Int.J.Curr.Microbiol.App.Sci (2018) *7*(6): 1850-1859

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 06 (2018)**
Journal homepage: http://www.ijcmas.com

Review Article https://doi.org/10.20546/ijcmas.2018.706.220

Geothermal Ventilation System for Animal House: A New Approach

P. D. Patel, A. K. Srivastava*, H. D. Chauhan, K. J. Ankuya, R. K. Prajapati and A. B. Paregi

Department of Livestock Production and Management, College of Veterinary Science and Animal Husbandry, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar – 385 506, Gujarat, India

**Corresponding author*

Keywords

Geothermal ventilation system, Animal house, Ground loop, Heat pump, Distribution system

Article Info

Accepted:
18 May 2018
Available Online:
10 June 2018

ABSTRACT

Geothermal ventilation provides a better alternative in securing the energy crises. Geothermal energy is a heat contained within the earth that generates geological phenomena on a planetary scale. It is not only available in the form of volcanoes, hot water stream but, whole earth acts as a source of geothermal energy for 365 days and all season of year. There are three basic components of geothermal heating pump system (GHPS); ground loop, geothermal heat pump and distribution system. Different types of GHPS are used from a simple open loop system to close loop system as per the need and sources available. GHPS works on the heat transfer mechanism not on the heat generation. It is just transportation of heat of earth to the room environment. Geothermal ventilation system is an eco-friendly system; it reduces emission of the different types of animal house gases like ammonia, hydrogen sulphide, sulphur dioxide and greenhouse gases. Geothermal ventilation reduces energy requirement for animal house up to 28-70%. It has no any type of deleterious effect found on animal growth and their body weight gain, health status of animal. GHPS can be modified and use for multipurpose for example in Oregon zoo has develop multilayer ground loop for elephant and bear. Relative operating cost of geothermal heat pump system, coal fired system and air conditioning system was found 0.94, 1.00 and 0.98, respectively. In many cases geothermal waters could be used profitably in a combination of animal husbandry and geothermal greenhouses. Geothermal ventilation system is efficient, safe, flexible source of renewable energy and it may be considered as best alternative to create favourable microclimatic condition in animal house during adverse climate.

Introduction

In present scenario everyone in the world concerned about global warming, ozone layer depletion, greenhouse gases, deforestation and many more things happens after the industrialization and revolution. Many new ways were come in existence for reducing the pollution but renewable energy has attracted attention of people and scientists globally. Geothermal energy is one of the best gifts of earth. This energy can be used without any disturbance to environment.

The adjective *geothermal* originates from the Greek roots *γη(ge)*, meaning earth, and *θερμος (thermos)*, meaning hot. Heat is a form of energy and *geothermal energy* is, literally, the heat contained within the Earth that generates geological phenomena on a planetary scale (Dickson and Fanelli, 2004). Geothermal energy is not only available in the form of volcanoes, hot water streams, but whole earth surface is a source of energy throughout the year. Temperature of earth below 2 - 3 meter remains in the particular range throughout the year. At 3 m depth it is between 24°C and 29.8°C. The strata between 2-3 m appear well suited for sitting of earth tube heat exchanger (Sharan and Jadhav. 2002).

Geothermal heating and cooling involves the use of constant heat (geothermal energy) that exists two to three metres below ground for heating and cooling purposes (Stein, 2013). It can be described schematically as 'convecting water in the upper crust of the Earth, which, in a confined space, transfers heat from a heat source to a heat sink, usually the free surface'. (Hochstein *et al.,* 1990)

Utilization of Geothermal Resources

For utilization of geothermal resources, the Lindal diagram emphasises two important features. The first aspect state that it is possible to enhance the feasibility of geothermal projects with cascading and combined use, while the second aspect points out that the resource temperature may limit the possible uses (Gudmundsson, 1988).

Electricity generation mainly takes place in conventional steam turbines and binary plants, depending on the characteristics of the geothermal resource.

