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Development Dynamic, Existing Problems and Countermeasures of Geothermal Resources in Tianjin,China

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ABSTRACT

Tianjin is the economic center of northern China, located at the west of the capital, Beijing. Tianjin is one of the first batch of "hot spring capital" cities in China, has abundant reserves of geothermal resources, the total recoverable reserves is 76.06×10^6 m^3/a. The starting flag of geothermal resources development in Tianjin is the first Neogene geothermal well drilled by French in 1930s, and the 1990s is the large-scale development phase, until now the number of geothermal wells has reached 474, and geothermal resources are widely applied in the aspects of space heating, bathing, spa treatments, tourism etc. However, there are some existing problems in the process of development and utilization such as declining reservoir pressure, low utilization and reinjection rate, monitoring technology lag etc. To solve these problems, local government is actively promoting the cascade technology of development and utilization of geothermal resources, strengthen efforts to reinject, constantly adjust the mining layout and the utilization structure of geothermal resources, to ensure the sustainable development and utilization of geothermal resources.

1. INTRODUCTION

Tianjin, which located in China's northeast, is the economic center of northern China, and at the west of the capital Beijing. Tianjin is one of the earliest cities that developing and utilizing geothermal resources. The French drilled the first Neogene geothermal well in 1936, and this opened the prelude of geothermal resources utilization in Tianjin. The large-scale development and utilization of geothermal resources began after the 1970s in Tianjin. After 44 years of development, it has formed a multi-field utilization pattern, which contained space heating as the main and also included agricultural production, spa treatments, living bathing, mineral water production. According to 2010 statistics released by the World Geothermal Congress, China is the most geothermal direct use country in the world, and Tianjin is the largest geothermal direct use city in China. Tianjin attracted the attention of the international geothermal community. Geothermal experts from Iceland, New Zealand and other countries have visited Tianjin repeatedly. They believed Tianjin has achieved the ideal model of low temperature geothermal utilization, and highly commended the healthy development of geothermal in Tianjin. However, in the process of geothermal resources utilization, there are still some problems, such as geothermal reservoir pressure declining, lower utilization and reinjection rate, and monitoring means backward. To solve these problems, Tianjin has increased capital investment to research and generalize reinjection and cascade utilization technology. Based on the bedrock reinjection relatively becoming mature, Tianjin has solved the difficult problem of porous geothermal reservoir reinjection, and researched and tested reinjection techniques of lake water. Therefore, Tianjin's overall reinjection rate of geothermal resources increased every year, which effectively alleviate the drawdown rate and constantly improve the level of automation monitoring.

2. GEOTHERMAL RESOURCES AND RESERVES CONDITIONS

Geothermal resources of Tianjin are belonging to sedimentary basin of middle and low temperature geothermal. The area of geothermal resources distribution is 8700km2, and the area where average geothermal gradient of cap rock is larger than 3.5 °C/100m is 2300km^2. Geothermal reservoir type can be divided into porous geothermal reservoir (including Cenozoic Neogene Minghuazhen Group(Nm), Guantao Group(Ng) and Paleogene Formation Dongying Group(Ed)) and bedrock geothermal reservoir (including Paleozoic Ordovician(O)， Cambrian(∈) and Mesoproterozoic Jixian Wumishan Group（Jxw）). By the end of 2010, the Reserve Committee had identified eight geothermal field exploration zones that had been exploration and evaluated. These were Wanglanzhuang geothermal field, Shanlingzi geothermal field, Coastal areas geothermal field, Wuqing geothermal field, Wanjiamatou geothermal field, Panzhuang～Lutai geothermal field, Ninghe～Hangu geothermal field and Zhouliangzhuang geothermal field. Total allowable production of geothermal fluid(above 25°C) which had been approved is 76,066,000 m^3/a， includ 51,966,000 m^3/a of Neogene porous geothermal reservoir and 24,100,000 m^3/a of karst fractured geothermal reservoir.

3. HISTORY AND CURRENT SITUATION OF GEOTHERMAL RESOURCES EXPLOITATION AND UTILIZATION

3.1 Exploitation and utilization history

In the 1930s, the French drilled the first artesian hot well in Tianjin Laoxikai, this opened the prelude of Tianjin geothermal research, exploitation and utilization. Tianjin geothermal exploration and exploitation experienced the developing process that ranging from shallow to deep, from urban to suburban and from extensive to intensive.

