The above investigation establishes the optimal water flow rate for a given circumstance.

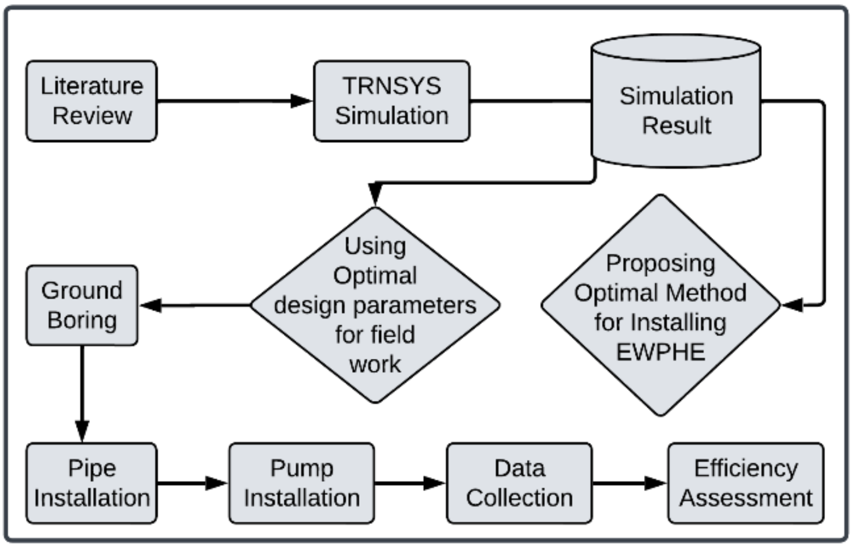

**Figure 1:** Workflow process of research methodology

The evaluation can proceed by maintaining this water flow rate fixed for the HDPE conduit and varying the total measured length of the pipe with a specific diameter. In addition, the last assessment involves calculating the impact of various HDPE pipeline diameters on both water flow rate and constant length. The fieldwork involved the installation of a horizontal borehole and collecting temperature data, which were subsequently utilized for numerical calculation and simulation. Overall, fieldwork was done in several steps. For the horizontal borehole installation, PVC pipe, thread tape, an elbow joint, and a spade are used. A soil thermometer was used to record the model's inlet and outlet temperature data. To test and evaluate the efficacy of the system in Bangladesh's climatic conditions, a plot of land in the northern district of Joypurhat was chosen. To assess the system's performance, it was necessary to consider whether situations were characterized by extreme cold or extreme heat. A significant difference in temperature between the atmosphere and the ground is essential to the system's optimal performance. January, our performance month, is the coolest month in Bangladesh. It is also known that the northernmost regions of Bangladesh are the coolest. Figure 2 and Figure 3 depict the installation of underground PVC pipelines in Joypurhat, Bangladesh, for the purpose of evaluating the efficiency of an EWPHE system. To investigate the thermal efficacy of the horizontal EWPHE in Bangladesh, a 3-meter-deep trench was dug. A 40-meter-long pipe made of PVC with a 30-millimeter inner diameter was buried at a depth of 3 meters. A soil thermometer measures the inlet, outlet, and ambient air temperatures. A pump with adjustable speed was used to regulate the flow of water. is used to regulate the water flow rate. After allowing the soil near the borehole to settle for a few days, the temperature was measured at random intervals for three days, from January 4th to January 6th, 2022.

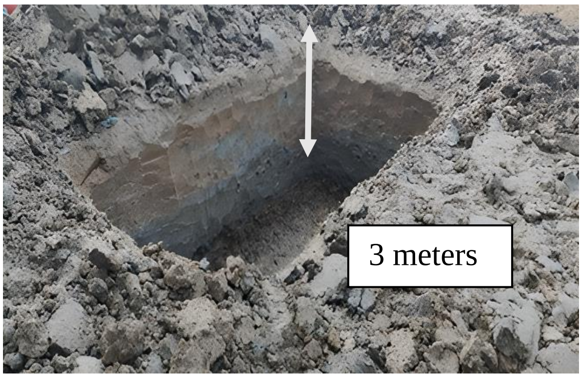

**Figure 2:** Boring of 3 meters deep trench

**Figure 3:** Pipe loop installation for EWPHE system

### 4.1 Field Data Collection

The field setup was conducted using the optimal value generated from the simulation, and temperature data were thereafter gathered at regular intervals over a period of three days. As it was peak winter time in Joypurhat, the ambient temperature fluctuated a lot from 9.8 °C to 21.1 °C while the system's outlet temperature difference was as low as 6.3 °C. The system's heat transfer rate and efficiency were computed using the recorded data and the provided formula. This calculation was performed for each of the data sets. Table 2 illustrates the field temperature recordings.

