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Study on Collection of Shallow Geothermal Energy by Riverside Pumping with Example of GSHP Project of Huangshan City Natatorium in Anhui Province, China

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ABSTRACT:

Anhui province is in monsoon climate region, transition zone of warm temperate and subtropical zone with four distinctive seasons. It is hot in summer and cold in winter, and the buildings have the double requirements of refrigeration in summer and heating in winter. The surface water is sufficient in the local, whereas the temperature of the surface water could get lower than 5°C or more than 28°C in the extreme condition of winter or summer, respectively. In the same time, the supplement of surface water in some place is not seasonal balanced, and it is unfavorable for geo-thermal pump utilizing surface water. Another reason is that the ground water in the hilly areas of south Anhui is not sufficient to recharge the surface water.

In the project of Huangshan City natatorium, shallow geothermal energy is collected by riverside pumping for heating/ refrigeration of 10,800m^2 area in the summer/winter, and heating the natatorium in the winter. The water yield of radial well next to rivers is 140m^3/h, and the recharge well is also placed next to rivers.

Through energy efficiency test, the project is proved to be energy conservation, emission reduction and cost saving. It solved the problems that the yield and temperature of surface water varies greatly seasonally, and lacking of ground water. It also cost much lower than the project of buried-type GSHP. The way for exploitation of shallow geothermal energy is suitable for popularization and application in other similar areas.

1. INTRODUCTION

Shallow geothermal energy is the heat resource occurred mainly in shallow rock and earth mass, groundwater and surface water within 200m depth which is worth developing. Anhui Province is located in the east-central China. There are plains, hills and mountains. It is in monsoon climate region, transition zone of warm temperate and subtropical zone with four distinctive seasons. It is hot in summer and cold in winter, and each season last 4 months. The annual average temperature is 14-17°C, and rainfalls vary greatly in spatial and temporal distribution. Surface water in Anhui Province is abundant, with Yangtze River, Huaihe River and Xin'an River distributed. They could be exploited as surface water-type shallow geothermal energy in general. The temperature of the surface water could get lower than 5°C or higher than 28°C in the extreme condition of winter or summer, respectively. In the same time, the supplement of surface water in some place is not seasonal balanced. Groundwater in the province is not abundant in general, and the loose deposit aquifers are mainly composed of silty-fine sand, resulting difficulty for artificial recharging.

In order to utilizing the water-type shallow geothermal rationally, the GSHP project of Huangshan City natatorium was put into practice for space heating/cooling and natatorium heating rely on collection of groundwater by riverside pumping in 2008.
Passing through energy efficiency test, the project is proved to be energy conservation, emission reduction and cost saving. It solved the problems that the yield and temperature of surface water varies greatly seasonally, and lacking of groundwater. Besides, its cost is much lower than the project of buried-type GSHP. This study on the collection of shallow geothermal energy by riverside pumping with the GSHP project as an example is significant for the popularization in other similar areas.

2. PROJECT OVERVIEW

Huangshan City is located in the south Anhui Province, with abundant tourism resources, and it is one of demonstration cities for national renewable energy construction application. The Huangshan Mountain is one of the top ten attractions countrywide in China. It was recognized as a world natural and cultural heritage by UNESCO in 1990. The conservation of the natural environment, utilizing of new energy resources like shallow geothermal energy are vigorously promoted in Huangshan City.

Huangshan City Natatorium located in the mountain front basin in north Tunxi District. Xin'an River flows past in the South. The GSHP project is one of demonstration projects for national renewable energy construction application. It is started in June, 2008 and finished in September, 2009. The building has a height of 18.1m with 2 floors above ground and 1 floor under ground. The total building area is 10,800m^2, and the 6,412.2 m^2 of which is demanded by are-conditioning with cooling load 1,759.7kW, heating load 1,134.82 kW and other load 750.7kW, respectively. It collects shallow geothermal energy by riverside pumping to supply the space heating/cooling and natatorium heating in winter. The disadvantage of lacking groundwater and instable temperature of surface water is compensated by taking groundwater in loose deposit beside Xin'an River, which got storage and recharge by river water.

Water pumping is mainly distributed along the riverside of Xin'an River near the natatorium, include a large diameter radial well and 20 tube wells. These wells are connected by high density PE pipeline, and lead to the main pumping room. The main radial well is 18.4m in depth, 3m in diameter and 146m^3/h in water yield. There are 8 horizontal radial holes with hole diameter 140mm and installed tube of 80 mm in diameter. Each hole is 47-60 m in length. The water is gathered into the main well by radial holes.

The 10 tube wells are 16-18m in depth with deposit tube of 1.5m down to fresh rock stratum. These tube wells are used to collecting ground water, with water yield 20-40 m^3/h for single well. Another 10 tube wells are used for reinjection. There are two sets of screw units of central air conditioning installed in the GHSP system. This system had been checked and accepted by experts in August, 2010.

