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Environment Friendly, Low Energy, Heating, Ventilation and Air Conditioning (HVAC) System, Using Water Medium as a Heat Exchanger

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Abstract- Now that there is an ever-increasing demand of energy all over the world and the subsequent problem of global warming and climate change due to rise in the level of carbon dioxide in the atmosphere; there is an intense need for a cooling/heating system which would be energy efficient and environment friendly. The conventional air conditioning system consumes a lot of energy, which has a major contribution to present energy crises globally. Moreover, it is responsible for large emissions of CO_2, chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs). CO_2, particulate matter, and other air pollutants are also produced due to burning of fuel wood and fossil fuel for heating in the winter season. The objective of this study was to devise an economical, environment friendly and low energy HVAC system. The novelty of the proposed HVAC system is that it uses no compressor and no evaporation technique for cooling. No humidity problem, there is only an exchange of heat between water and air. The system is capable to deliver air at the temperature of fresh groundwater of that city or location in any season of the year. A simple experimental method was adopted to test the proposed HVAC system i.e. air was blown in pipe which passed through water medium. Temperature of the system air at outlet was measured and recorded in the form of a table for various lengths of the pipe. Results show that atmospheric air assumed the temperature of water, as it passed through it in a plastic or copper pipe. The suitable length for copper pipe and plastic pipe was experimentally determined i.e. the length of pipe at which the temperature of system air and that of water medium becomes more or less equal. In case of fresh groundwater as a medium the suitable length for copper pipe was less than 2.44 feet, while for plastic pipe the suitable length was 20 feet. In Peshawar the groundwater temperature is 23.38 ^{O}C and in majority of the cities of Pakistan the groundwater temperature lies in the range of 17 to 27 ^{O}C, so, the proposed HVAC system would work efficiently in most of the cities of Pakistan.

Keywords- Energy saver cooling/heating system, fresh air supplied to the building, fresh air blown in pipe passed through water tank, water as refrigerant, no increase in humidity, no use of compressor, water air heat exchange.

I. INTRODUCTION

People spent most of their daily lives inside the buildings, so achieving thermally comfortable buildings are the prerequisite of a good quality of life at affordable economic and environmental cost. A lot of research has been dedicated to make the buildings thermally comfortable with increased emphasis on energy conservation. Given below is a brief account of the relevant research studies. Leskovar [1] maintain that the climate change is a burning issue, the sciences of civil engineering and architecture place great emphasis on ecological solutions and construction methods which are eco-friendly and energy efficient and which will emit less CO_2 by saving energy during heating, cooling and lighting of the building. It is a fact that buildings are one of the largest energy consumers and greenhouse gas emitters, so any energy saving strategy, related to buildings would be of great value and significance.

The energy consumption by the building sector is the largest, surpassing the industry and transportation sectors. At present, globally buildings consume 40% of the total energy consumption [2]. In the European countries the share of the buildings in energy consumption is 40% of the total social energy use, while, in New York this share is approximately 66% [3]. In Organization for Economic Cooperation and Development (OECD) countries buildings consume 25% to 40% of the total energy consumption. Buildings have a long life, so any decision about building, for example energy consumption on space conditioning, bears long term consequences. In temperate climates, indoor air conditioning, that is heating and cooling, consumes 50% of the total energy consumed by a building [4].