**Table 2:** Temperature recordings at different time intervals.

| 4/01/2022 | | | 5/01/2022 | | | 6/01/2022 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Input Temp. (°C) | Output Temp. (°C) | Time | Input Temp. (°C) | Output Temp. (°C) | Time | Input Temp. (°C) | Output Temp. (°C) |
| 6.00 | 11.7 | 18.8 | 6.00 | 12.3 | 18.6 | 6.00 | 10.2 | 15.9 |
| 8.00 | 12.4 | 18.9 | 8.00 | 12.7 | 18.6 | 8.00 | 11.3 | 16.9 |
| 10.00 | 13.2 | 19.1 | 10.00 | 15.1 | 19.7 | 10.00 | 14.7 | 19.2 |
| 12.00 | 14.3 | 19.4 | 12.00 | 18.8 | 21.7 | 12.00 | 20.2 | 22.7 |
| 14.00 | 17.6 | 21.3 | 14.00 | 20.7 | 22.9 | 14.00 | 21.1 | 23.2 |
| 16.00 | 18.3 | 21.4 | 16.00 | 16.4 | 20.1 | 16.00 | 19.2 | 21.4 |
| 18.00 | 15.9 | 19.8 | 18.00 | 14.8 | 19.5 | 18.00 | 16.9 | 20.8 |
| 20.00 | 15.1 | 19.6 | 20.00 | 13.2 | 18.9 | 20.00 | 16.4 | 20.6 |
| 23.00 | 13.8 | 19.3 | 23.00 | 12.5 | 18.3 | 23.00 | 15.1 | 19.6 |
| 1.30 | 13.1 | 19.2 | 1.30 | 12.2 | 18.1 | 1.30 | 13.2 | 18.8 |
| 2.30 | 12.2 | 18.9 | 2.30 | 9.8 | 16.4 | 2.30 | 11.7 | 17.1 |

## 5. RESULT AND DISCUSSION

### 5.1 Parametric Optimization of EWPHE System

Before selecting the pipe material and measurement for the fieldwork setup, a simulation was conducted to determine the most optimal values for the impacting parameters. The simulation involves an analysis of the performance of the EWPHE system by adjusting various parameters, such as the type of pipe, its length, diameter, and the flow rate of the mass of water within the pipe. The analysis is additionally conducted to assess the impact of pipe burying depth over a one-year timeframe, specifically for the context of Joypurhat, Rajshahi.

The Earth is a radiator of heat for warmer temperatures, causing the ground's temperature to approach the average yearly ambient temperature as depth increases. Figure 4 illustrates the fluctuation in ground temperature at various levels. The mean temperature throughout the year ranges from 10.9 °C to 35.1 °C for a depth of 0.5 m, whereas for a depth of 3.5 m, the temperature stays within the narrower span of 18.8 degrees Celsius to 22.4 degrees Celsius. Given the slight fluctuation in temperature, a depth of 3.5 meters has been selected for the purpose of performing the simulations. The operation of the EWPHE is assessed at this specific depth for three distinct pipe materials, namely, steel pipe, galvanized iron (GI) pipe, and high-density polyethylene (HDPE) pipe. During the simulation of the burial depth influence on the performance of the EWHE system, all other design parameters were held constant for each outcome. This methodology is employed in all instances of subsequent simulations.