Direct heat use is one of the oldest, most versatile and also the most common form of utilization of geothermal energy. Bathing, space heating and district heating, agricultural applications, aquaculture and some industrial uses are the best known forms of utilization, but heat pumps are the most widespread. There are many other types of utilization, on a much smaller scale, some of which are unusual.

Space cooling is a feasible option where absorption machines can be adapted to geothermal use. The technology of these machines is well known, and they are readily available in the market. The absorption cycle is a process that utilises heat instead of electricity as the energy source (Sanner, *et al.,* 2003).

According to Lund *et al.,* (2003) ground-coupled and ground-water heat pump systems have now been installed in great numbers in at least 30 countries, for a total thermal capacity of more than 9500 MW.

Agricultural applications of geothermal fluids consist of open-field agriculture and greenhouse heating. Thermal water can be used in open-field agriculture to irrigate and/or heat the soil (Barbier and Fanelli, 1977).

Farm animals and aquatic species, as well as vegetables and plants, can benefit in quality and quantity from optimum conditioning of their environmental temperature. In many cases geothermal waters could be used profitably in a combination of animal husbandry and geothermal greenhouses (Barbier and Fanelli, 1977).

Geothermal Heating and Cooling System

Geothermal Heating and Cooling Systems offer space conditioning heating, cooling along with humidity control. They may also provide water heating either to supplement or replace conventional water heaters. Geothermal heating and cooling systems works on the principle of moving of heat, rather than by converting chemical energy to heat like in a furnace. There are three major subsystems or components present in geothermal heating and cooling systems. The first component is a geothermal heat pump which is needed to move heat between the building and the liquid in the earth connection. Second component is an earth loop for transferring heat between its fluid and the earth, and finally a distribution subsystem for delivering cooling or heating to the house.

Geothermal system components

Ground loop

Closed ground loop system comprised of PVC or metal pipes buried in earth. This pipe contains heat transfer fluid (water) and anti-freezing agent. This fluid transfers heat from house to earth or from earth to home in cooling and heating mode, respectively (MH, 2017).

Geothermal Heat Pump

The geothermal heat pump system is packaged in a small single cabinet. It includes the loop-to-refrigerant exchanger, compressor and control unit.

This heat pump unit provides both heating and cooling to animal house. It improves the consistency of heat or cool air ventilation which is circulated by the distribution system (MH, 2017).

Distribution Subsystem

Distribution system distributes the fresh air throughout the animal house. A fan in the pump furnace unit blows air to this system and heated or cooled air is circulated by the ductwork (MH, 2017).

Different Types of geothermal ventilation Systems

Geothermal ventilation system basically works on theory of heat transfer from Earth to room and vice versa. Here the Earth acts as a source or a sink of heat. A series of pipes known as "loop" carry a geothermal fluid as a medium of heat transfer. Two basic types of geothermal ventilation system based on types of loops: open and closed but other types are also available.

Open loop systems

This are the most simple and old system used for GHPS. In open loop system water is drawn from the one well and supplied to GHPS pump here the heat exchange take place and now the remaining water is discharged to same aquifer source through the second well at a distance from the first one. Lake or river water also can be used for this system. Open loop system is most economical system for the establishment about per cent less expensive than the vertical closed loop system. It is a very high thermal efficient system as compare to other GHPS. Besides this there are also some challenges, like local water chemical conditions can lead to fouling the pumps heat exchanger, increasing environmental concerning water that local officials must be consulted about the project to assure compliance with regulations concerning water use and acceptable water discharge methods (Wale and Attar,2013).

Closed loop system

Now days the close loop system has become more popular than open loop system. Closed loop system is environment friendly system because water (or a water and antifreeze solution) in loops is continuously and repeatedly circulated through the closed system and prevents the contamination of environment. The length of loop varies depending on the ground thermal temperature, system design, thermal conductivity of the ground and soil moisture (Wale and Attar, 2013).