The European Union through the framework of the Smart Cities and Communities Initiatives calls upon the cities to adopt innovative measures to significantly decrease greenhouse gas emissions by efficient use of energy. In 2012, the first Smart Cities Initiative was taken, supporting the use of innovative measures for heating and cooling of buildings. The heating and cooling strategy involves the use of renewable energy sources via improved energy efficiency [5]. Vladimir J. [6] put forward guidelines for the urban planners, architects, engineers, and students who are involved in the design and construction of energy–efficient buildings. The author is of the view that the energy efficiency of the existing building stock will play a crucial role in lowering energy consumption because of the fact that about 80% of the existing building stock in the European Union will be functional even in the year 2050. So, any plan of reducing energy consumption of the future building stock must include the energy performance of the existing buildings. In space heating, a lot of energy is lost due to low thermal quality of the external walls, windows, floors, and ceiling and also due to air infiltration. Hence thermal insulation is a must to curtail energy demand in buildings [7]. The US government is sponsoring building energy efficiency research and implementation programs, aimed at focusing on decreased energy demand in residential and commercial buildings as well as decreased carbon emissions. It is expected that these energy efficiency related programs, in 2020, would lower site energy demand in the US buildings by more than 2 Exajoules (EJ) and primary energy demand by more than 3.5 EJ – more than the required amount to overcome the expected rise in cooling energy demand because of climate change and growth in the building stock of the US. It is estimated that these savings, in monetary terms, would have an annual net value of $ 45.0 to $ 47.3 billion to consumers as per 2005 energy prices [8]. For curtailing the ever-increasing building energy requirements, the best strategy is passive solar design which helps minimize the thermal load of residential buildings [9]. It has been found through simulation and orthogonal analysis that a passive solar house, having a water thermal storage wall (WTSW) instead of an ordinary wall, can minimize the annual energy consumption by 8.6 % and upgrade the indoor thermal comfort evaluation index by 12.9 % [3].

The research into HVAC system is gaining much more importance because of the ever-increasing demand for cooling even in countries with mild climate like UK. [10] In a quest for optimization in the energy consumption of air conditioning, LuLu, [11] through a modified genetic algorithm, simulation model, came to the conclusion that the energy consumption of air conditioning could be minimized by operating the components of the system at the optimal set points of the controllable variables like chilled water supply temperature, chilled water pump head, differential pressure of the air in duct networks, and sequencing of chiller and pumps. Chretien, [12] report that the energy consumption share of HVAC system is more than 45 % of the total energy consumption, in US households. In the three main categories of HVAC system namely; Fixed or Single- speed system, Multi-speed system, Variable- speed system, majority of the households are using Single- speed system and only 10 % households are using Variable- speed system, in spite of the fact that Variable- speed system is significantly energy efficient as compared to the other two categories. This may be due to the complex circuitry associated with variable compressor speed and the high cost of the system. Early Fault Detection Diagnosis (FDD) of HVAC systems in smart buildings through a software based Non – Intrusive Load Monitoring (NILM) tool can help save heavy energy losses due to faulty and inefficient HVAC equipment [13]. A Rafati, et al. [13] wrote the first review paper on the significance and limitations of NILM techniques. They maintain that a lot of improvements and development is needed in the NILM based FDD methods to meet the real world challenges. Dai, et al. [14] found that HVAC systems were capable to remove bio aerosols from the air in the hospitals. Moreover, in the under ventilated areas, only high efficiency particulate air (HEPA) filter component of the laminar air flow (LAF) could remove bio aerosols efficiently.

Using earth as a heat exchanger through buried pipes for cooling/heating natural air is a very old concept. However, very little study has been carried out on this subject in European countries [15]. The use of earth passive cooling/heating is gaining importance nowadays. At a depth of greater than 30 feet the earth has a constant temperature [16], which is equal to the average annual air temperature above the surface of the land at that location [17]. Due to this property the earth can be used as a heat exchanger for cooling/heating the ambient air. The ambient air after passing through buried pipes assumes the temperature of the earth and thus the conditioned air is supplied to the building. As a result, the heating and cooling load of the building is minimized. Thus, the use of conventional energy is curtailed leading to low emission of CO_2. The earth – air heat exchanger system is cost effective, easy, and environment friendly. During the month of June, the room fitted with an earth – air heat exchanger has 6.8 ^{O}C less temperature as compared to ordinary room [18]. Similarly, the temperature of fresh or outside air is tempered while passing through an underground tunnel. In summer hot air is cooled and in winter cold air is warmed. So, the heating and cooling loads of the underground installation are minimized [19]. In Pakistan the electric power demand is 15000 to 20000 MW per day whereas, it is producing 11500 MW per day, so, there is an electric power shortfall of about 4000 to 9000 MW per day [20]. Air conditioning is the main cause of electric power shortfall and the consequent load shedding because the consumption rate of air conditioning in Pakistan is more than 5000 MW which is more than the electric power shortfall. So, it can be rightly said that no air conditioning, no load shedding [21]. However, in the majority of the cities of this country, including Peshawar, life is comfortless without air conditioning due to extreme weather conditions i.e. very hot in summer and very cold in winter. The average maximum temperature of the district Peshawar is more than 40 ^{O}C and the average minimum temperature is 25 ^{O}C in summer season, while in winter the average minimum temperature is 4^{O}C and the average maximum temperature is 18.35 ^{O}C [22].