Tianjin is one of the earliest cities which have drilled the geothermal wells in China. The early extraction layer is shallow porous geothermal fluid of Neogene. Its total dissoloved solid, hardness and temperature are low. The first geothermal well was drilled in Laoxikai in 1936 for domestic water. In 1967, Geological Bureau of Hebei Province drilled a geothermal well in Darezhuang food-processing factory, and the well's depth was 1004.08m and temperature was 51°C. A long-term dynamic monitoring of that well began in February 1968. In 1971, the 4644th hospital and Cotton Fourth respectively drilled a geothermal well which water temperatures was around 50°C. The same year, the Jin 2th well was drilled in Gegu, the reservoir was Ordovician. The well attracted the experts because of its artesian and 50° C temperature. In 1972, East Asian woolen mill drilled a well of 868.24m depth for wool fabric dyeing, the well's artesian flow was 15m^3/h, and temperature was 45° C. The 1970s is the starting of Tianjin

geothermal exploration and research. Under the advocacy of a famous geologist Professor Li Siguang (Figure1), Tianjin began a large-scale geothermal battle. Tianjin delineated 10 geothermal anomaly areas, people had a preliminary understanding of Tianjin geothermal distribution.

Figure 1：Working photo of Li Siguang

Since the 1980s, the state had invested a lot of manpower and material resources in Tianjin. Exploration began to develop for deep bedrock geothermal reservoir, and conducted exploration on three geothermal fields of Wanglanzhuang, Shanlingzi and Tanggu. Then "Exploration report of urban and Wanglanzhuang geothermal fields in Tianjin" and "Detailed investigation report of Shanlingzi geothermal resources in Tianjin" were submitted respectively in 1987 and 1990. The more comprehensive discussion on geological structure and each geothermal reservoir characteristics of exploration area provide the appropriate reserves for large-scale development and utilization of geothermal with the corresponding reserves. The discussion also played an important guiding role for exploration of other geothermal fields and provided a reliable basis for large-scale development and utilization of geothermal resources in Tianjin.

In the early 1990s, the state gradually transformed from planned economy to market economy. At that time, the State Geological Prospecting funds invested significantly reduced, and exploration funds reduced significantly, the pre-feasibility of geothermal exploration only conducted in the coastal regions of. In the late 1990s, geothermal exploration was into standstill, then market development was into the birth and infancy period, geothermal development was rising gradually.

In the 21st century, geothermal resources as a clean energy aroused more people's attention, especially real estate developers. Its exploitation and utilization entered a rapid development stage, and developed from the urban area to the suburban area. Geothermal resources were used in the fields of space heating, domestic hot water, spa treatments, agricultural planting and breeding. As the drilling depth gradually increasing, production of bedrock reservoir occupied the dominant position, so bedrock reservoir turn into the largest geothermal heating system in Tianjin.

3.2 Exploitation and Utilization Situation

By the end of October 2013, there were about 474 geothermal wells in Tianjin , including 359 production wells and 115 reinjection wells. The total annual production of geothermal wells was 32,393,800 m^3, the total annual reinjection was 12,951,200 m^3, reinjection rate of geothermal resources in the year was 39.98%. Overall, Tianjin geothermal development has the following characteristics:

1. The geothermal reservoir currently focused on Minghuazhen Group, Guantao Group, Ordovician and Wumishan Group geothermal reservoir in Tianjin (Figure 2). Each geothermal reservoir has drilled reinjection well, and the amount of reinjection wells is increasing year by year, but the proportion is still small, accounting for only 24.26% of the total geothermal wells (Figure 3).

2. Production and reinjection of geothermal resources generally increased year by year, especially in recent years, with the increase of reinjection wells, reinjection increased rapidly. The overall reinjection rate of geothermal resources was 39.98% in 2013, but there is a gap from the planning target of 52% in《Tianjin geothermal resources plan》(2011-2015), so we still need to strengthen efforts to reinjection (as shown in Figure 4).