Horizontal Loops

In horizontal loop system the ground loops, burying up to 6 pipes, usually in parallel connection, are buried in each trench. Space between two pipes is about one foot and fifteen feet between the two tranches. Horizontal closed loop system is most economic for small scale installation, where sufficient land for new construction is available (Wale and Attar, 2013).

Vertical Loops

These loops are most preferable in areas where shortage of land is major issue. Vertical loop minimizes the landscape disturbances. In this system U-tube pipes are installed in 100 to 400 feet deep well. The loop length ranges from the 130 to 300 feet per ton of heat exchange because of geological feature of ground may vary greatly. Generally multiple holes are required for the most of installation, where the pipes are joined in parallel (series) configuration (Wale and Attar, 2013).

Slinky loops

Slinky means the coils overlapping and it will increase the area for the heat exchange per foot of trench. But, in this way more polyethylene pipes are required for per ton capacity of ventilation system. As increase the number of pipes in trench or slinky coil overlaps the length of trench will decreases. In two pipe system for one ton capacity 200 to 300 feet trench is required. This system can be used for the pond or lake application (Wale and Attar, 2013).

Pond loops

Pond loops are special kind of closed loop system. This loop system can be useful where; plenty of water is available like a stream, lake, pond, rivers etc. The loops are placed at the bottom of water. Whole pumping system is as like as closed loop system only pond loop used in place of ground loop. Pond loop system is economically efficient where favourable conditions are available and no any harm to aquatic system in any how (Wale and Attar, 2013).

Anatomy of a Geothermal Heat Pump (GHP)

In a conventional furnace heat is produced, while in a geothermal system heat is not generated, it is conveyed from one place to another place. In a geothermal heat pump cool, liquid refrigerant enters into the indoor coil during cooling. As it enters the coil temperature of refrigerant is in the range of 40^o to 50^oF. This warm, moist air is passed over the coil during that the refrigerant inside absorbs the heat and provide a cooler and fresh dry air back for circulation into the room with the blower fan. Refrigerant, continuously moving in the system, is now moves into compressor, where due to high pressure refrigerant become hot, up to the $120^o$to 140^o F and become a vapor. This vapor is transferred to the underground loops in which it losses heat and become condensed liquid. In winter season the system is reverse in direction the indoor coil act as a condenser and underground piping act as the evaporator.

After leaving the compressor, refrigerant is still under high pressure until it reaches to the expansion valve, where the pressure is reduces instantly. The refrigerants become cooler in temperature which would be used for heat transfer in room. The cycle is complete here and refrigerant is ready for next cycle. In simple words the indoor coil and underground coils causes the change in state of refrigerant by releasing and absorbing the heat. Compressor and expansion provides pressure for moving refrigerant into the whole system (HSW, 2017).

Calculation of geothermal ventilation and energy requirement

The ventilation (V) required for the bird/animal may be calculated using the equation

$\dot{V}$ = no. of birds/animals X average body weight X flow rate per kg

Geothermal energy supply

To calculate the amount of heat that can be supplied to the house, following equation may be used:

$Q_{Geo} = \dot{m}_{Geo} X\ C\rho\ X\ (T_{Geo} - T_i)$

Where,

Q_{Geo} = Water temperature (^oC)
$\dot{m}_{Geo}$ = Ground water mass flow rate (kg/s)
$C\rho$ = Air specific heat (kJ/kg.K)
T_{Geo} = Ground water temperature (^oC) (Busoul and Elayyan, 2014)

Advantages of Geothermal Systems

Efficiency

At different temperature (°C) like 32.2, 37.7, 43.3 the energy efficiency ratio of geothermal ventilation compare to electrical heating are 17, 10.5 and 9.8, respectively (Choudhury, 2013). It indicates that geothermal ventilation is more efficient as compare to electrical heating even at higher temperature but more efficient at lower temperature.