So, there is an intense need to devise such a cooling and heating system which will consume very little energy as compared to the conventional air conditioning and which will be environment friendly. The proposed energy saver cooling/heating system is a system which will meet the above requirements i.e. it will consume less energy and will be environment friendly as it does not utilize the so called CFCs or HFCs as a refrigerant. This system is analogous to Earth to Air Heat Exchanger (EAHE) system, in which the hot atmospheric air loses its heat to the earth, while passing through the underground pipes during summer season; the cooled air is then supplied to the building through the outlet. In the winter season, the cold atmospheric air while passing through the underground pipes gains heat from the earth; consequently, warmed air is supplied to the building through the outlet [23]. Likewise, in the proposed HVAC system the hot atmospheric air in the summer season gets cooled as it passes, inside a pipe, through fresh groundwater medium. Similarly, in the winter season, the cold atmospheric air inside a pipe gains heat from the fresh groundwater while passing through the fresh groundwater medium and gets warmed. The underground earth and underground freshwater has a constant temperature throughout the year [16], [17].

Novelty of the Research Work

The proposed HVAC system is unique in a manner that it uses no compressor and no evaporative cooling technique. It uses water as a refrigerant unlike the conventional CFCs and HFCs refrigerants. Water is a natural refrigerant which has no environmental impact. The conventional air conditioning requires a lot of energy for the operation of compressor; moreover, it uses CFCs and HFCs as refrigerant which have serious environmental impacts with respect to ozone layer depletion and global warming. The evaporative cooling technique has the drawback of increasing humidity. It works better in the dry and hot climates, however in the wet and humid climates it fails to work properly. The proposed HVAC system consumes very low energy as compared to conventional air conditioning and evaporative cooling systems. In this system the fresh atmospheric air is blown into a pipe which is passed through a water medium. At the outlet the tempered air is supplied to the building. There is no physical contact between the air and the water; however, there is only transfer of heat, so no chance of increase in the humidity. This system is suitable for both dry and wet sort of climates and all seasons of the year. The proposed HVAC system is capable to deliver air at 17 to 27 ^{O}C, in both summer and winter seasons, in most of the cities of Pakistan. This system is very economical, low energy and environment friendly. The water tank must be insulated to isolate the water medium from the surroundings thereby increasing the efficiency of the system.

II. Materials and Methods

Study Area

Peshawar is the capital city of the Khyber Pakhtunkhwa province. The geographical location of Peshawar is 34^{o} 01$^{/}$ N and 71^{o} 35$^{/}$ E. The maximum average temperature of the district Peshawar is more than 40 ^{O}C and the average minimum temperature is 25 ^{O}C in summer season, while in winter season the average minimum temperature is 4 ^{O}C and the average maximum temperature is 18.35 ^{O}C [22]. The calculated value of temperature of the fresh groundwater of Peshawar is 23.38 ^{O}C [refer to table – 1]. The whole of the district can be divided into well developed, moderately developed, and less developed areas.

Experimental Work

Several experiments were performed to check the utility and efficiency of the proposed HVAC system. The experimental arrangement was such that the tank of an air compressor was connected to the hose pipe which in turn connected to the copper pipe. Then a specific length of the copper pipe was immersed in a bucket filled with fresh groundwater, hot water or cold water leaving one end of copper pipe, slightly, out of water called the outlet. Alcoholic Thermometer was used to record the temperature of the air, gushing out of the outlet. First the temperature of the air of the outlet was to be noted before immersing the copper pipe in water and then when the copper pipe was immersed in water, the temperature of the air, gushing out of the outlet, was noted. The experiment was repeated, using different lengths of copper pipe and plastic pipe. The observations were recorded in the form of a table. Experimental arrangement for demonstration of the proposed HVAC system is shown in figure – 1 (a), (b).

