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A review of the earth-to-air heat exchanger as a passive cooling and heating technique and the affecting parameters

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ABSTRACT

In recent times the EAHE is widely used as a passive cooling and heating technique due to the mounting thermal potential of the earth and because of the energy crisis. In the past years much, research has been published including studying this type of heat exchanger and using it in many applications and many locations with different climate conditions. Also, this research investigated the most affecting parameters. In this paper, a review is prepared to survey the published literature in this field to shed light on the research.

1. Introduction

The requirement to reduce the consumption of energy for heating and cooling loads improved through past time. Energy saving can be reached by depending on renewable energies for example solar, wind, and geothermal energy. For heating and cooling buildings, it can be reliant on the ground for example warmth source in the winter and a heat sink in the summer. The utilities of the geothermal energy in heating and cooling spaces can be consummate by using (EAHE) or moreover named earth heat exchanger Singh et al. [1].

The earth-to-air heat exchanger is a passive heating and cooling system and it is used in wide types of applications, for example, heating and cooling greenhouses, and industrial and inhabitation buildings. EAHE is usually involved in pipes or more -pipes that are inside the earth vertically or level. First, the end of the tube is linked to the supply end of the fan and the other side is open for air. While the air flows during the inhumed of tubes, the heat is the transmission from the air to the contiguous soil through a summer period and the opposite in the winter.

2. Applications

The earth-to-air heat exchanger is used in many applications mainly in Agricultural applications and residential building Equations [2].

2.1. Agricultural applications:

Okonkwo, W et al. [3] conducted an experimental investigation of the poultry house, with a solar Trombe wall which is equipped in order to provide ventilation, cooling, and heating to a poultry house. They noted that

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the EAHEs maintained the temperature in the range from 28°C -35°C, 586 grams of the average body weight, the rate of mortality is around 3%and the feed conversion ratio is 1.87%. Ahachad, M et al. [4] and Fawaz, H et al. [6] performed experimentally the influence of the heat stress phenomenon are offered with simulating and modeling the poultry house and the effect of all parameters on the performance of the building (shape, ventilation, orientation, etc) in North of Morocco. The results showed temperature will decrease per 2 air changes per hour by about 1.5°C, for 5 air changes per hour to 2.7 C° and 10 air changes per hour by 3.8 C°, the temperature of the inlet air reduction (up to 9 C°), and the production quality is enhancement. the ventilation led to a full decrease in the cycle cooling capacity of 29.9 %. Choi, Salim, et al. [5] studied the geothermal heat pump for heating poultry houses, the geothermal heat pump allows a lesser cost of heating and developed the product performance with a declining amount of the gas's discharges. Kapica, et al. [7] estimated the decrease of CO2 by using the solar-wind hybrid system for heating the house of poultry they discovered that the larger system provides a greater CO2 drop, however, the energy utilization ratio reduces. Azzeddine [8] studied the plan and modeling of the earth-to-air HE for the typical poultry house to estimate the potential of cooling and heating. The results found that the outlet temperature is 15°C for the cooling mode of summer and the heating mode in winter was 21.8°C. Azzeddine et al. [9] studied the thermal performance of the EAHEs through the parametrical to investigate the influences of the velocity of the air, the physical properties, and the diameter of the pipe. The results displayed that a heat exchanger gives a coefficient of performance that is higher with an upper efficiency and a system has a potential energy of 146.38 M W h in heating and 104.3 M W h in cooling modes. Wasseemet al. [10] studied experimentally the thermal performance of EAHE in arid and humid soil in the Basra in the semi-desert region for a poultry shed. They found results advance the overall heat exchange efficiency. The (COP) of the wetted exchanger with an average COP of 6.41, while the dry exchanger (DE) obtained a value of 5. 07. On average, the exit temperature from the wet exchanger (WE) was 37.35°C, however in the dry exchanger it was 38.91°C in the warmest hours of the day. Also, the WHE warmed the air over the dry exchanger system, throughout the night-time.

