Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Analysis of Deep and Shallow Geothermal Resources Development and Utilization in Wuqing District of Tianjin

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Keywords: Wuqing district, deep and shallow geothermal resources, technical proposals.

ABSTRACT

Wuqing district is abundant in deep and shallow geothermal resources. The relevant geothermal geology and dynamic monitoring data in this area were collected, the development status was summarized, and the economic/environmental benefits have been evaluated. Technical proposals for deep and shallow geothermal resources, provide technical support for the scientific management of geothermal resources in Wuqing district.

1. INTRODUCTION

Known as the “Beijing-Tianjin Corridor” and “Beijing-Tianjin Pearl”, the Wuqing District is the hub of Beijing and Tianjin coordinated development, high-end manufacturing R&D, modern service industry gathering area, and the national ecological civilization demonstration zone. In recent years, with the rapid economic development of Wuqing district, there is a large demand for energy and the environmental pressure has increased. Especially because of the frequent occurrence of haze weather, Wuqing city and rural areas began to promote gas and electric heating instead of coal. At the same time, the demand for clean energy is increasing allowing the deep and shallow geothermal resources in this region to become more and more favored.

2. DEEP GEOTHERMAL RESOURCES

2.1 Tectonic position

The Wuqing geothermal area is mostly located on Jizhong Depression, a Quaternary structural unit. It extends from west to east, and is divided into HeXiWu bulge and Wuqing Sunken. To the south of Wuqing city lies Dacheng bulge ,which is the Fifth level construction unit and belongs to the fourth-level tectonic unit-Cangxian uplift belt(figure 1).

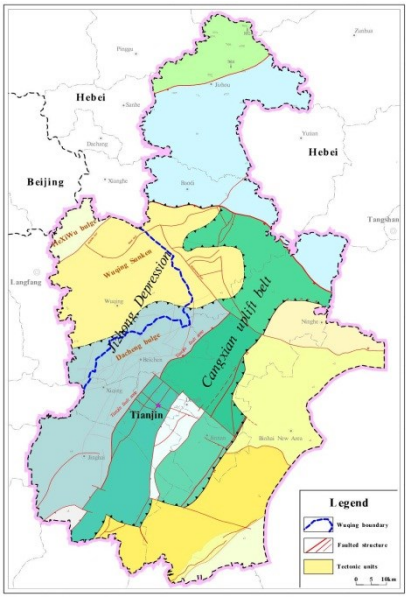

Figure 1: Geological structure location of Wuqing

2.2 Geothermal field characteristics

The Wuqing District is located on the low temperature distribution area of the geothermal gradient in the region. In most areas, the average geothermal gradient of the caprock from 2.5 to 3.5℃/100m, the gradient also increases from north to south. (Fig.2). According to the geothermal gradient calculation, the average temperature of the 1000m，2000m and 2500m stratum in the area, respectively is 25~35℃，50～70℃，63～88℃.

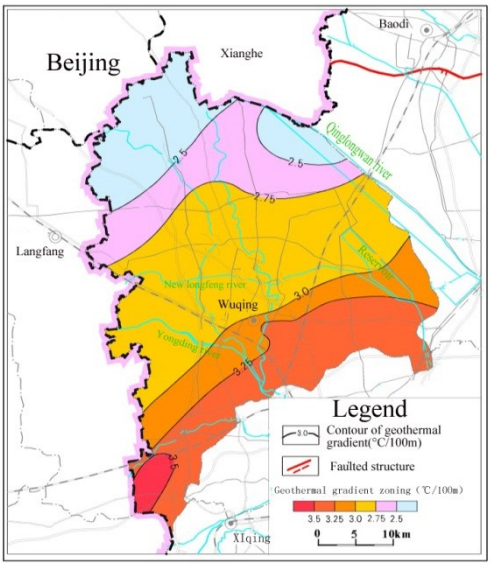

Figure2: The average geothermal gradient of the caprock

2.3 Geothermal reservoir characteristics

According to the results of geothermal achievements in the past, there are three main thermal reservoirs that have been identified and developed in the vertical direction; The Neogene Minghuazhen Formation, the Guantao Formation, and the Paleogene thermal reservoir. The main features of the reservoir are as follows.

2.3.1 Minghuazhen Formation

The lithology of this layer is sandstone and mudstone interbed, with a thickness of 320-1657.5m. There are 6 geochemical wells of Minghuazhen formation, the depth of well range from 1300m to 2000m. Single water inflow is generally 30-90m^3/h, the outlet water temperature is 45-66°C, the water quality is well, the hydrochemical type is HCO_3-Na, and the salinity is 0.4-1g/L. At present, static level is 58-86m, declined by 1.0-3.0m/a.