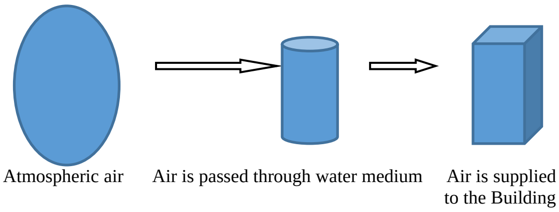

Figure-1 (a): Schematic diagram of the proposed HVAC system.

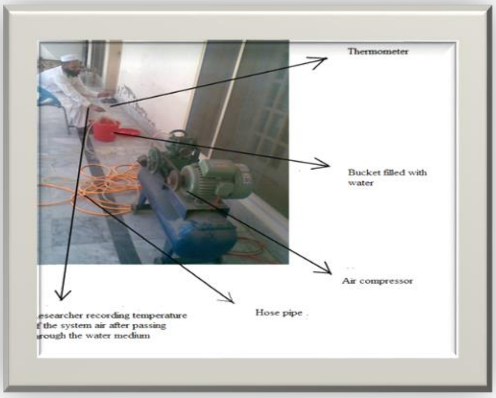

Figure-1 (b): Experimental arrangement for demonstration of the proposed HVAC system.

Equation for Heat Transfer by Conduction

Heat transfer by conduction is given by the equation as

$$\frac{Q}{t} = KA\frac{Thot - Tcold}{d}$$

Where Q = heat conducted

t = Time, K = thermal conductivity A = surface area

T_{hot} = temperature of the hot body, T_{cold} = temperature of the cold body

d = thickness [24].

Groundwater temperature in different cities of Pakistan

The groundwater temperature remains constant throughout the year [16]. It is usually equal to the mean annual air temperature above the surface of the land [17]. The groundwater temperature in different cities of Pakistan was calculated from the decadal mean monthly maximum and decadal mean monthly minimum temperature data as received from Pakistan Meteorological Department, Head Office at Islamabad. The calculated values of groundwater temperature in different cities of Pakistan are given in table – 1.

How will the system practically work?

Fresh groundwater has a relatively constant temperature at depth 30 to 50 feet below the surface of the land [16]. It is usually equal to the mean annual air temperature above the surface of the land [17]. In summer the hot atmospheric air can be cooled to 23 – 25 ^{O}C by passing it through fresh groundwater medium in most of the cities of Pakistan. Similarly, the cold atmospheric air in winter season can be heated up to 23 – 25 ^{O}C by bringing it in contact with fresh groundwater medium. The proposed energy saver system will consist of an insulated tank containing fresh groundwater. A copper pipe of 5 - 6 inch diameter and length less than 2.44 feet will be passed through the water medium. One end of the copper pipe will serve as inlet, while the other as outlet. At the inlet end a 1400 rpm fan will be fitted [23]. The fan will propel the atmospheric air inside the copper pipe and will supply it to the room through the outlet. The air while passing through the pipe will attain the temperature of the groundwater medium. In case plastic pipe is used instead of copper pipe then the length of the 3 inch dia. plastic pipe should be 20 feet. The tank may be fitted with a motor pump at one end and at the other end with a water storage tank. The groundwater in the tank may be refreshed by the use of a motor pump and the old water thus passed to the water storage tank may be used for domestic purposes.

Suggested Size of the Tank

Air has very low volumetric heat capacity, that is 0.00121 $J.cm^{-3}.K^{-1}$ [25], so it readily gets heated or cooled and attains the temperature of the water medium through which it is passed. The heat capacity of water at 25 ^{O}C is 4. 1796$J.cm^{-3}.K^{-1}$[25], that is, more than four thousand times higher than that of the air. In other words one volume of water is capable of raising or lowering the temperature of more than four thousand volumes of air by one ^{0}C by passing it through the water medium. It means that an insulated water tank of 1m^3 volume containing fresh groundwater at 23 ^{O}C is equivalent to 1.23 ton A/C and is sufficient for a room having area of 15x15 Sq. ft.