Reliability and safety

Geothermal heating and cooling systems have few moving parts, so they are highly reliable. There is no risk of vandalism. Geothermal heating systems can last far longer than most heating systems up to 25-50 years. It will also eliminate the risk of carbon monoxide poisoning associated with natural gas heating and hot water.

The risk of fires is also much lower than in an animal house equipped with a gas furnace and/or gas water heater.

Flexibility and convenience

Geothermal heat pumps can be set up to supply hot water as well as space heating and cooling. In some cases, the hot water comes at no additional energy cost. Geothermal heating and cooling systems create no noise outside the home and almost no noise inside either (Choudhury, 2013).

Renewable energy

Geothermal is a renewable source of energy for heating, cooling, and air conditioning. There is no pollution caused and no any adverse effects on flora or fauna.

Geothermal heating and cooling systems do not contribute to global warming (Choudhury, 2013).

Financial

Geothermal systems are costly and may cost several times higher than conventional system. But even though the system is cost-effective as according to some estimates the payback period may be within 2-10 years. This system is more economical as compared to heating ventilation and air cooling (HVAC) system (Choudhury, 2013).

Disadvantages of Geothermal Systems

These systems are very expensive to install.

During the time of installation trenching is required for loop establishment it will disturb the land structure. In case of horizontal loop system disruption of landscape is observed.

Use of copper pipes to circulate the refrigerant, and copper pipes buried under ground can easily corrode over time, leading to leaks that are hard to locate and almost impossible to fix (GEEH, 2016).

Further, the leaked refrigerant may cause environmental pollution.

Environmental Effects

The environmental effects of geothermal development and power changes in land use associated with exploration and plant construction, noise and sight pollution, the discharge of water and gases, the production of foul odor and soil subsidence. Most of those effects, however, can be mitigated with current technology so that geothermal uses have no more than a minimal impact on the environment. This technology has been successfully established in Klamath Falls, Oregon city of United States which is a known geothermal resource area. City is using geothermal power directly for geothermal heating in the area since the beginning of twentieth century.

According to the Oregon Institute of Technology, the system is used to provide direct heat for homes, city schools, greenhouses, Government and commercial buildings, geo-thermally heated snowmelt systems for sidewalks and roads, and process heat for the wastewater treatment plant with objective of conservation of renewable energy source (Anonymous, 2017).

In addition, GHPs have a very minimal effect on the environment, because they make use of shallow geothermal resources within 100 meters (about 330 feet) of the surface. GHPs cause only small temperature changes to the groundwater or rocks and soil in the ground (EB, 2017).

Myths about Geothermal HVAC system

Egg, (2013) have mentioned many myths about the geothermal ventilation system like geothermal energy is just experimental and can't be used widely, geothermal resources are nonrenewable, extraction and injection of geothermal brines will contaminate the drinking water, geothermal ventilation development will disturb the land features, geothermal ventilation is applicable only in temperate region of earth, geothermal ventilation system can't cool the home, it can only heat the room etc. Morrison and Ahmed, (2010) reported myth about GHPS that this technology is too expensive, the technology doesn't work in India and Geothermal HVAC requires geothermal energy to operate. All these assumptions were found to be myth and were not reasonable.

Geothermal system in different animal house

Various projects have been conducted to study the sustainability of geothermal system in different animal houses. Shah, *et al.,* (2017) found that earth-to-water heat exchanger (EWHE) pens were slightly warmer than the control pens cooled with stir fans and sprinklers in very hot days and performance of pigs in the EWHE pens was unaffected. The EWHE reduced the electricity use by >50 per cent and eliminated the sprinkling water use. They concluded that EWHE is sustainable and cost effective for high value pig and greenhouse in any part of the world. Recently, Kankariya Zoo, Ahmedabad, has initiated a project to develop a nocturnal animal house with the geothermal ventilation system to provide fresh air at ideal temperature which is suitable for the nocturnal wild animal species (IE, 2017).