2.2. Residential building:

Sodha et al. [11] investigated the EAHEs pipe length requisite in the cooling of the model with different earth surface dealings of Delhi (India) for the compound climate. Observed from the result that for meeting the cooling load demand the dry sunny superficies required a long tunnel, while wet covered surface required the smallest length. From the parametric of their research, saw that improvement for the temperature of the profiles in soil with great moisture of substances is faster than compared to the soil with little moisture substances. Sharan and Jadhav [12] used EAHEs to be heating and cooling with modes that were working in India, and Ahmedabad, with yearly middle-temperature varieties between (23◦C and 43◦C). They found that a system was capable of rise the temperature by nearly 14◦C in January and reducing the temperature in May with the same value. The performance coefficient (COP) for heating and cooling was 3.8 and 3.3, correspondingly. F. Al-Ajmi et al. [13] improved a theoretical model to calculate the earth-to-air heat exchanger temperature of the air outlet and the potential of this cooling apparatus in warm and dry weather. The model for the classic home of Kuwait City. They found that the EAHEs could decrease home cooling energy requests through the summer season by 30%. M.K. Ghosal and G.N. Tiwari.[14] in India, an analytical model was advanced to study the efficiency of the earth's thermal air heat exchanger combined greenhouse found in New Delhi. Their Results presented that the thermal performance was suitable and advanced by using of EAHEs. M.K. Ghosal et al. [15] presented the advanced numerical model of using the kept thermal energy of earth for space warming to investigate the potential with the advantage of (EAHE) systems with the greenhouses situated in Delhi, India. Experimental. They found that the air temperature was discovered to be on average (7-8 C°) greater than the same greenhouse when operational minus EAHE. Celestial et al [16] executed experimentally during winter season thermal analysis with EAHE systems for the building integrated. The dimensions of building air temperature showed that using the EAHE system is increase by 5 – 15.8 ˚C in the temperature of the air of the building compared to ambient air temperature, consequently, it the concluded that the EAHE is appropriate for an axillary system for heating and cooling buildings. Transient Systems Simulation Software (TRNSYS) by Abdullahi Ahmed. et al. [17] estimated the thermal performance of the EAHEs for unlike shapes and work conditions in the UK. Their result showed a major enhancement in potential and internal thermal conditions to decrease the use of the energy-concentrated conservative cooling system. Bansal et al. [18] and Vaz et al. [20] showed out a numerical study with the help of FLUENT based on the computational fluid dynamics (CFD) surroundings for calculating the heating and cooling capability of earth to air-pipe heat exchanger (EAPHE) system. Mohammad Jia et al. [19] investigated experimentally the measurement of the capacity of cooling the ETAHEs in Bangladesh. They found that the COP and the capacity of Cooling increased with the increase of the mass rate of flow, and the outlet temperature declined below ambient temperature as the inlet air. Khalajzadeh et al. [21] estimated the performance thermal of earth heat exchanger (GHE) and evaporative cooler hybrid systems of Tehran, Iran in summer climate. They [60] saw that the hybrid systems can change the conventional air conditioner efficiently and its cooling efficacy is higher than unity. Tudor et al. [22] analyzed and advanced the suitability of using the EAHEs as the passive method for heating and cooling houses under the climate of five cities of South–Eastern Europe. They obtained that the exit air temperature from EAHEs noted during July and August month was the maximum monthly average, while in January month was the minimum. Moreover, they discussed, best the thermal performance and the high heat gain record by using pipe diameter of 100 mm instead of 200 and 300 mm &17 m pipe length instead of 10 and 5 m, 2.5 & 3.5 m burial depth in its place of 1 m. Ramirez-Davila et al [23] executed a numerical study on the performance thermal of the (EATHE) system by changing climatic conditions for three cities in Mexico. Their results presented that the use of EAHEs was suitable for extreme and enough temperature areas wherever the thermal inertia influence is greater in soil. Earth-to-air heat exchangers (EAHE) s with solar chimneys Haorong Li. et al. [24]. Experiments were studied to estimate the performance of the system in summer to investigate an innovative passive air conditioning system. They noted that EAHE full cooling aptitude in that Experimental was 3308 W, while the maximum cooling ability of coupled system EAHEs and solar chimneys was 2582 W, and they concluded that the increase in the exit air temperature. Trilok Singh Bisoniya et al. [25] discussed the decreased cooling of the energy demand of buildings experimentally in dry and hot climates in Bhopal (Central India). Observations of; the temperature were dropped from 12.90 °C to 11.30 °C and the gain energy of cooling of EAHEs improve from 0.85 to 1.87 MJ h for the airflow of speeds of 2m/s to 5m/s. Trilok Singh Bisoniya et al. [26] discussed the efficiency of decreasing the heat of energy requests of buildings in dry and cold winter climate conditions by using EAHE. Experimental results showed that heating potential various from 0.59 to 1.22MJ h for the air of flow speeds of 2 to 5 m/s, also correlation coefficient and root mean square of percentages deviance of 2.1% and 0.999. Nitish Shrestha et al. [27] Performance analysis of EAHE at different atmospheric conditions, Experimental that system consists of finned tube. Observed that in cooling mode the inlet temperature of the air drops with rise in the pipe length. The temperature reduction for a length of 1.2m differs from 1-3 C° at a velocity of 6.5m/sec. G.N. Tiwari et al. [28] experimentally estimate the thermal conductivity of soil, the EAHE system has been planned, measurement of room with improved values of radius of the pipe, length of pipe, number of air variations, and depth at which (HE) be fixed under the superficies of the ground. They observed that the outlet air temperature had a reduction of (5 – 6 °C) in summer for several 5 air variations with 0.10 m and 21 m enhanced diameter and pipe length respectively. Sanjeev Jakhar. et al. [29] expected experimentally the thermal performance of earth to air tunnel heat exchanger (EATHE) system linked by the solar air heating duct to develop the capacity of heating the EATHE system. They noted that the capability of heating of EATHE system improved from 1217.625 to 1280.753 kWh after it was linked with the solar air heating duct with a significant rise in temperature of a room by 1.1– 3.5 ◦C. The effect of the thermal performance of EAHE by its design parameters is planned numerically by Thakur et al. [30]. The results displayed that the thermal performance improved with using finned pipe wherever the air temperature was recorded to drop about 20.5 ˚C compared with 17.7 ˚C when the pipe is finless. A numerical study by Benhammou et al. [31] to estimate the thermal performance of the (EAHE)system in a passing one-dimensional season below the climate conditions of the Algerian Sahara. through summer. They found that the decline in the air temperature between the inside and exit of the system is greater with high inlet air temperature consequently by the tube length of 50 m, the drop in the air temperature is 11 ˚C for the air inside temperature of 44 ˚C and is 5 C° for the air inside temperature of 29 ˚C. After observing their results, they reached that the thermal performance of EAHEs developed at great air temperatures through the summer season. Hiresh. et al. [32] performed an experimental operation to study the Earth to Air Heat exchanger performance. They found that about 261.5 W was the maximum quantity of heat transfer from air to surrounding soil at 5 m/s the velocity of air. Also, they explained from the results that with the temperature of inlet air changing from 32 ˚C to 40.3 ˚C the exit air temperature increased by 4.5 ˚C at 5 m/s. Anuj Mathur et al [33] showed a numerical the problematic of the increase of heat nearby the tube during the summer period by soil having low moisture content and great specific heat. They obtained that the saturation of soil with heat hampers the performance of EAHEs and the heat can be enhanced on winter days by running the system. Sanjeev et al. [34] discuss experimentally and simulation typically using TRNSYS 17 to evaluate the heating of potential of earth air heat exchanger with and without solar heat pipe (SHD). They establish through the simulation results and experimental results that the heating capacity and exit air temperature of EAHEs are enhanced by using solar heat ducts.