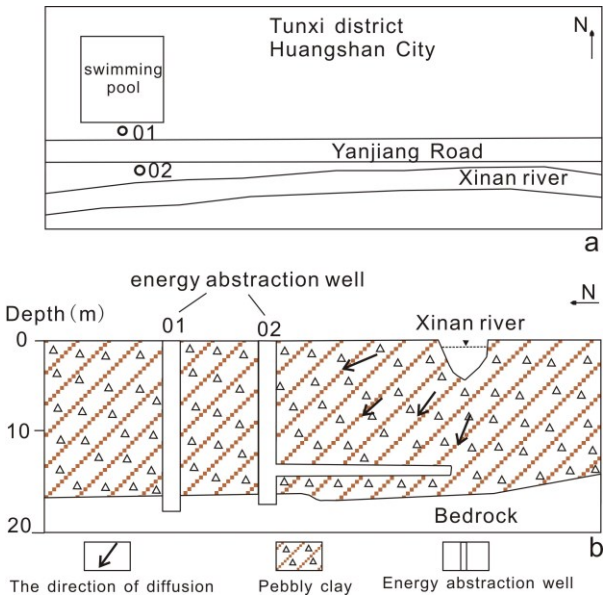

Figure 1 Layout of riverside pumping project (a: ichnography; b: section plan)

3. SITE CONDITION OF EXPLOITING SHALLOW GEOTHERMAL ENERGY

It is subtropical humid monsoon climate in the site of project, with cold winter and hot summer, with an annual average temperature of 15.5°C. The winter lasts from December to February next year with minimum temperature -13.5°C; the summer lasts from June to September with maximum temperature 40.3°C. This area receives 1,679.3 mm of rainfall a year on average. The Xin'an River located in the south, 90m far from the project area, distributed nearly E-W direction. The water quantity is significantly affected by meteoric water and the temperature is affected by air temperature. Water levels at the Tunxi hydrometric station is 127.84m (above sea level) in maximum, 118.72m in minimum and 119.92m in average. The flow rate is 10.2m^3/s in minimum with annual average of 95.1m^3/s. The water temperature of the river ranges from 8 to 27°C annually. The water could get lower than 5°C or higher than 28°C in extreme condition, respectively. Ground temperature has an alternating temperature zone of 20m in depth, while the constant temperature zone of 19.0-19.5°C is generally 15 m in thickness. The geothermal gradient in increasing temperature zone is 1.9°C/100m (Fig. 2).

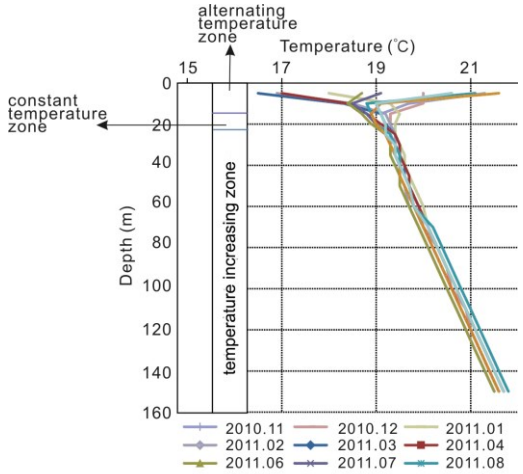

Figure 2 Vertical variation of shallow ground temperature in Huangshan City

Lithology of stratum in the site: 0-2 m, isabelline loam, ferruginous manganese nodule and gritty, lower part is mixed up with dimension stone. 2-12 m, grayish yellow sand-cobble layer with 25% gravel, grain size ranges from 10 to 30 mm. It is the main aquifer for the good permeability. 12-18.4 m, isabelline intense- moderately weathered mudstone, the upper part is claylike and the lower part is fragmental. Hard and integrate rocks lie under this layer.

Porous groundwater in loose deposit occurred above 18 m depth in the site, the aquifer is mainly composed of sand gravel. The radial well yields 146 m^3/h with 2 m drawdown. Its temperature is 16±2°C. The groundwater is recharged mainly by meteoric water and surface water from Xin'an River. It discharged by evaporation and artificial exploitation. The peak level of groundwater is relevant to surface water, mainly appears in the period from June to September, with annual amplitude of variation about 2 m. The groundwater is HCO_3-Ca.Na type, Groundwater could implement totally reinjection in the condition of exploitation.

Subject to local climate features, dynamic of ground water and surface water, lithology of strata, and technical and economy condition, single scenario of collecting shallow geothermal energy by ground source- type, surface water- type or ground water- type in the site have disadvantages.

Ground source-type (buried tube) scenario may encounter hard rocks, difficulty for drilling and high cost; the surface water-type scenario may encounter the water quantity and temperature vary greatly with the climate; the ground water-type scenario will meet small water yield for single well.