Cost of the Proposed HVAC Unit

The cost of one unit of the proposed HVAC system, with 0.5 m^3 water tank, is less than Rs.30000 with power consumption rate of 200 watt.

III. Results and Discussions

The values of the groundwater temperature of different cities of Pakistan were calculated by calculating their average annual air temperature. The average annual air temperature of a city is actually the groundwater temperature of that city [17]. Table-1shows that the groundwater temperatures of Quetta, Rawalpindi, Peshawar, Faisalabad, D.I. Khan, Lahore, Sargodha, Multan, Tando Jam, and Rohri are 16.94 ^{O}C, 21.90 ^{O}C, 23.38 ^{O}C, 24.49 ^{O}C, 24.51 ^{O}C, 25.21 ^{O}C, 25.27 ^{O}C, 25.75 ^{O} C, 26.44 ^{O}C, and 27.69 ^{O}C respectively. The data suggest that the proposed HVAC system will work efficiently in Quetta, Rawalpindi, Peshawar, Faisalabad, D.I. Khan, Lahore, Sargodha, Multan, and Tando Jam, however, in Rohri the system will deliver air at 27.69 ^{O}C as explained earlier. In other words the system air temperature in Rohri will be 1.69^{o} higher than China's standard (26 ^{O}C) set for air conditioning, in summer.[26]

Table – 1: Calculated values of the groundwater temperature of different cities of Pakistan.

S/No.	Name of city	Mean max. annual temperature (^{O}C)	Mean mini. annual temperature (^{O}C)	Average (^{O}C)	Groundwater temperature (^{O}C)
1	Peshawar	29.81	16.96	23.38	23.38
2	Rohri	34.49	20.91	27.69	27.69
3	Multan	32.70	18.8	25.75	25.75
4	Lahore	30.64	19.78	25.21	25.21
5	Faisalabad	31.5	17.48	24.49	24.49
6	Tando Jam	33.89	19	26.44	26.44
7	Sargodha	31.76	18.79	25.27	25.27
8	D.I. Khan	31.83	17.19	24.51	24.51
9	Quetta	24.27	9.61	16.94	16.94
10	Rawalpindi	29.16	14.65	21.90	21.90

The data in table – 2 suggest that as the air in a copper pipe passes through the water medium it suddenly adopts the temperature of the water medium. In other words, hot air in a copper pipe becomes as cold as the water medium through which it passes. Similarly, cold air becomes as hot as the water medium after passing through it. For the fresh groundwater medium, it can be seen that at the length of the copper pipe even as little as 0.61 foot the system air adopts the temperature of the fresh groundwater medium. It is clear from figure – 1 that the graphs of the temperatures of groundwater medium and system air after it passed through water medium overlap each other, regardless of the temperature of the system air before.

Table – 2: The proposed HVAC system data for various lengths of copper pipe, using fresh ground water medium.

S. No.	Length of the copper pipe (Foot)	Temperature of the surrounding air (^{O}C)	Temperature of the system air before passing through water medium (^{O}C)	Temperature of the system air after passing through water medium (^{O}C)	Temperature of the system water medium (^{O}C)
1	19.5	38	38	30	29
2	19.5	30	30	24	25
3	19.5	33.5	33.5	26	25
4	19.5	31	31	24	24
5	19.5	31	31	23	24
6	19.5	33	33	24	24
7	19.5	32	32	23	23
8	19.5	9	9	16	16
9	19.5	12.5	4	19.4	20.4
10	9.75	--	32	20	25
11	9.75	38	36.2	28	27
12	9.75	33	31	23.5	24.5
13	4.87	34	34	23.7	25
14	2.44	--	29	23	24
15	1.22	32	30	25	23.5
16	0.61	31	30	25	24