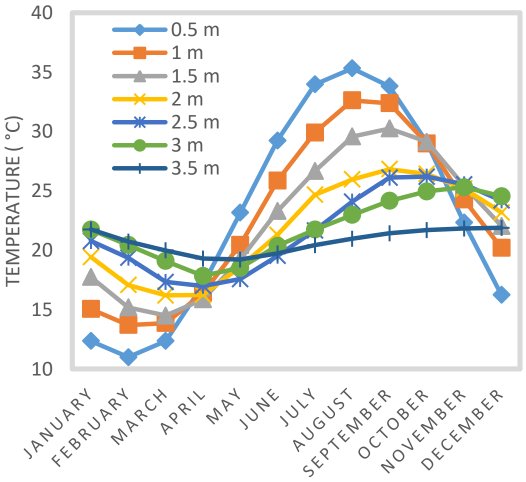

**Figure 4:** Range of annual ground temperatures in Joypurhat, Rajshahi (Bangladesh) at various depths

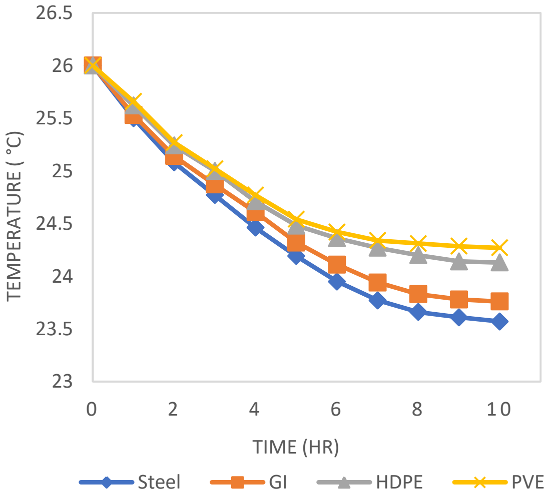

**Figure 5:** Comparison of EWPHE System's Output Temperature among different Pipe Materials

Subsequently, a simulation was conducted to determine the optimal pipe material for further simulations, wherein the pipe material would remain consistent for the purpose of conducting fieldwork. Figure 5 illustrates the outlet temperature of the EWPHE (Earth Water Pipe Heat Exchanger) for four distinct pipe materials while maintaining a constant input temperature of 26 °C throughout all scenarios. The specified conditions for this analysis include a pipe length of 50 meters, a diameter of 30 millimetres, and a fluid flow rate of 0.025 kilograms per second. The results suggest a minimal temperature difference of 0.2 °C between the heat-conducting fluid at the system's output for steel pipes and Galvanized Iron (GI). In contrast, when comparing PVC and HDPE pipes with Steel pipes under identical intake conditions, the variation in temperature is estimated to be roughly 0.7 °C. The observed variation can be caused by the smaller coefficient of friction shown by PVC and HDPE pipes. While GI and steel pipes display higher heat conductivity in comparison to HDPE and PVC pipes, they are also characterized by a more increased coefficient of friction. Moreover, these pipes are susceptible to increased weathering effects and corrosion. This results in a somewhat lower output temperature than the HDPE and PVC pipe. Based on this assessment, it can be inferred that the qualities of the materials in the EWPHE system have a negligible effect on its performance. The HDPE pipe was chosen for subsequent simulation purposes, whereas the PVC pipe was picked for field setup due to its lower cost in comparison to GI and steel pipes.

The HDPE pipe sizes that have been selected for investigation in this study vary between 20 millimetres to 80 millimetres, which is commonly available in the market. Figure 6 depicts the influence of varying diameters upon the EWPHE system, spanning between 20 mm to 80 millimetres, on a high-density polyethene (HDPE) pipe measuring fifty meters in length and having a water mass flow rate of 0.025 kg/s. The output temperature undergoes a steady change over time, either increasing or decreasing, when the pipe diameter is increased with respect to the corresponding season. There is expected to be a more noticeable decrease in temperature for High-Density Polyethylene (HDPE) pipes with a maximum diameter of 80 millimetres following a few hours of system conduction.