Bostami *et al.,* (2016) reported that geothermal cooling system potentially reduces the cost of energy about 28 per cent as compared to conventional heating system. Geothermal ventilation suppresses the emissions of (NH_3, H_2S, SO_2) and also the risk of microbial contaminant into the animal house environment. It has no any negative impact on the growth performance of the growing pigs.

They further suggested that, geothermal system was more effective in maintenance of internal house temperature compared to ground channel; whereas, ground channel system was more effective in saving energy consumption and reducing CO_2 emissions.

Thus, on a broader view, geothermal and ground channel system can contribute to the global energy crisis and global gas emissions reduction through potential saving of energy consumption and reduction of CO_2 and odorous gas emissions (Bostami *et al.,* 2016).

Islam *et.al.,* (2016) found that the Conditioning System for Geothermal Heat Pump has the potential to reduce electricity use, overall cost and Carbon monoxide (CO) and other noxious gases emission. Therefore, the GHP system has the potential to be used as an environmental friendly renewable energy source for animal houses.

Copenhagen Zoo had conducted a project for preliminary study of geothermal ventilation system for their zoo animals and birds. They have done project for penguin exhibition and they have saved about 142 MWh energy during the year (Hestmark *et al.,* 2015).

Krommweh *et al.,* (2014) suggested that use of a modular housing with GHE may be more effective for heat-intensive piglet production. The investment costs are higher than in comparable conventional livestock buildings. The modular housing with integrated GHE is assessed as positive from energy and environmental point of view for pig houses where high indoor temperatures are required on a year-round basis.

Predicala *et al.,* (2014) conducted an experiment on swine barn and found that geothermal ventilation system is more significant than the convention gas fired heater, GSHP room was cooler during the warm months there were no considerable difference between two rooms during cold months. Methane and Nitrous Oxide concentrations were lower in GSHP room compare to conventional ventilation system. With the geothermal ventilation system no any type of adverse effect on pig's average daily gain, feed intake and feed conversion efficiency. Geothermal ventilation loop have multiple use for example in Oregon zoo they had develop a multilateral ground loop which provide a cool environment to bear and warm environment for elephants (OZ, 2014).

A study conducted at Chumathang, Himachal Pradesh, to calculate the energy cost per unit exergy for parallel combination of a phase change system with a heating system. At low flow rate and -5°(C) ambient temperature cost per unit exergy were 0.32 and 0.69 (USD MJ^{-1} hr^{-1}), respectively (Chauhan, 2013).

Stein, (2013) reported that University of Missouri, has developed a geothermal energy system for a large turkey farm in that state. The project has been jointly funded by the US Department of Energy as a demonstration project in partnership with the farm's owner. The system is being used both for brooding and grow-out. The project team have assumed that they will save on energy costs between 50 and 70 per cent.

It has been concluded that a GHP system could increase the production performance of broiler chicks due to increase inside air quality of the broiler house. The GHP system had lower CO_2 and NH_3emissionswith lower energy cost than the conventional heating system for broiler chickens (Choi *et al.*, 2012).

Jacobson, (2012) suggested that there are cooling alternatives to the traditional evaporative systems used in pig facilities in the Midwestern USA and other pig growing areas of the world that could result in reduced energy and emissions per pound of pork produced while still being economically viable. According to his studies, a geothermal system has been evaluated as one possible method to provide cooling for swine buildings that could provide an economic and cost effective approach for cooling pig amenities.

In a comparative study between the ground source heat pump (GSHP) heating and cooling system, coal fired heating system (CFH), wet curtain fan cooling system (WCFC) and air conditioning, it was found that initial investment of GSHP heating and cooling system was higher than that of the CFH system integrated with WCFC system, the relative operating cost of GSHP, CFH and AC were 0.94, 1.00, 0.98, respectively (Wang *et. al.*, 2012).