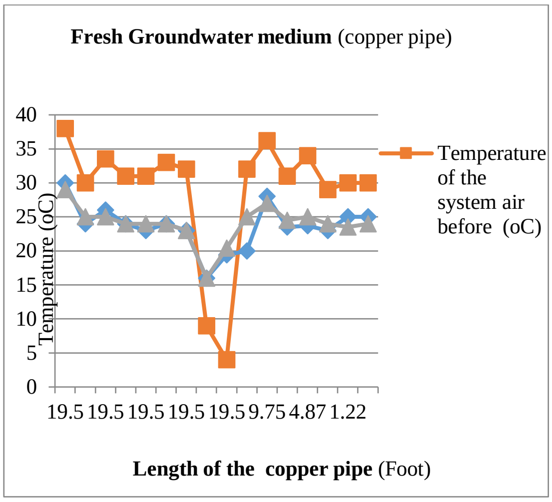

Figure - 2: Graphical presentation of the efficiency of the proposed HVAC system at different lengths of copper pipe using fresh groundwater medium

The data in table – 3 reveals that the temperature of the system air is directly affected by the length of the copper pipe. As the length of the copper pipe is increased the temperature of the system air also increases and the difference between the temperatures of the system air and that of the hot water medium decreases. When the length of the copper pipe is increased up to 18 feet then the temperatures of the system air and that of the hot water medium become more or less the same.

Table – 3: The proposed HVAC system data for various lengths of copper pipe, using hot water medium.

S. #	Length of the copper pipe (Foot)	Temperature of the surrounding air (^{O}C)	Temperature of the system air before passing through water medium (^{O}C) (A)	Temperature of the system air after passing through water medium (^{O}C) (B)	Temperature of the system water medium (^{O}C) (C)	(B – C)	(A – B)
1	0.61	26	24	47	75	-28	- 23
2	4.87	26	24	62	72	-10	- 38
3	4.87	34	37.5	60	70.5	-10.5	- 22.5
4	9.75	34	37.5	66	69	-03	- 28.5
5	9.75	34	37.5	59.2	64	-4.8	- 21.7
6	12	34	37.5	58	60	-02	- 20.5
7	16	34	37.5	55.8	57	-1.2	- 18.3
8	18.8	34	37.5	53.8	54.9	-1.1	- 16.3

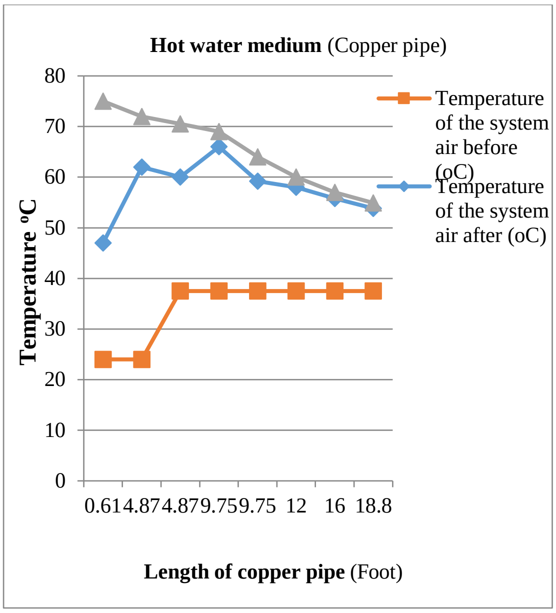

Figure - 3: Graphical presentation of the efficiency of the proposed HVAC system at different lengths of copper pipe using hot water medium

Considering table – 4 it is found that the temperature of the system air depends on the length of the plastic pipe through which it passes the hot water medium. The temperature of the system air increases with the increase in the length of the plastic pipe until it becomes equal to that of the water medium at the length of 20 feet as shown graphically in figure – 3. Comparing tables 3 and 4 it can be seen that the behavior of the plastic pipe is the same as that of the copper pipe. There is a regular increase in the temperature of the system air with the increase in the lengths of both the pipes. The use of plastic pipe is more favorable because it is easier to handle and can be molded to any shape, moreover it is several times cheaper than copper pipe.

Table – 4: The proposed HVAC system data for various lengths of plastic pipe, using hot water medium.