Moreover, in the winter season, they found that the exit air of temperature improved by reduced air velocity. Badgaiyan P et al. [35]. evaluated the performance of EAHE with several operating parameters was studied experimentally and numerically. They proved that thermal performance enhanced with increasing the length of the pipe, wherever the outlet temperature was reduced. Additionally, they concluded that for three velocities of airflow (4, 5, and 6 m/s). the less outside temperature found with 4 m/s air velocity. Omar Hamdi et al. [36] study the performance of the earth-to-air heat exchanger (EAHEs) and discovery the usefulness of the cooling of buildings in the hot region in the southeast of Algeria at Biskra University. From the result observed. The air temperature at the outside of the exchanger is about 24 °C at the start of May to restart at 32 C° in early September.

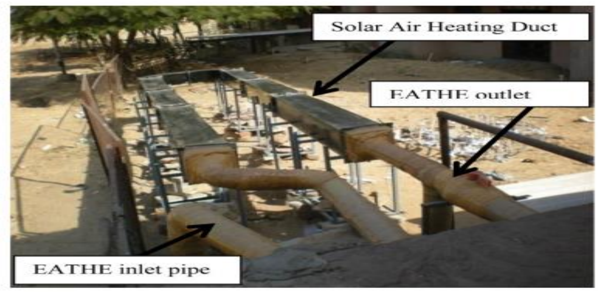

Figure 1. Experimental set-up of EATHE coupled with solar air heating duct.

Nasreddine Sakhri1 et al. [37] experimentally study is shown on the performance of a combined system: EAHEs and the solar chimney. in an arid region in the North-west of the city of Bechar, Algeria. They showed results of the capacity of the system to rise the outlet air temperature exit the system by 14 °C and produce the heating mode. The inside temperature increased, then, the system traveled to a cooling mode by decreasing this temperature of air by 11.6 °C (from 36.2 °C on the inside to 24.6 °C on the outside). Three-dimensional EAHEs combined with a house building by Mushtaq I. Hasan and Sajad W. Noori [38] discussed a numerical potential for a drop in energy consumption for heating and cooling loads by using the EAHE system in southern Iraq in the weather of Nasiriya city. The results showed that thermal performance and the outlet air temperature improved with the length and the pipe of a number of the EAHE system. So, The EAHEs is higher appropriate for work through winter month, wherever, the drop in energy saving and heating capacity is great compared with the decrease in energy saving and cooling capacity in summer months.

2.3. The earth-air heat exchanger with solar chimney

Also, they used MATLAB software with CFD modeling. Salman H et al. [39] studied to the investigating the influence of tube length, air speed, and tube diameter on the performance of the air thermal HE system in Basra, used (EAHE) collected with Solar chimney (SC).

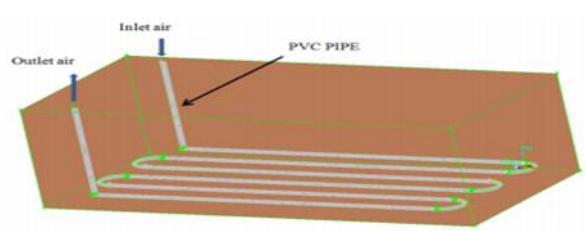

Figure 2. The Earth–tube–air heat exchanger system

Earth to -air heat exchangers (EAHEs) with solar chimneys by Haorong Li. et al. [24]. Experiments were studied to evaluate the performance of the system in summer to investigate an innovative passive air conditioning system. They noted that EAHE's maximum cooling capacity during that Experimental was 3308 W, while the full cooling capability of coupled system EAHEs and solar chimneys was 2582 W, and they saw a rise in the outside air temperature. Nasreddine Sakhri1 et al. [40] an experimental investigation is shown on the performance of a combined system: earth-to-air heat exchanger and a solar chimney, in an arid region in the North-west of the city of Bechar, Algeria. They showed results of the capacity of the system to rise the outlet air temperature exit the system at 14 °C and produce a heating mode. The inside temperature increased, then, a system traveled to the cooling mode by decreasing this temperature of the air to 11.6 °C (From 36.2 °C at the inside to 24.6 °C at the exit).