4. COLLECTION OF SHALLOW GEOTHERMAL ENERGY BY RIVERSIDE PUMPING

According to the occurrence of the shallow geothermal energy and exploitation conditions of the site, the underground heat exchanging mode of the GHSP project of Huangshan City Natatorium adopted riverside pumping combing both advantage of groundwater and surface water to be as the best scenario. By this method, both advantage of groundwater and surface water complement each other.

There were also project examples of single scenario using surface water-type. Their efficiency were affected due to frequent changes of water temperature and quantity. When the air temperature is about -5°C, the temperature of surface water would be lower than 5°C, while the in/out water temperature difference is about 5-8°C usually. In order to ensure normal operation of the WSHP, extra installation and anti-frozen are needed. However, rely on the riverside pumping of the Xin'an River, benignant transformation of surface water and groundwater could be achieved. It made the water temperature reach about 16°C and water yield of a single well reach 140m^3/h, with dynamic stability. The radial well increases the water yield and heat collecting efficiency, compared to traditional tube-wells. According to centralized air conditioning system of GSHP in the project, the used temperature difference could reach 7°C and 5°C in summer and winter respectively. In winter, absorption of low level heat from groundwater by GHSP units could produce hot water with temperature 50/45°C; in summer, by discharge air-conditioning condenser heat to the groundwater, it made the condensed water with temperature 7/12°C. In winter and other transitional seasons, the groundwater could be used as domestic hot water and heat source of the natatorium; in summer, the condensed water could be heat source of domestic hot water. In general, the shallow geothermal energy collected by riverside pumping, can ensure the operation of the WSHP units, and satisfy the demand of cooling and heating of air conditioning.

5. ANALYSIS OF APPLICATION BENEFIT

5.1 Benefit of energy saving

As the demonstration project of national renewable energy building application, the benefit of energy saving for Huangshan City Natatorium project is evaluated by Sichuan provincial Building Scientific Research Institute, which is entrusted by Ministry of Housing and Urban-Rural Development. Assessment items include rate of building energy saving, system energy efficiency, the sum instead of conventional energy, ratio of cost/efficiency, carbon dioxide emission reduction, dust emission reductions and saving cost etc. According to the energy saving evaluation results, when it runs in winter the COP (coefficient of performance) is 3.25. It means that put into 1 kW electric energy, 3.25 kW of heat energy can be obtained. When it runs in summer the COP is 3.00. It means that put into 1 kW electric energy, 3 kW of cold energy can be obtained. This can save about 30% energy than conventional air conditioning system. By calculation, the annual conventional energy substitution quantity is 169 tons of standard coal (Table 1).

Table 1 List of energy efficiency

Item	Unit	Amount
Water-saving amount	ton	3,678
Heating capacity of hot water and swimming pool all year	kWh	1,144,178
Amount instead of conventional energy in cooling stage	tons of standard coal	11
Amount instead of conventional energy in heating stage	tons of standard coal	89
Amount instead of conventional energy for swimming pool and bath hot water	tons of standard coal	67
Amount instead of conventional energy by water saving	tons of standard coal	1
Amount instead of conventional energy all year	tons of standard coal	169
Coefficient of performance for heating system		3.25
Coefficient of performance for cooling system		3.00
Building energy saving rate		50%

5.2 The economic benefits

Monetization comparison analysis of the shallow geothermal energy acquisition project with common air conditioning system: the cost of facilities and control room is 2.71 million CNY. The cost of air-condition terminal is 2.93 million CNY. The total investment of construction part is 6.04 million CNY. Heat exchanger and heat pump cost 150,000 CNY. The heating floor costs 250,000 CNY. For total construction area of 10,800 m^2 the unit cost is 564 CNY/m^2. Common air conditioning system plus boiler

heating for hot water (including heat exchanger for swimming pool water, domestic hot water heat exchanger and circulating pump) calculated at 480 CNY/m^2 (figure 3). The incremental cost for this project is 0.9 million CNY and as 84 CNY/m^2 (figure 3).

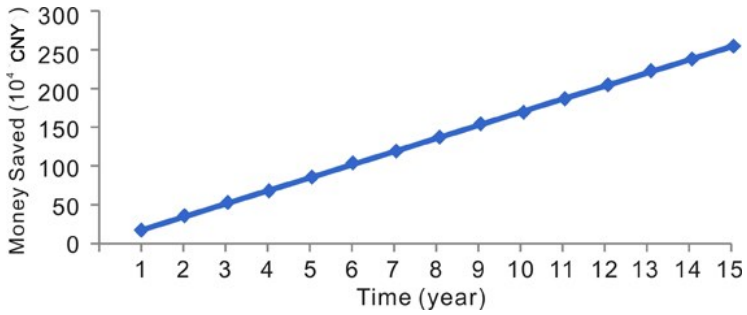

Figure 3 The saving cost of riverside pumping project

Replacement of conventional energy sources is 169 tons of standard coal equivalent, according to a price 1,000 CNY per ton, it saves 169,000 CNY a year. If working life of heat pump system is 15 years, assume its effect is consistent with the common air conditioning system, as showing in figure 3 the initial investment of incremental cost will be pay back after 6 years. It means that the project about will be better than the ordinary air conditioning at 6 years later. With the increase of project running time, the economic benefits will be more obvious. It will save cost 2.535 million CNY during the 15 years.