S. #	Length of the plastic pipe (Foot)	Temperature of the surrounding air (°C)	Temperature of the system air before passing through water medium (°C) (A)	Temperature of the system air after passing through water medium (°C) (B)	Temperature of the system water medium (°C) (C)	(B – C)	(A – B)
1	20	31	31	68	68.5	-0.5	- 37
2	10	31	31	63	66	-03	- 32
3	5	31	31	51	63.5	-12.5	- 20
4	2.5	31	31	44	61.5	-17.5	- 13
5	1.25	31	31	37	60	-23	- 6

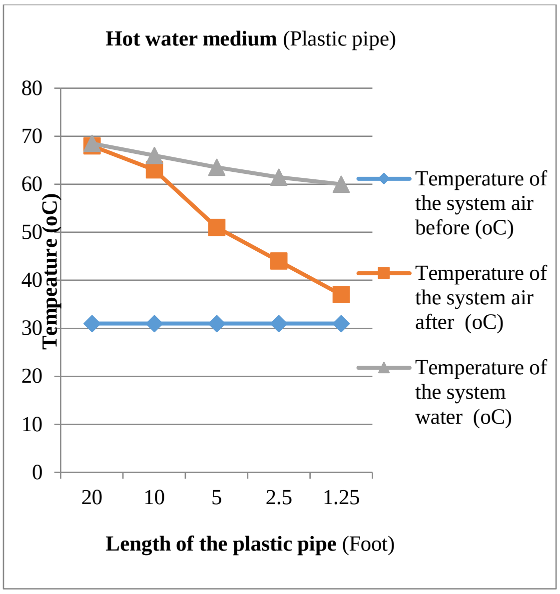

Figure - 4: Graphical presentation of the efficiency of the proposed HVAC system at different lengths of plastic pipe using hot water medium

It is evident from the data in table – 5 that the temperature of the system air decreases with the increasing length of the plastic pipe till the temperature of the cold water medium is achieved. The medium is whether hot or cold water, sufficient length of the plastic pipe is required to achieve the temperature of the water medium through which the system air is passed. Figure – 4 shows that at a length of 20 feet of the plastic pipe, the temperature graph of the system air nearly overlaps over that of the water medium.

Table – 5:- The proposed HVAC system data for various lengths of plastic pipe, using cold water medium.

S. #	Length of the plastic pipe (Foot)	Temperature of the surrounding air (°C)	Temperature of the system air before passing through water medium (°C) (A)	Temperature of the system air after passing through water medium (°C) (B)	Temperature of the system water medium (°C) (C)	(B – C)	(A – B)
1	1.25	32.5	33	22	09	13	11
2	2.5	32.5	33	19	08	11	14
3	5	32.5	33	26	10	16	07
4	10	32.5	33	16	10	06	17
5	20	32.5	33	14	12	02	19
6	26	32.5	33	14	12.5	1.5	19

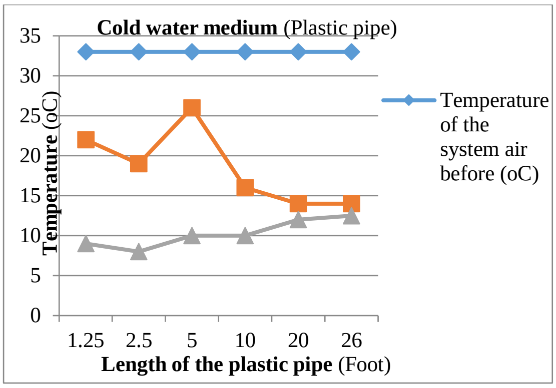

Figure - 5: Graphical presentation of the efficiency of the proposed HVAC system at different lengths of plastic pipe using cold water medium

The data in table – 6 depicts that the temperature of the system air decreases with increasing length of the plastic pipe through which it passes the fresh groundwater medium. At a length of 20 feet of the plastic pipe, the temperature of the system air becomes equal to that of the fresh groundwater medium through which it is passed in the plastic pipe. It means 20 feet is the appropriate length for the plastic pipe to cool the hot atmospheric air in summer through the proposed energy saver cooling system. Figure – 5 clearly indicates that in case of fresh groundwater medium 20 feet is a suitable length for the plastic pipe. Plastic has very low conductivity of heat (0.19 w/m. k.) as compared to copper (401 w/m. k.) at 25 ^{O}C.[27] The heat exchange through plastic pipe will be much slower as compared to copper pipe. In other words the length of plastic pipe will be much greater as compared to that of copper pipe to exchange the same amount of heat. The longer length of plastic pipe will affect negatively the flow rate of the air to be blown in the pipe. However, the plastic is several times cheaper than copper.