3. The overall reinjection rate of geothermal resources has reached 39.98%, but each geothermal reservoir distribution uneven. Bedrock geothermal reservoir such as Ordovician, Cambrian and Wumishan Group, the overall reinjection rate is 57.16% . While the reinjection rate of porous geothermal reservoir is relatively low. The overall reinjection rate of porous geothermal reservoir is only 5.98%(as shown in Figure 5).

4. Tianjin, with its rich reserves and the development and utilization achievement of geothermal resources, obtained the first batch honorary title of "hot spring capital of China" approved by MLR, and also won two "hot spring city of China" and a "hot spring town of China", it was second to none in China. According to statistics, there are about 310 companies utilizing geothermal resources for space heating in Tianjin. The city's geothermal heating area is about 19,530,000 m^2, accounting for 6% of central

heating area of the city. Tianjin is the largest city that using geothermal resources for space heating , and the space heating fluid account for 81.66%. The geothermal fluid is also used for domestic hot water, agriculture, and so on. The percentage of different utilization patterns is shown in Figure 6.

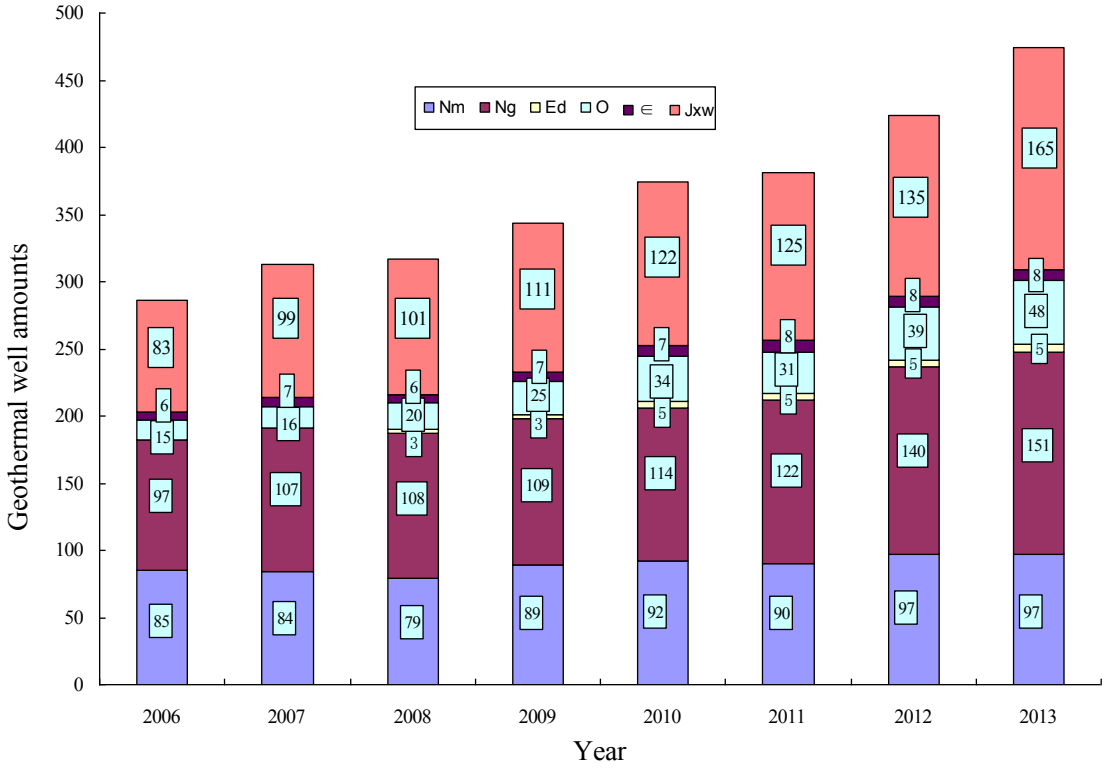

Figure 2: Geothermal well amounts chart of different geothermal reservoirs in Tianjin