2.4 Effect of soil type and moisture content on EAHEs

After the parametric study by Puri. [40] Saw that advance of temperature profiles is quicker in soil by great humidity substances than in soil by little humidity contents. Their result is the improvement of the temperature with soil moisture contents. Sodha et al. [11] studied the earth air HE pipes length requisite in the cooling of the model with different earth surface dealings of Delhi (India) for the compound climate. Observed from the result that for meeting the cooling load demand the dry sunny surface required a long tunnel, while wet-shaded superficies required the smallest length. And improvement of the temperature of the profiles in soil by great moisture of contents is faster than compared to the soil with little moisture substances. Santamouris et al. [41] studied the effect of different earth superficies on the boundary of conditions on the multiple and single parallel EAHEs They provide efficiency high by using EAHE. Clara et al. [42] Presented the influence of soil shields, soil composition, and climate, on the performance of the EAHE systems. They reached that the bare surface for heating develops the performance of the EAHE, while the surface humid for the cooling object is better. They additionally, showed that the higher water content and carefully packed soil nearby the tubes of EAHEs develop EAHE system performance. Mathur et al. [43-44-45] evaluated that the soil temperature of the tube depends on the thermal conductivity of the soil wherever the soil with a lesser thermal conductivity will saturate the quicker than the soil with a greater thermal conductivity. Mushtaq I. Hasan and Sajad W. Noori.[46] explained numerical the influence of some plan and environmental factors (the material of the pipe and the thickness of the pipe wall, moist content of soil,) on the overall performance of an EAHE system. They showed that the saturated soil shows the greatest general performance of EAHEs compared with further soils, also the wall thickness and tube material have no significant influence on the overall performance. Agrawal. et al. [47] discuss experimentally the influence of sub-soil moisture content in hot and arid climates to enhance soil thermal properties and its influence on EATHE the pipe of length and thermal performance requisite for selected temperature declined for the summer cooling. They noted that COP and the average heat transfer rate improved by 24.0% and 24.1% correspondingly for 20% moisture content at 30 m EATHEs the pipe of length than to the dry system. Kamal Kumar A et al. [48] studied the moisture content and its effect on the pipe length and the performance of thermal necessary for selected temperature increases in the winter season. They saw that the coefficient of performance and the average heat transfer rise to 26.1% and 26.0% correspondingly, for 15% of the moisture content at the 30 m long pipe of the EAPHE system as than to the arid climate.

3. Affecting parameters

3.1. The effect of flow velocity

Bansal et al. [50] numerical study carried out on the ETHE systems through the winter period. From their results, they proved that 23.4 m of long the earth air thermal heat exchanger system can increase air temperature for the flow of speeds of 2–5 m/s in the range from 4.1–4.8 C°. Vikas et al [51, 54], and Sanjeev et al. [34] showed experimentally and numerically the influence of airspeed on the performance of earth-to-air heat exchanger systems. Their result found experimentally and numerically during summer and winter seasons that the exit air temperature improved with rising airspeed. Vikas Bansal. et al. [53] presented experimentally the effect of the operative parameters (air of velocity, the pipe materials) on the performance of thermal EPAHE systems to reduce the cooling capacity of the buildings in the summer period. They found that air temperature reduces with the rise in the velocity, and the performance of the coefficient of the system differs from 1.9 to 2.9 for the rise in speed from 2.0 to 5.0 m/s. V. Bansal et al. [52-56] performed the numerical simulation of the cooling capacity and thermal performance of EAHEs in hot and dry conditions. They have seen that the velocity of air during a pipe burial has been noted significantly influenced the performance of the earth-to-air heat exchanger. Mohammad Hossein et al. [55] Carried out experimental treatments on the influence of important parameters, counting pipe material and burial pipe (pipe of length, depth, air velocity), and on the performance of EAHE systems. They obtained that 5.5 of COP of the system for cooling type was greater than 3.5 for heating COP of material which is higher for steel than PVC. Also, the differential temperatures were 14.4 C° and 9.4 C° for cooling and heating modes.

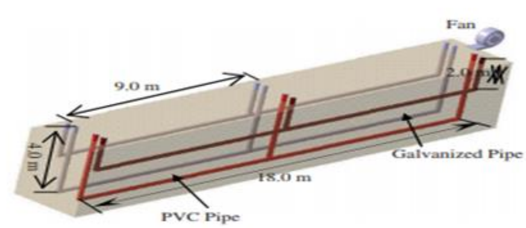

Figure 3. Schematic of the EAHE piping design.