2.3.2 Guantao Formation

The lithology of this layer is characterized by thick-thin-thick from top to bottom , and has a thickness of 101 to 776 m. There are 33 geothermal wells of Guantao Formation in the area. These wells are 2000 to 2660 meters deep. Single water inflow is generally 60-150m^3/h, the outlet water temperature is 60-86°C, the hydrochemical type is HCO_3-Na, and the salinity is 0.8-1.3g/L. At present, the static level is 66-106m, declined by 3.0-7.88 m/a.

2.3.3 Dongying Formation

The lithology of this layer is gray-green, green mudstone and gray-white, light-gray sandstone. At present, there is only one well（No.YR15E）in the Dongying formation ,which lies in Tianshi Health Industrial Park. The depth is 2848.3m, YR15E well was completed in 2007 (currently closed). The thickness of the geothermal reservoir is 348.3m. The water inflow is 41m^3/h, the outlet water temperature is 90°C, the hydrochemical type is HCO_3-Na, and the salinity is 1.2g/L.

2.4 Utilization status

The mainly geothermal reservoirs are the Minghuazhen Formation and the Guantao Formation in Wuqing District. At present, there are 40 geothermal wells in the area (1 geothermal well of Dongying Group has been closed). There are 6 geothermal wells Among them is Minghuazhen Group well. The total mining volume was 486,500 m^3 in 2017, and the total heating area was 180,000 m^2, which solved the domestic hot water demand of 12,500 households.

There are 33 geothermal wells of Guantao Formation. In 2017, the total mining volume of Guantao Formation was 2,360,600 m^3, the total reinjection was 379,800m^3, the reinjection rate was 16.05%. The geothermal well provide a total heating area of 738,000 m2, which solves the domestic hot water demand of 27,857 households.

According to the calculation of the geothermal fluid used for heating in Wuqing District, it can replace 22,500 t/a of coal. This can respectively reduce carbon dioxide, sulfur dioxide, nitrogen oxide, dust and coal ash emissions by about 53,600 t/a, 0.038 million t/a, million t/a, 0.018 million t/a, and 0.23 million t/a. Excluding coal ash slag transportation costs, the environmental protection costs can be saved by $6.249 million per year. For this, it has a significant economic and environmental benefits (Tab.1).

Table1: Environmental benefit analysis table of exploitation and utilization of geothermal resources in Wuqing

Project	Quantity（1000 t/a）	Cost savings（$ 1000/a）
carbon dioxide	5.36	536.2
Sulfur dioxide	0.038	42
Nitrogen oxides	0.014	32.3
Suspended dust	0.018	14.4
Coal ash slag	0.23	transportation
total	5.66	624.9

3. SHALLOW GEOTHERMAL

3.1 Utilization status

According to the "2017 Tianjin Dynamic Monitoring Report on Shallow Geothermal Energy Development and Utilization", there are 15 ground source heat pump projects in Wuqing District, with a total heating area of $49.78\times10^4m^2$. The main type of buildings includes office buildings, schools, hospitals, shopping malls, hotels and so on.

According to the calculation of 15 shallow geothermal energy development and utilization projects in Wuqing District, it can replace coal burning of 9,450t/a, and respectively reduce carbon dioxide, sulfur dioxide, nitrogen oxide, dust and coal ash emissions by about 22500t/a，160t/a，60t/a，80t/a and 90t/a. Excluding coal ash slag transportation costs, the environmental protection costs can be saved by $\$262.8\times10^4$ per year. For this, it has a significant economic and environmental benefits.

3.2 Potential analysis

According to the Investigation report on shallow geothermal energy resources in Tianjin, through establishing a conceptual model and a mathematical model for the shallow geothermal energy of Quaternary in Wuqing District. It is calculated that the Quaternary (within 200m) has a shallow geothermal capacity in this area is 822×10^{12}kJ/°C. It is mean that the heat released or absorbed by the formation is equivalent to 28 million tons of standard coal when the formation raised or lowered by 1℃.

According to the calculation results, the annual heat extraction capacity of the ground-coupled heat pump system in Wuqing district within 120m is 1.028×10^{17}J. This is equivalent to about 3.5076 million t/a of standard coal, which can meet the needs of heating an area of $19.67\times10^7m^2$, with great potential.