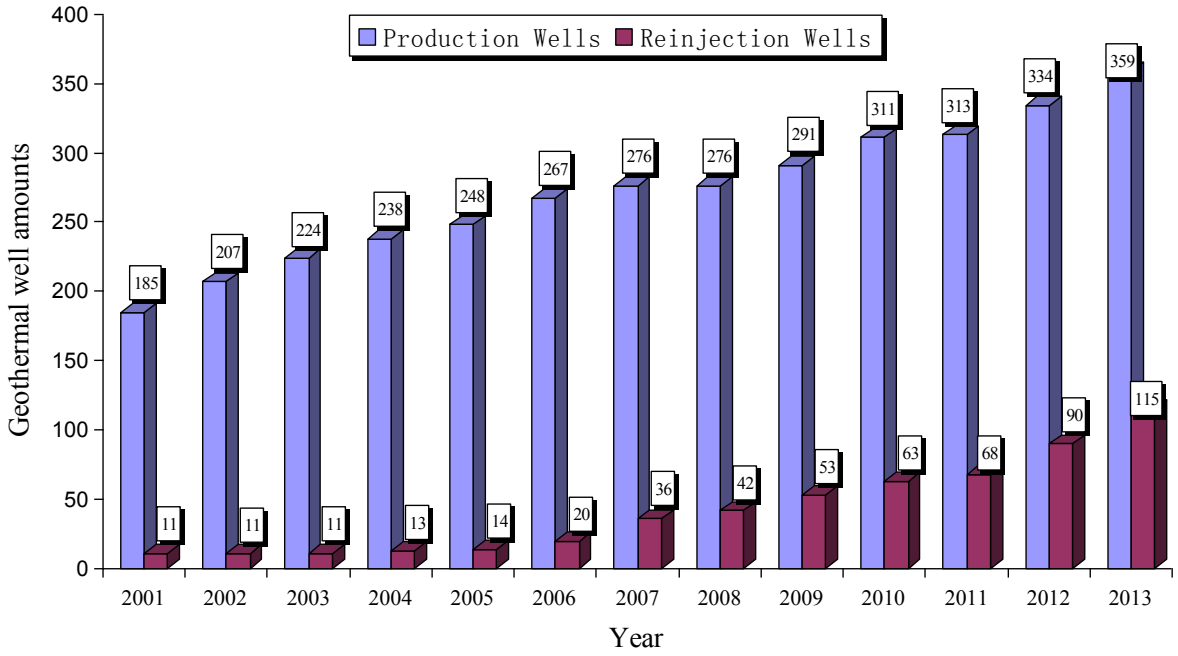

Figure 3: Amounts chart of geothermal production well and reinjection well in Tianjin

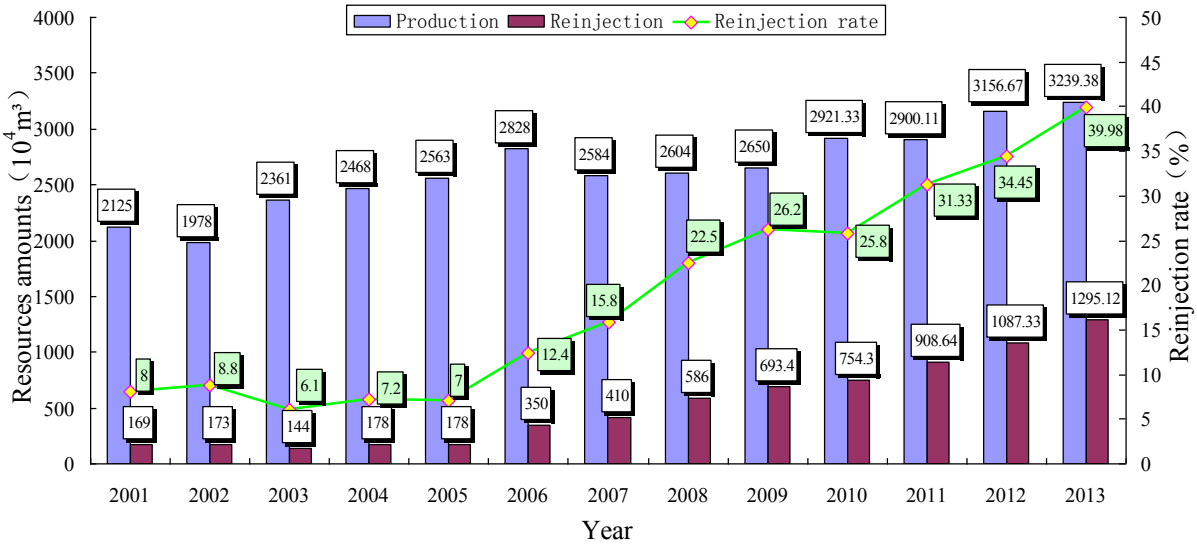

Figure 4：Chart of production, reinjection and reinjection rate of geothermal resources in Tianjin