Misra et al. [57] Estimate the variant of the derating element of the EAHEs because of the influence of the parameters. The result displayed that the rise in the flow of velocity causes a decline in the thermal performance of EAHEs. Nitish Shrestha1. et al. [28] performance analysis of EAHE at different atmospheric conditions observed that in cooling type the inlet temperature of the air drops with rise in the pipe length. The temperature reduction for a length of 1.2m differs from 1-3 C° at a velocity of 6.5m/sec. Salman H et al. [39]. studied to show the effect of the tube length, airspeed, and pipe diameter on the performance of the air thermal HE system in Basra. The result has presented that the potential of the Earth Tube is providing a lesser exit temperature of the air inside the area. They discover that the temperature at the outlet from the buried pipe declines with rising the length of the pipe, declining pipe diameter, declining mass flow rates of flowing air in the tube and rising depths above 4.m .Experimental and theoretical studies have been by Mohammed Benhammou and Belkacem

Draoui [58] to show the impact of dynamical and geometrical parameters on the thermal performance of EAHEs the thermal performance of (EAHEs) to the summer cooling in the Algerian Sahara. Their result obtained that the air exit temperature declines with rising the length of the pipe, but it rises with rising the velocity of air and pipe cross section, also experimental that COP declined quickly with increasing the velocity of air. the numerical study by Benhammou et al. [31] to estimate the thermal performance of earth-to-air heat exchanger systems in a passing one-dimensional season below the climate conditions of the Algerian Sahara. through summer. They noted from the results that the air temperature in an outlet from the system with a pipe length of 30 m is less by 2 ˚C compared with a 10 m pipe length. Also, they observed that the air temperature in the outlet decreased by 1.8 and 1.2 by using a 10 cm pipe diameter of 30 cm and 1 m/s air velocity in place of 3 m/s. Similarly, with the foundation of Krarti et al. [49]. Ahmed et al [59]. discussed the numerical and experimental investigation of the thermal performance of EAHE systems with diverse parameters (pipe length, pipe space, pipe diameter, and pipe material) in Egyptian weather conditions. The results showed by using computational fluid dynamic saw that the air temperature at the exit increases with reduced diameter, increasing pipe length, and decreasing the flow rate. Sanjeev J et al. [34] showed experiment was through the winter season for the influence of diverse inside flow velocities, and concluded that the best rise in EAHE exit temperature at the speed 5m/s compared with the velocity at 2.5m/s and 3.5m/s. While Jahkar et al [60] studied the parametric done to analyze the influence of mass flow rate, the radius of buried pipe, length of the tube, and the material of pipe on the performance study of an EWHE system. They obtained that by a rise in mass flow rate, the temperature in the outlet of EHWE rise.

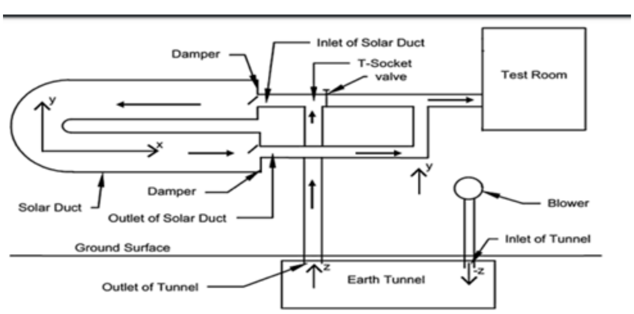

Figure 4. Schematic diagram of the experimental setup

Badgaiyan P et al. [35] estimated the performance of EAHEs with several operating parameters studied. They proved that thermal performance enhanced with increasing the length of the pipe, wherever the outlet temperature was reduced. Additionally, they concluded that for three velocities of airflow (4, 5, and 6 m/s). the less outlet temperature found with 4 m/s air velocity. Mushtaq I. Hasan and Sajad W. Noori [61] studied numerically the overall performance of the EAHE by five forms of the EAHEs channel. They discover that the outlet air temperature reduced through the summer and increased through the winter season period, with increasing pipe length or declining airspeed, so, they showed that there is the circular form gives the greatest general performance since it has the smallest pressure drop than by further figures.