The initial investment of common air conditioning system is low, but its operation cost is high. The initial investment of heat pump systems in the project is lager, while the daily operation cost is low. Based on the average efficiency of 0.31 for heat/power conversion in thermal power industry in China in recent years, it will save about 426,430 kWh equivalent. If the work life of the project is 15 years, its cost-benefit ratio is as: 900,000 ÷ (426,430 × 15) = 0.14 CNY/kWh.

According to the calculation, compared to use ground source type, the unit price of the riverside pumping project reduces about 100 CNY/m^2. If it supplies heating for 90 days in winter and cooling for 120 days in summer, the daily operating cost will save about 15% than the surface water source type. And the operation management is relatively simple. Compared with using other traditional ways, such as water source heat pump with fuel boiler or lithium bromide unit or air-cooled heat pump, this project can save 35-65 % of money.

5.3 Environmental benefit

As a clean energy, collection of shallow geothermal energy by riverside pumping consumes a small amount of electricity during the operation process, but zero emissions. While the traditional fuel oil, gas and coal fired boiler have a common drawback of air pollution.

The energy saving by this kind of ground source heat pump system can be converted into 169 tons of standard coal. Therefore it will save 416.6 tons of CO_2, 3.4 tons of SO_2 and 1.7 tons of dust.

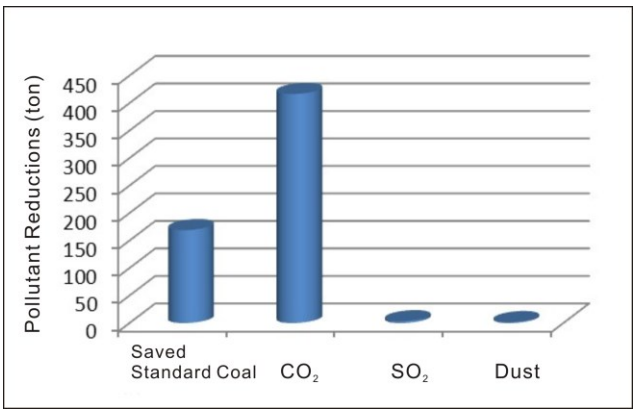

Figure 4 Pollutant emission reduction analysis histogram

6. CONCLUSIONS

(1) The groundwater resource is relatively poor in Anhui, and temperature of surface water is low in winter and high during summer in Anhui province, China. Shallow geothermal energy can be collected by using riverside pumping on a suitable area with permeable layer side of the surface water. It can be used for building air conditioning heating and cooling. Riverside pumping can make up for the surface water temperature instability and for the defects of groundwater water shortage. It will also obviously save investment cost compare to the ground source type heat pump.

(2) Study of shallow geothermal energy collected by riverside pumping in Huangshan City Natatorium show that this demonstration project have the advantages of energy conservation, emissions reduction, cost saving and higher efficiency. This method can be applied in similar area

(3) It needs long-term monitoring of water level, water quantity, water temperature, and water quality for groundwater and adjacent surface water to ensure the effective operation for the system.

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REFERENCES

[1] Wang, J.X., Ma, W.W., Gong, Y.L., 2004, Geothermal utilization technology. Beijing: Chemical Industry Press, 147pp. (in Chinese with English abstract)

[2] Wang, B.C., 2008, Scientific use of ground source heat pump technology development of geothermal energy. Hydrogeology and Engineering Geology, 35(3): 1-1. (in Chinese)

[3] Ministry of Land and Resources of the People's Republic of China, 2009, Specification for Shallow Geothermal Energy Investigation and Evaluation. (in Chinese)

[4] Zheng, K.Y., 2012, Developing Prospects of Ground Source Heat Pump in China. Geothermal Energy, 6: 30-32. (in Chinese)

[5] Guan, Y., 2012, Research of regional shallow geothermal energy. Proceeding of Important Geological Results in Anhui Province, 142-148. (in Chinese)

[6] Anhui Institute of Geo-Environment Monitoring, 2013, Shallow geothermal survey assessment report in Anhui province. (in Chinese).

[7] Guan, Y., Huang, D.C., Chen, X.F., Li, Y.H., 2012, Shallow geothermal energy conditions in Anhui. Geology of Anhui, 23(2): 137-141. (in Chinese with English abstract)