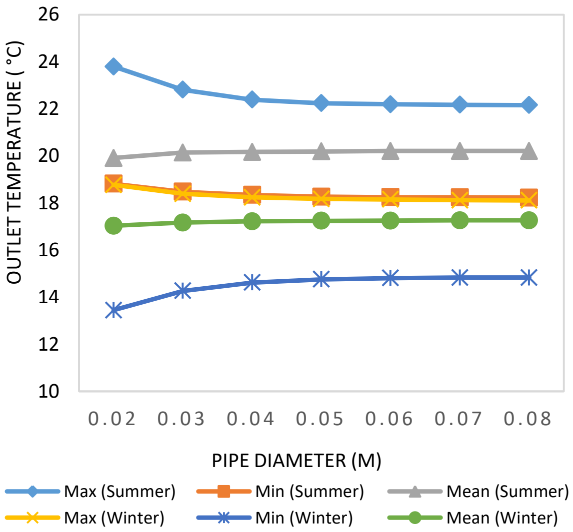

**Figure 6:** The relationship between outlet temperature and pipe diameter in an EWPHE system

After 10 hours of operation, the discharge fluid temperature for a pipe with a diameter of 30-millimeters is 14 degrees Celsius, while the discharge temperature for a pipe with an 80-millimeter diameter is 15.1 degrees Celsius. Conversely, during the peak summer season, the temperatures dropped to 23.1 °C for the 30 mm pipe and 21.8 °C for the 80 mm pipe. The difference can be caused by the larger surface area of the larger diameter pipe, which increases its contact with the underground soil and consequently enhances its capacity to absorb or emit heat. Although the variation in temperature is only 1.1 °C and 1.3 °C respectively, the cost of a 30 mm diameter pipe is around 78% lower than that of an 80 mm diameter pipe. Therefore, a pipe diameter of 30 mm may be suitable for real-world uses.

The effect of effective length was evaluated by maintaining a flow rate of water mass at about 0.025 kilogram/second for an HDPE conduit with an inner diameter of 30 millimetres. The outcomes resulting from the range of lengths, ranging from 20 m to 80 m, are illustrated in Figure 5. The data demonstrates that as the length rises, the corresponding temperature change also increases, as predicted. This relationship is expected, as longer lengths allow for a greater amount of time for the heat-conducting fluid to absorb or release heat. During the peak summer and peak winter periods, the temperature disparity between the 20 m and 80 m pipes is recorded at 5.9 °C and 2.3 °C, respectively. Notably, upon increasing the length of the pipe beyond 50 meters, there was a gradual decrease in the rate of temperature changes. A length of 50 meters should be sufficient to get the desired outcome. In order to optimize the efficiency of the EWPHE system, it is necessary to take certain measures into account. The utilization of a polyvinyl chloride (PVC) pipe has demonstrated notable efficacy. However, if feasible, employing an HDPE pipe for optimal performance inside the system is recommended. A burial depth ranging from 3m to 3.5m appears to be viable. The recommended range for the length of the pipe is between 40 and 60 meters, while the recommended range for the diameter is between 20 to 30 millimetres. It is necessary to ensure that the mass flow rate of water is kept at or below 0.025 kg/s. Considering these parameters, installing an EWPHE system will result in an efficiency of around 80% and minimal cost. Table 3 presents the values of the suitable design parameters.

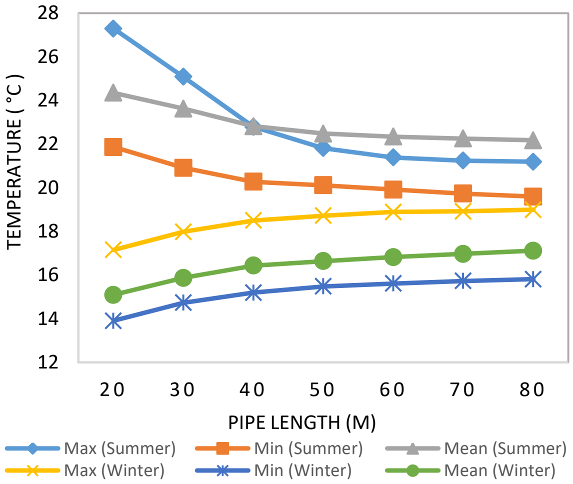

**Figure 7:** The relationship between the outlet temperature and pipe length in the EWPHE system

**Table 3:** Optimal design parameter values

| Variable design parameter | Optimal value |
|---|---|
| Pipe burial depth | 3.5 meter |
| Diameter of the pipe | 30 millimetres |
| Length of the pipe | 50 meters |
| Water mass flow rate | 0.025 kg/second |
| Built material of the pipe | HDPE / PVC |