3.2. Effect of length of pipe

Mihalakakou et al. (1995) [62] discuss the parametrical model in which changing parameters were tube radius, pipe length, speed of the air inlet the pipe, and the buried depth pipe under the earth superficies. conclude with an increase in the velocity the temperature is enhanced. Bansal et al. [50] numerical study carried out on the earth's air HE systems through the winter periods. From their results, they proved that 23.4 m of long the earth air thermal HE systems can increase the air temperature for a flow of velocities of 2–5 m/s in the range from 4.1–4.8 °C. Maerefat and Haghighi [63], and Pohstiri et al., [65] have advanced a mathematically typical based on energy conservation equations and resolved by iterative way to find out the ability of the solar chimney and EAHE system. pipe lengths of EAHE must be used to afford the best thermal security condition of less than 35m. The results showed of the influence of EAHEs tube radius on the system performance exposes that the rise of the EAHEs diameter up to 0.5m does not rise the room air temperature. Ascione et al. [64]. evaluated the energy of performance of the air-to-conditioned building joined by a ground heat exchanger (GHE) in the Italian weather. Their result obtained for a 50 m length of ground heat exchanger pipe was about 14.2 kWh/m2 is the maximum major energy saving. Mohammad Hossein et al. [55] Carried out experimental treatments on the influence of important parameters, counting pipe material and burial pipe (pipe of length, depth, air velocities), and on the performance of an EAHE system. They obtained that 5.5 of COP of the system for cooling style was greater than 3.5 for heating COP of material which is higher for steel than PVC. Also, the differential temperatures were 14.4◦C and 9.4◦C for cooling and heating modes. academics [66-67] have discovered that the system provides best the thermal performance by rising the tube length burying, the pipe at a depth above 3 m, expanding the superficies of a pipe, and decreasing the tube radius and the air flow rate inlet the tube. Nitish Shrestha1. et al. [28] performance analysis of EAHEs at different atmospheric conditions observed that in the cooling style, the inlet temperature of the air drops with the rise in the tube length. The temperature reduction for the length of 1.2m differs from 1-3 C° at a velocity of 6.5m/sec. Experimental and theoretical studies have been by Mohammed Benhammou and Belkacem Draoui [58] to show the influence of dynamical and geometrical parameters on the thermal performance of EAHEs the thermal performance of (EAHEs) for summer cooling during the Algerian Sahara region. Their result concluded that the air exit temperature declined with rising the length of the pipe, then it increased with increasing the velocity of air and pipe cross section, also experimental that the coefficient of performance declined fast with rises in the velocity of air. the numerical study by Benhammou et al. [31] to estimate the thermal performance of an earth-to-air heat exchanger system in a passing one-dimensional season below the climate conditions of the Algerian Sahara. through summer. They noted that the air temperature in the outlet from the system with a pipe length of 30 m is less by 2 ˚C compared with a 10 m pipe length. Also, they observed that the air temperature in the outlet decreased by 1.8 and 1.2 by using a 10 cm pipe diameter of 30 cm and 1 m/s air velocity in place of 3 m/s. Similarly, with the foundation of [49]. Ahmed et al [59] discussed the numerical and experimental investigation of the thermal performance of EAHEs with parameters (pipe length, pipe space, pipe diameter, and pipe material) in Egyptian weather conditions. The results showed by using computational fluid dynamics observed that the air temperature at exit increases with reduced diameter, increasing tube length, and decreasing the flow rate. Jahkar et al [67] studied the parametric done to analyze the influence of mass flow rates, the radius of the buried tube, pipe length, and pipe substance on the performance analysis of the EWHEs. They obtained that with the rise in mass flow rate, the temperature in the outlet of EHWEs rises. While [76] showed experiment was through the winter season for the influence of diverse inside flow velocities, concluded that the best growth in EAHE exit temperature at the velocity 5m/s than to velocity at 2.5m/s and 3.5m/s. Badgaiyan P et al. [35] estimated the performance of EAHE with several working parameters studied. They proved that thermal performance enhanced with increasing the length of the pipe, wherever the outlet temperature was reduced. Additionally, they concluded that for three velocities of airflow (4, 5, and 6 m/s). the less outlet temperature found with 4 m/s air velocity. Mushtaq I. Hasan and Sajajd W. Noori.[61] study numerically the general performance of the EAHE by five forms of the earth air heat exchanger channel. They discovered that the exit air temperature reduced through the summer and increased through the winter period, with the rising pipe of length or declining air of velocity, so, they established that there is the circular form gives the greatest general performance since it has the smallest pressure of drop compared by further figures. Agrawal. et al. [48] studied experimentally the influence of sub-soil humidity content in hot and arid climates to improve soil thermal properties and its influence on EATHE the tube of length and thermal performance requisite for selected temperature declined for the summer cooling, COP, and the average heat transfer rate improved by 24.0% and 24.1% correspondingly for 20% moisture content at 30 m EATHE the pipe of length as compared to the arid system. Mushtaq I. Hasan and Sajad W. Noori [46] studied numerically the effect of the parameters (inside the condition, pipe diameter, pipe length, and exit condition) on the general performance of the EAHEs. They pretend results presented that the EAHE systems with pipe radius (6 in) have the best values of general performance. Then, the diameter of the pipe more suitable is 2 in from the thermal performance point of overview.