Mohamad, (2012) reported the case study of poultry farm in Syria have concluded that coefficient of performance of GSHP for heating and cooling were 6.2 and 10 respectively, while corresponding values of ASHP were 4 and 4.3 only. In the same study it was also found that annual cost of GSHP has been reduced up to 38 per cent, 69.2 per cent, and 79.7 per cent as compared to ASHP, coal heater combined with ASHP and diesel heater combined with ASHP, respectively.

In recent era of energy crisis geothermal ventilation system is a good alternative. Geothermal ventilation will reduce the greenhouse effect by reducing the production of greenhouse gases like CFC and HCFC etc. Geothermal ventilation reduces the emission of harmful gasses and also risk of microbial contamination into the farm shed. Geothermal ventilation provides natural air with improved quality which is favourable to maintain animal growth and health. It is efficient, safe, flexible source of renewable energy. Geothermal ventilation system is best alternative to create favourable microclimatic condition in animal house during adverse climate.

References

Anonymous, 2017. Oregon Department of Energy available at http://www.oregon.gov /ENERGY/RENEW/docs/tp124.pdf accessed on 7th May, 2018

Barbier E, and Fanelli M, 1977. Non-electrical uses of geothermal energy. Progress Energy Combustion Science. 3:73-103.

Bostami, A.B.M.R., Seok M.H., Islam, M.M. and Yang C, 2016. Potential of geothermal and ground channel system house on reduction of energy consumption and CO_2 emissions with maintenance of performance of growing pigs. International Journal of Recent Scientific Research. 7(2):8974-8979.

Busoul, M.A. and Elayyan, M. 2014. Utilization of Geothermal Energy in Poultry Farming. Journal of Energy Technologies and Policy. 4(10): 2224-3232.

Chauhan V, 2013. Geothermal space heating and thermal storage using phase change material in Chumathang, India. In: Geothermal training programme, Orkustofnun, Grensasvegur, Iceland, pp: 65-90.

Choi, H.C., Salim, H.M., Akter, N., Na, J.C., Kang, H.K., Kim, M.J., Kim, D.W., Bang, H.T., Chae, H.S., Suh, O.S., 2012. Effect of heating system using a geothermal heat pump on the production performance and housing environment of broiler chickens. Poultry Science. 91(2): 275-81

Choudhary A, 2013. HVAC vs Geothermal Heat Pump—Myth & Truth. Open Journal of Energy Efficiency. 2: 42-45.

Dickson M.H. and Fanelli M, 2004. Istitutodi Geoscienze e Georisorse, CNR, Pisa, Italy pp: 1-33.

EB, 2017. Encyclopedia Britannica Available at https://www.britannica.com/science/geothermal-energy accessed on 5th May, 2018.

Egg, J. 2013. Ten Myths about geothermal heating and cooling. Available on http://energyblog.nationalgeographic.com/2013/09/17/10-myths-about-geothermal-heating-and-cooling/ accessed on 22nd November, 2017.

GEEH, 2016. Green-energy-efficient-homes at http://www.green-energy-efficient homes.com /advantage -disadvantage-geothermal.html accessed on 1st may 2018.

Gudmundsson, J.S., 1988. The elements of direct uses. Geothermics. 17: 119-136.

Hestmark K, Peret, K.G., Castro, G.M., 2015. Assessment of ground source heat pumps for the new penguin exhibit in USA. In: Denmark Renewable Energy Program, pp: 1-18.

Hochstein M.P., Dickson, M.H. and Fanelli M., 1990. Classification and assessment of geothermal resources. In: Small Geothermal Resources: A Guide to Development and Utilization (Ed) pp. 31-57.

HWS, 2017. K. Kelly, Inc. available at https://www.hws.edu/fli/pdf/geo_heating_cooling.pdf accessed on 4th May, 2018.

IE, 2015.Kankaria Zoo: Nocturnal animals to stay wide awake during the day for visitors available at http://indianexpress.com/article/cities/ahmedabad/kankaria-zoo-nocturnal-animals-to-stay-wide-awake-during-the-day-for-visitors accessed on 9th September, 2017.