Table – 6:- The proposed HVAC system data for various lengths of plastic pipe, using fresh groundwater medium.

S. #	Length of the plastic pipe (Foot)	Temperature of the surrounding air (^{O}C)	Temperature of the system air before passing through water medium (^{O}C) (A)	Temperature of the system air after passing through water medium (^{O}C) (B)	Temperature of the system water medium (^{O}C) (C)	(B – C)	(A – B)
1	1.25	32.1	31.8	30.5	25	5.5	1.3
2	2.5	32.1	31.8	28	25	03	3.8
3	5	31.8	31	27	24	03	04
4	10	31.8	31	25.2	24	1.2	5.8
5	20	31.8	31	24.5	24	0.5	6.5
6	26	31.8	31	24.5	24.8	-0.3	6.5

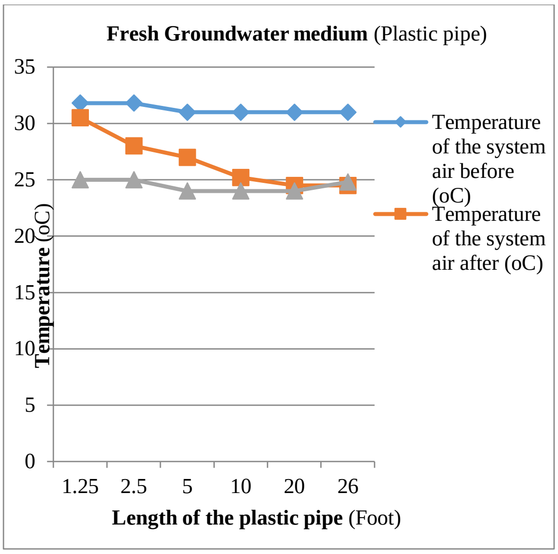

Figure - 6: Graphical presentation of the efficiency of the proposed HVAC system at different lengths of plastic pipe using fresh groundwater medium

IV. CONCLUSIONS

From the results of a series of experiments it can be concluded that air readily attains the temperature of the water medium through it is passed. If the water medium is cold it gets cooled, on the other hand if hot water is used as a medium, it readily gets heated.

Now, as already explained in the introduction section that groundwater has constant temperature throughout the year, which is always equal to the average annual air temperature above the surface of the land at that location e.g. in Peshawar the groundwater temperature is 23.38 ^{O}C, whereas in Lahore it is 25.21 ^{O}C. Similarly, other cities have their respective groundwater temperatures. Now if fresh groundwater is used as a medium in the proposed HVAC system at Peshawar, the system will deliver air at 23.38 ^{O}C in summer as well as in winter season. In Lahore, it will deliver air at 25.21 ^{O}C and so on in other cities at their respective groundwater temperatures. The groundwater temperatures of different cities of Pakistan are given in table -1 of this report. 22 to 27 ^{O}C is the range of comfortable room temperature which can be attained by the proposed HVAC system in most of the cities of Pakistan throughout the year.

In the experiments plastic and copper pipe were used to blow in air and pass through water medium. For water at 23 ^{O}C the suitable length of copper pipe was found to be less than 2.44 feet, while that of the plastic pipe was 20 feet.

The tank of the water medium must be insulated to isolate it from the surroundings, thereby increasing the efficiency of the proposed HVAC system.

The system may be mobile or fixed, sky scrapers can be equally benefitted from the system. Thermal comfort may be provided to even town and cities through centralized system working on the principal of the proposed HVAC system.

V. Acknowledgements

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Conflict of Interest
The authors declare that there is no conflict of interest.

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