3.3. Effect of the diameter of the pipe

Mihalakakou et al. (1995) [62] discuss the parametrical typical in which changing parameters were pipe radius, pipe length, speed of the air inlet the cylinder, and the buried depth pipe under the ground superficies. conclude with an increase in the velocity the temperature is enhanced. Maerefat and Haghighi [63], and Pohstiri et al. [65] have advanced the mathematical typically based on energy conservation equations and resolved by iterative way to find out the ability of the solar chimney and EAHE system. pipe lengths of EAHE must be used to afford the best thermal security condition of less than 35m. The results showed the influence of EAHE system tube radius on the system of performance exposes that the rise of the EAHEs diameter above 0.5m does not rise the area air temperature .academics [66,67] have discovered that the system provides best the thermal performance by rising the tube length burying, the tube at the depth up to 3 m, expanding the superficies of the pipe, decreasing the tube diameter and the airflow rates inlet the pipe. G.N. Tiwari et al. [69] experimentally estimate the thermal conductivity of the soil, earth - to air heat exchanger system planned, measurement of room with improved values of radius of the pipe, length of pipe, number of air variations, and depth at which (HE). They observed that the exit air temperature had a reduction of 5 – 6 C° in summer for the number of 5 air variants with 0.10 m and 21 m enhanced diameter and length of pipe correspondingly. Salman H et al. [39] studied to investigate the impact of the pipe length, air velocity, and pipe diameter on the performance of the air thermal HE system in Basra. The result has presented that the potential of Earth Tube is providing lesser outside temperature of the air inside the area. They discover that the temperature at the outlet from the buried pipe declines with rising the length of the pipe, declining pipe radius, declining mass flow rates of the flowing air in the tube, and rising depths above 4m. The numerical study by Benhammou et al. [31] estimated the thermal performance of the Earth air HE system during a passing one-dimensional season below the climate conditions of the Algerian Sahara. through summer. They noted from the results that the air temperature in the outlet from the system with a pipe length of 30 m is less by 2 ˚C compared with a 10 m pipe length. Also, they observed that the air temperature in the outlet decreased by 1.8 and 1.2 by using a 10 cm pipe diameter of 30 cm and 1 m/s air velocity in place of 3 m/s. Similarly, with the foundation of [49]. Ahmed et al. [59] discussed the numerical and experimental investigation of the thermal performance of the EAHE system with diverse parameters (pipe length, pipe space, pipe diameter, and pipe material) in Egyptian weather conditions. The results showed by using computational fluid dynamic saw that the air temperature at the outlet increases with reduced radius, increasing tube length and decreasing the flow rate. Jahkar et al. [68] studied the parametric was done to analyze the influence of mass flow rate, the diameter of the buried tube, pipe length, and tube of material on the performance inquiry of the EWHE system. They obtained that with a rise in mass flow rates, the temperature in the outlet of EHWE rises. While [76] showed experiment was through the winter season for the influence of diverse inlet flow velocity, concluded that the batter growth in EAHE exit temperature at the velocity 5m/s than to the speed at 2.5m/s and 3.5m/s. Mushtaq I. Hasan and Sajad W. Noori [48] studied numerically the influence of the parameters (inside the condition, pipe diameter, pipe length, and exit condition) on the general performance of the earth air heat exchanger (EAHE) system. The simulated result presented that the EAHE systems by pipe diameter (6 in) have better values of general performance. Then, the diameter of the tube more suitable is 2 in from the thermal performance point of overview.

3.4. Effect of pipe thickness

Mushtaq I. Hasan and Sajad W. Noori (2018) [70] explained numerical the influence of specific design and environmental factors (pipe material and thickness of tube wall, moist content of the soil,) on the overall performance of the earth-to-air heat exchangers. they showed that the saturated soil displays the greatest general performance of EAHEs than by other soils, also the wall thickness and pipe material have no significant influence on the overall performance.

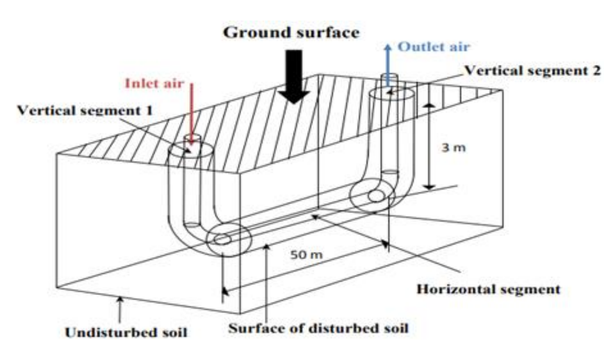

Figure 5. Schematic of EAHE system

Mushtaq I. Hasan and Sajad W. Noori.[71] studied numerically the effect of wall thickness and tube material on the overall performance of EAHEs. Their results noted the more suitable to use is PVC pipe because it is non-corrosive and less costly compared with a steel pipe. The influence of wall thickness on the overall performance is less and can be neglected.