Islam, M.M., Mun, H.S., Bostami, A.B.M.R., Park K.J. and Yang, C.J., 2016. Combined active solar and geothermal heating: A renewable and environmentally friendly energy source in pig houses. Environmental Progress & Sustainable Energy. 35(4):1156–1165.

Jacobson, L.D. 2012. How to Economically Cool Pig Buildings. In: XI National Congress of Swine Production (CNPP), Salta, Argentina, pp. 14-17.

Krommweh, M.S., Rosmann, P., Buscher, W., 2014. Investigation of heating and cooling potential of a modular housing system for fattening pigs with integrated geothermal heat exchanger. Biosystems Engineering 121: 118 – 129.

Lund, J.W., Sanner, B., Rybach, L., Curtis, R. and Hellstrom, G., 2003. Ground-source heat pumps. Renewable Energy World 6(4): 218-227.

MH, 2018. Manitoba Hydro available at https://www.hydro.mb.ca/your_home/geothermal_ heat_pumps/components.shtml accessed on 4th May, 2018.

Mohamad, K., 2012. Ground-Source Heat Pumps and Energy Saving, Heat Exchangers - Basics Design Applications, Dr. Jovan Mitrovic (Ed.), ISBN: 978-953-51-0278-6, InTech, Available from: http://www.intechopen.com/books/heat-exchangers-basics-design-applications/ground-source-heat-pumpsand-energy-saving accessed on 11th April, 2018.

Morrison, G., Ahmed, P., 2010. Dispelling the myths of geothermal HVAC. Air Conditioning and Refrigeration Journal. 4: 64-70.

OZ, 2014. Zoo polar bears will use 'slinky' to warm up elephants. Available at http://www.oregonzoo.org/news/2014/09/zoo-polar-bears-will-use-slinky-warm elephants accessed on 29th April 2018.

Predicala B.A., Alvarado and Dominguez, L, 2014. Evaluation of a ground source heat pump system for heating and cooling a swine production barn. In: Proceedings International Conference of Agricultural Engineering, Zurich, 10th September, pp: 6.

Sanner, B., Karytsas, C., Mendrinos, D., Rybach, L., 2003. Current status of ground source heat pumps and underground thermal energy storage. Geothermics. 32:579-588.

Shah, S.B., Lentz, Z.A., Heugten, E.V., Richard, D., Currin, R.D and Singletary, I., 2017. Tempering ventilation air in a swine finishing barn with a low-cost earth-to-water heat exchanger. Journal of Renewable and Sustainable Energy. Available at http://aip.scitation.org/doi/abs/10.1063/1.4979359?journalCode=rse accessed on 1st January, 2018.

Sharan, G. and Jadhav, R., 2002. Ahmedabad Soil Temperatures Regime at Ahmedabad, Journal of Agricultural Engineering. 39 (1): 27- 32.

Stein, B., 2013. An overview of geothermal systems - heat pumps - and how they might be used its heat or cool poultry houses. The Drumstick winter. 13(2):10.

Wale, P.M. and Attar, A.C., 2013. Design, application and result analysis of geothermal ventilation system. International Journal of Scientific & Engineering Research 4(8): 2229-5518.

Wang, M.Z., Wu, Z.H., Chen, Z.H., Tian, J.H. and Liu, J.J., 2012. Economic performance study on the application on ground source heat pump system in swine farm in Beijing China. In: Proceedings AASRI conference on power and energy systems, pp: 8-13.

How to cite this article:

Patel P. D., A. K. Srivastava, H. D. Chauhan, K. J. Ankuya, R. K. Prajapati and Paregi A. B. 2018. Geothermal Ventilation System for Animal House: A New Approach. *Int.J.Curr.Microbiol.App.Sci.* 7(06): 1850-1859. doi: https://doi.org/10.20546/ijcmas.2018.706.220