### 5.2 Efficiency Assessment from Field Data

Figure 8 illustrates the fluctuation of the heat transfer rate over time in the EWPHE system, which was calculated using the collected field data. The heat transfer rate reached its maximum during the late-night hours, as the ambient temperature was at its lowest, and the flowing fluid had the best chance to collect heat from the underground soil. However, as the ambient temperature increases, the water running through the pipe has a reduced potential to absorb heat. This is due to the fact that a bigger temperature difference results in a higher rate of heat transfer. The heat transfer rate reached approximately 200 J/s during the midday peak for three consecutive days. Conversely, during the night period, the rate exceeded 700 J/s, representing an increase of nearly four times compared to the aforementioned amount. The efficiency of the system consistently fell between the range of 50 to 65 percent (Figure 9), with the exception of occasional dramatic increases. The minimal fluctuation in outlet temperature, caused by the stable ground temperature, significantly impacts maintaining a nearly constant efficiency. There are instances at midday when there are significant increases in efficiency when the ambient temperature approaches the ground temperature. These increases result in efficiencies above eighty percent. The findings indicate a little disparity between the results obtained from fieldwork and those obtained through modelling. This variation is believed to be caused by ambient energy dissipation, as well as the use of PVC pipe and a suboptimal depth of pipe burial. The utilization of HDPE pipes and maintaining a pipe burial depth exceeding 3m, together with keeping to appropriate pipe separation distances, has the potential to enhance efficiency.

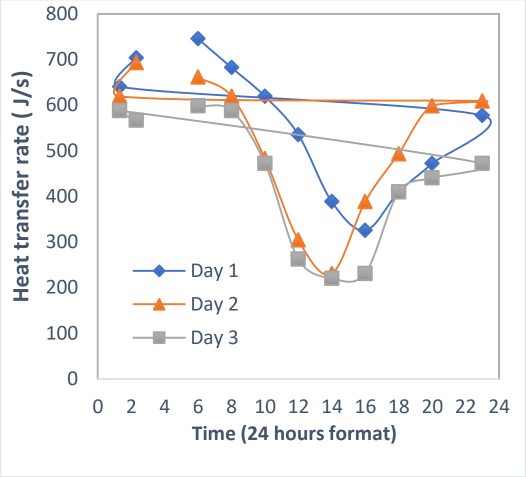

**Figure 8:** The relationship between the heat transfer rate of the EWPHE system and the time

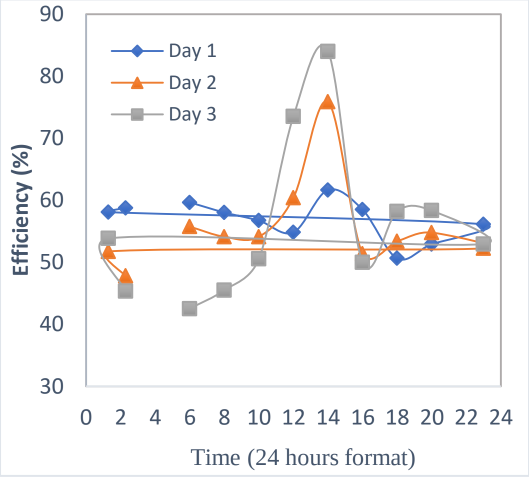

**Figure 9:** The relationship between the efficiency of the EWPHE system and the time

## 6. CONCLUSION

The Earth-Water Heat exchanger is a prospective technological solution that has promise for effectively adjusting air temperature by providing warmth during winter and cooling during summer. The system operates by taking advantage of geothermal energy, relying solely on a completely natural mechanism. The device demonstrates exceptional performance in the hot and humid as well as cold environmental conditions prevalent in Bangladesh. During the month of January, in Joypurhat, Bangladesh, the EWPHE system indicated an average efficacy of 55%. There is potential for additional optimization to enhance its performance. The utilization of an Earth-Water Heat Exchanger is highly recommended as a preferable alternative to the conventional Air Conditioning system in the context of Bangladesh based on the result. The rural population in Bangladesh has significant hardships due to the adverse effects of harsh climate conditions. Given the prevailing socioeconomic conditions in rural areas, where a significant proportion of the population faces financial constraints and lacks the means to purchase air conditioning (AC) units, the implementation of an EWPHE system emerges as a viable and practical solution for this group of people. The installation of the EWPHE system is cost-effective and requires minimal electricity consumption. The EWPHE can be widely implemented throughout Bangladesh due to its notable endurance and efficacy. In general, it can be asserted that the Earth-Water Heat Exchanger shows potential as a sustainable cooling system in the context of Bangladesh, with room for further enhancements. In order to facilitate the adoption of EWPHEs, it is important to conduct an economic feasibility evaluation that incorporates an optimization criterion. Future studies could potentially focus on enhancing the efficiency of a horizontal Earth-Water Heat Pipe Exchanger (EWPHE) through the use of a cost-effective approach.

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