3.3 Shallow geothermal suitability partition

According to the survey, the results of the suitability of the ground-source heat pump system of a buried pipe in Wuqing District are as follows (Fig.3): Wuqing center District, Caozili Town, North Chengguan Town, GaoTownship and South Wangqingtuo Town. These all belong to the suitable area of ground-source heat pump system (I); other areas belong to the not very suitable area (II). This type of system is also the preferred method for the development and utilization of shallow geothermal energy in this area.

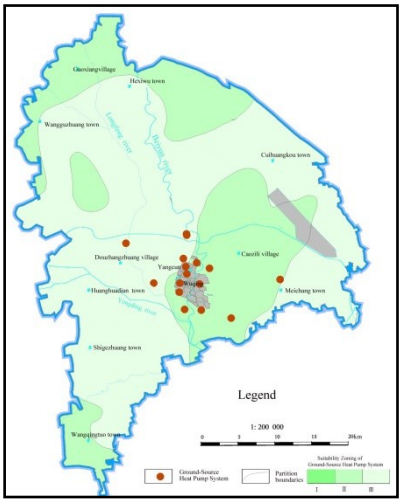

Fig.ure3: Suitability Zoning Map of Ground-Source Heat Pump System

4. SUGGESTIONS

4.1 Deep geothermal

4.1.1 Strengthen geothermal resources exploration

The exploration and evaluation of geothermal resources in the north and southeast of Wuqing region, as well as geothermal research on Paleogene thermal reservoirs, should be strengthened to ensure the sustainable development of geothermal resources and meet the needs of resources for economic development in Wuqing region.

4.1.2 Strengthen research on cascade and comprehensive utilization technology

At present, the total geothermal heating area in Wuqing district is $91.8\times10^4m^2$, and the tailwater temperature of most geothermal utilization projects is around 40℃, with a low utilization rate. In order to improve the utilization rate of geothermal resources, it is necessary to promote the utilization mode of cascade utilization of geothermal resources combined with water source heat pump. In addition, according to different conditions and characteristics of geothermal resources, the utilization and utilization direction of geothermal resources should be determined scientifically, reasonably, and improve the technology and management of resource development and utilization.

4.1.3 Strengthen the research on geothermal resources environmental protection and recharge technology

Through the research of the past two years, some breakthroughs have been made in the reinjection technology of guantao group in Wuqing District. The next step is to optimize the allocation of resources, improve the overall recharge rate, and ensure the sustainable use of resources, by means of resource integration and refill reinjection well for old heating wells and domestic water wells in Wuqing District. To ensure the continuous reinjection, the geothermal wells should strictly adopt the "recover- reinjection " mode to achieve better reinjection effect.

4.1.4 Optimize the distribution of resource extraction

Wuqing urban area has formed a larger landing funnel in the concentrated exploration area. It is highly important to alleviate the funnel area production as the principle, and strictly control the exploitation of main thermal reservoir resources in concentrated mining areas in Wuqing city. The geothermal wells should be distributed in the blank area outside the concentrated mining area to reduce the mining pressure and the head drop pressure in the center of the funnel.

4.1.5 Attach importance to dynamic monitoring

The geothermal fluid dynamic monitoring system should be restablished and improved, and the old and broken wellhead devices should be reformed. It is the best way to improve the monitoring quality based on the existing monitoring wellhead points.

4.2 Shallow geothermal

(1) To further improve the exploration accuracy, find out regional geothermal geology and hydrogeological conditions, and provide scientific basis for the exploitation and utilization of shallow geothermal energy.

(2) Suggested to establish a demonstration base in Wuqing district, this is to promote the application of ground source heat pump system with buried pipes. At present, existing projects are mainly concentrated in Wuqing District, which can be combined with local specific geological conditions to establish demonstration projects. By adopting the groping method, summarize experiences, and gradually popularize to increase the application of the surrounding and more remote areas. This is a way to partially achieve overall development and utilization of Wuqing district, including scattered industrial parks and villas and so on.

(3) Formulate practical plans for the development and utilization of shallow geothermal energy, including the development and utilization of shallow geothermal energy. It should be included in the short-term or long-term planning and construction as a specific measure to promote energy conservation and consumption reduction.

(4) Through long-term observation, to establish of a long-term monitoring system of geothermal field, we can provide reliable scientific basic data for the design, investigation and construction management department of the construction of shallow geothermal energy system. So as to continuously improve the heat pump system and improve the efficiency.

ACKNOWLEDGEMENTS

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by National key R&D program of China (2018YFC0604305), China Geological Survey project (DD20190127 & DD20179621).

Sincerely thanks Tianjin Geothermal institute for providing the data to finish this paper

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