3.5. Effect of pipe material

Vikas Bansal. et al. [72] discuss experimentally the influence of the operative parameters (the air velocity, the tube material) on the thermal performance of EPAHE systems to decrease the cooling capacity of the buildings in summer. they found the air temperature reduces with the rise in the speed, and the COP of the system differs from 1.9 to 2.9 for the rise in the velocity of 2.0 to 5.0 m/s. In addition, the maximum rises in temperature for steel and PVC pipes are 10.3 and 12.7 8C correspondingly. V. Bansal et al. [52-56] performed the numerical simulation of the cooling capacity and thermal performance of EAHEs in warm and dry conditions. They have observed that the performance of the EAHEs is not significantly influenced by the material of a pipe buried, while the velocity of air during a pipe buried has been noted significantly influenced the performance of the EAHEs. Mohammad Hossein et al. [55] Carried out experimental treatments on the influence of important parameters, counting pipe material and burial pipe (pipe length, depth, air velocity), and on the performance of the EAHE system. They discovered that 5.5 of COP of the system to cooling mode was greater than 3.5 for heating COP of material which is higher for steel than PVC. Also, the differential temperatures were 14.4◦C and 9.4◦C for cooling and heating types. Hatraf et al. [73] have studied the effectiveness of the parameters of the performance of EAHE during experimentation and modeling. They have done the design using the simple typical varied some and the supply of the air temperature. they found that the pipe of material does not influence the performance of the HE, which is an arrangement by the found of Bansal et. al [52]. Serageldin et al., [75] calculated the thermal performance of the EAHEs used for cooling and heating in the Egyptian climate conditions. They have advanced the mathematical typically founded on unsteady, one-dimensional, quasi-to-state energy conservation equations Three diverse kinds of pipe material were used, specifically steel, PVC, and copper. The exit air f temperature was 19.7 °C in the PVC tube, and 19.8 °C for together copper and steel correspondingly. So, it is established that the difference in the exit air temperature for many pipes material is also lesser and later it is negligible. Mushtaq I. Hasan and Sajad W. Noori [70], Mohd, Noor A, et al. [74] explained a numerical influence of certain design and environmental factors (tube material and thickness of pipe wall, moist content of the soil) on the overall performance of the earth to air heat exchangers systems in Nasiriyah town in the south of Iraq. they showed that the saturated soil displays the greatest general performance of EAHEs than with further soils, also the wall thickness and pipe material had no significant influence on the overall performance. Mushtaq I. Hasan and Sajad W. Noori.[71] studied numerically the influence of wall thickness and tube material on the general performance of EAHE. The results showed the more suitable to use is PVC pipe because it is non-corrosive and less costly compared with a steel pipe. The influence of wall thickness on the overall performance is less and can be neglected, the pressure drops and the exit air temperature for the two materials improved with rising the velocity of air.

3.6. Effect of pipe depth buried underground:

Pfafferot.[75] and Pfafferot et al. [76] studied the average yearly temperature profile at depths of 1 m, 2 m, 4 m, and 8 m. The result presented that the temperature at depths of 4 and 8 m was stable during the time in the range of 9 to 13°C. Cucumo et al. [77] explained the effect of the burial pipe depth on the performance of earth-to-air heat exchanger systems. The model was allowable also to calculate the temperature of air inlet the tube and soil nearby the buried pipe, taking into description the thermal perturbation of greater free superficies and the possible phase change (concentration) in the buried pipes. A like model was advanced by Su et al. [78] to discuss the thermal performance of EAHEs used for building energy saving. Mohammad Hossein et al. [55] Carried out experimental treatments on the influence of important parameters, counting pipe material and burial pipe (pipe length, depth, airspeed), and on the performance of an EAHE. They discovered that 5.5 of COP of the system for the cooling style was greater than 3.5 for heating COP of material which is higher for steel than PVC. Also, the differential temperatures were 14.4◦C and 9.4◦C for cooling and heating modes. Academics [66,67] have discovered that a system provides best the thermal performance by rising the pipe length burying, the pipe at a depth of up to 3 m, expanding the superficies of the pipe, decreasing the pipe diameter and the airflow rates inlet the pipe. Mushtaq I. Hasan and Sajad W. Noori.[79] thesis discussed a numerical study about the potential decrease in the request for energy and the overall performance of (EAHE) systems for heating and cooling of house buildings in the EAHE system of southern Iraq in Nasiriyah city. They showed that more appropriate to use is the EAHE system of case 2 compared with case 1 and case 3 II (consisting of one layer buried with a 3 m depth of EAHE system and the EHAE of this case3 II buried with a depth of 4 m) with saving in energy 17.84% of winter at January months and 9.33 % of summer months at August month.

4. The disadvantages. of the application

1. Possibility of Depletion of Geothermal Sources.
2. High Investment Costs for Geothermal Systems.
3. Land Requirements for Geothermal System to Be Installed.
4. environmental Concerns about Greenhouse Emissions.

5. Conclusions

The EAHE is one of the systems that can be used for decreasing energy consumed in buildings, thermal performance of the EAHE depends on several chief influences such as under earth temperature difference, plan and specification of the EAHE pipe, the following conclusions can be decided:

1. Thermal performance improved with using a finned pipe wherever the air temperature was recorded to drop about 20.5 ˚C compared with 17.7 C° when the pipe is finless.
2. The wall thickness and pipe material have no significant influence on the overall performance
3. The effect of EAHE system tube diameter on the system of performance exposes that the rise of the EAHE diameter leads to an increase in the area of the pipe causing an increase in temperature

outside of the pipe and it causes a decrease in pressure drop.

4. The EAHEs could decrease home cooling energy requests through the summer season by 30.
5. The increase in the length of the pipe of EAHE lead to a decline in the temperature interning to the poultry houses, then it increased with increasing the velocity of air and pipe cross-section.

Authors' contribution

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Declaration of competing interest

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