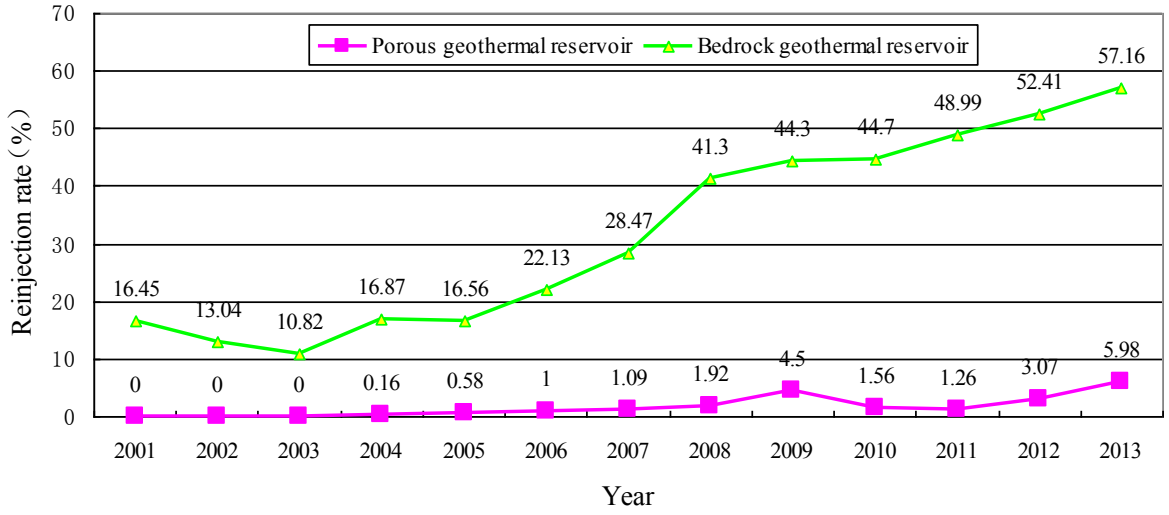

Figure 5：Chart of reinjection rate of porous geothermal reservoir and bedrock geothermal reservoir in Tianjin

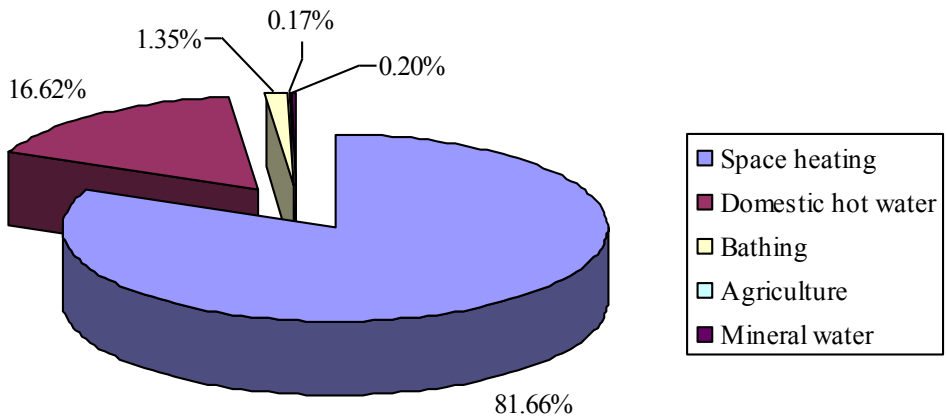

Figure 6：Percentage distribution chart of different utilization patterns of geothermal resources in Tianjin

4. PROBLEMS

4.1 Water level of geothermal reservoir is falling, concentrated extraction area has formed drawdown funnel and expanded year by year

With the continuous large scale of geothermal exploitation, geothermal reservoir pressure showed a rapid downward trend. In 2013, geothermal reservoir water depth of Wumishan Group was more than 140 m, the largest annual decline was more than 10 m. Funnel had formed in Tianjin urban, and it expanded year by year. Some early geothermal wells couldn't continue to use because the pump chamber depth was reserved only 150 m while current water depth is close to or exceeds the depth.

4.2Automatic monitoring level of geothermal wells is low

Dynamic monitoring is an important basis work in the development and utilization of geothermal resources. It is an important means to understand the dynamic characteristics of geothermal resources, and also the basis for geothermal resource management and decision-making, geothermal resource assessment and development planning foundation. Dynamic monitoring of geothermal resources in Tianjin began in 1980s, it had rich dynamic data on water level and water quality of geothermal wells, which had made important contributions to geothermal management and research in Tianjin. However, the current monitoring method is still relatively backward. It mainly relies on manual monitoring. Although automatic monitoring instruments of production and temperature are installed, but the higher failure rate of the instrument affecting the efficiency and quality monitoring.

4.3 The overall reinjection rate of geothermal resources is low, especially the reinjection of porous geothermal reservoir is difficult

Tianjin reinjection of geothermal exploration began in the 1970s. Study on production reinjection of bedrock reservoir began in 1997. Study on production reinjection of porous reservoir began in 2001. At present, bedrock reservoir reinjection rate of single well can reach more than 80% generally, but porous reservoir reinjection rate of single well is generally less than 40%. In recent years, although the amounts and reinjection of reinjection wells increased year by year, but the overall reinjection rate is still relatively low.

5. COUNTERMEASURES AND SUGGESTIONS

5.1 Do geothermal resources exploration and evaluation and monitoring well

First, increase exploration and evaluation efforts to find out the reserves, distribution and exploitation potential. Improve survey depth and accuracy of regions that have been exploited. Try to find back-up heat source for regions that have no extraction potential. Second, improve the monitoring system. Improve network upgrades and maintenance work of existing monitoring. Establish geothermal information databases, geographic information systems and geothermal resources warning systems. Improve dynamic, networked and automation level of geothermal resources monitoring to ensure the continuity and accuracy of monitoring data.

5.2 Continuously improve the level of sustainable exploitation and utilization of geothermal resources

First, reasonably control extraction strength and utilization structure. Scientifically determine and strictly implement total production control objective. According to scale and storage characteristics of geothermal resources, adjust exploitation intensity, distribution and utilization structure, promote stable and reasonable extraction and improve reinjection level. Second, strictly implement pair of wells approval system to ensure all new geothermal wells built with reinjection wells and promote exploitation-reinjection balance. Accelerate progress of drilling reinjection well for single exploitation well, transform neighboring production wells to “one exploitation one reinjection”, limit allowable production of single exploitation wells that can't be transformed until they are transformed or closed. Improve reinjection incentives and punishment mechanism. Third, strive to improve the comprehensive utilization. Accelerate building demonstration projects of the development and utilization of geothermal resources, promote new models, new technologies, new processes of cascade development and utilization. The geothermal tail water that was difficult to reinject, can be priority used for spa tourism, agriculture irrigation, aquaculture and urban domestic water.

5.3 Vigorously promote the development and utilization of shallow geothermal energy

Compared to the deep geothermal resources, shallow geothermal energy has advantages such as large reserves, shallow, mature development and utilization, etc. It is mainly used for building heating and cooling. The city is very suitable for the development and utilization of shallow geothermal energy with its geological conditions and climate character. According to incomplete statistics, the city's development and utilization amount of shallow geothermal energy is 3.03×10^{16}J/a, accounting for only 0.17% of the total available resources, so potential of shallow geothermal energy is great. Under the premise of strengthen environmental protection, should promote large-scale application of shallow geothermal energy, and gradually increase building energy use proportion of towns in the regions that have rich shallow geothermal energy.

6. CONCLUSION

Tianjin has abundant geothermal resources.The geothermal fluid is used for space heating,domestic hot water,bathing,agriculture and mineral water. But there are some problems, such as geothermal reservoir pressure declining, lower utilization and reinjection rate, and monitoring means backward. To solve these problems, local government is actively promoting the cascade technology of development and utilization of geothermal resources, strengthen efforts to reinject, constantly adjust the mining layout and the utilization structure of geothermal resources, to ensure the sustainable development and utilization of geothermal resources.

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