Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Analysis on Chemical Characteristics and Prospect of Development and Utilization of Geothermal Fluids in Tuanbo New Town, Tianjin

LI Yuanyuan, TANG Yongxiang, ZHAO Na, JIN Baozhen

Tianjin Geothermal Exploration and Development Design Institute, Tianjin, China, 300250

tj_lyy@126.com

Key words: Geothermal resources, chemical characteristics, rehabilitation therapy, social benefit, ecological town

ABSTRACT

Tuanbo New Town is located in Jinghai District, the North-west of Tianjin. As one of the eleven new towns in Tianjin General Planning, it is also approved as Leisure Tourism Town with Chinese Characteristics and as one of the eight natural landscapes of Tianjin. It is also included into the “twelfth-five year” strategic planning of Tianjin.

Tuanbo New Town is in the Wanglanzhuang Geothermal Field with abundant geothermal resources and belongs to the type of sedimentary basin with mid-low temperature. Because of the fluid temperature and the flow is of high quality, Tuanbo New Town was awarded with a title of The Chinese City of Thermal Water. Based on the geological exploration in this area, we found there were many features here. And there are two types of reservoirs: Neogene Porous-type System (Minghuazhen reservoir) and Bedrock Karst Fracture-type System (Ordovician and Wumishan of Jixian), in which Minghuazhen reservoir with a depth of 800 to 900m, a flow temperature of 30 to 60° C; Wumishan reservoir with a depth of 900 to 2500m, a flow temperature of 74 to 83° C.

Based on collecting the chemical data of the fluids from each reservoir, we drew piper triangular diagrams to analyze the chemical characteristics. We also inferred the formation types of different reservoirs, to provide evidences for the further exploit. The results show that the geothermal fluids here are medium corrosion and cannot form calcium carbonate scale, calcium sulfate scale and calcium sulfate scale. The fluids are not suitable for drinking, fishing and agriculture irrigation. But the good news is that the fluids of each reservoir are rich of dehydrated boric acid, fluorine and iodine. After dealing with them, they have high medical value. So if we develop space heating, bathing, tourism and rehabilitation therapy in Tuanbo New Town, it can create good social benefits and economic benefit. Furthermore, it also accords with the target that we build Tuanbo New Town as Spring Town and Ecological Town.

1. INTRODUCTION

Tuanbo New Town is located on the south of Duliujian River. Tuanbo Lake which is known as the "Pearl of North China" is the core, with rich rivers, lakes, wetlands and other natural resources, simultaneously having the only birds nature reserve in Tianjin. In addition, Tuanbo New Town area is rich in geothermal resources. The flowing wellhead temperature is up to 83 °C (the difference of temperature in summer and winter is ± 2 °C). The geothermal here not only can be used for house heating, greenhouse cultivation, aquaculture, but also has high medical value, health and other effects. The flow and the temperature of the geothermal fluid are stable and the water quality is nice, so the mining condition is extremely advantageous.

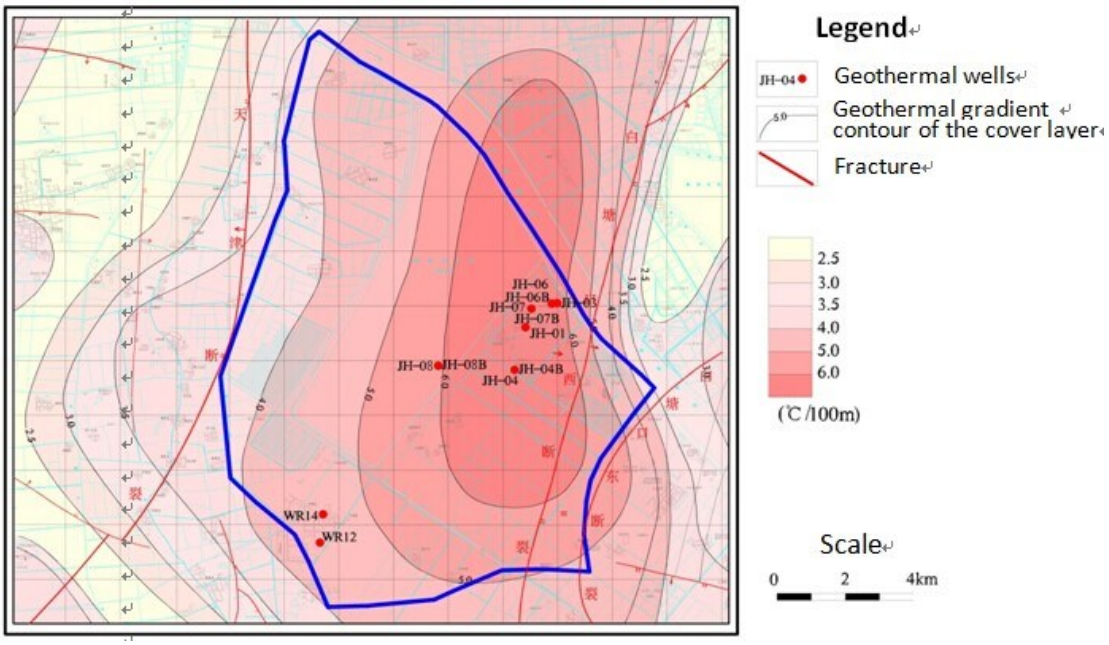

Figure 1: geothermal gradient contour map of the cover layer.

Tuanbo New Town is located in third grade tectonic units of Cangxian uplift zone. The type of the geothermal is low-middle temperature fluid type, the formation of which is conductive heat flow mechanism. Tuanbo New Town has high geothermal background (Zhang B.M., et al. 2006). The direction of the long axis of the equivalent coil cover closed layer average geothermal gradient is NNE, which is consistent with the extension direction of gradient projection. The highest value area (above 3 ℃ /100m) corresponding to the twin bulges, which cover the geothermal gradient maximum is 7.1 ℃ /100m. (Lu R., et al.1988)

2. CHEMICAL CHARACTERISTICS OF GEOTHERMAL FLUIDS

In Tianjin area, geothermal reservoirs are mainly of Neogene Minghuazhen, Guantao, Ordovician, Jixian Wumishan. At present, the main reservoirs in Tuanbo New Town are Minghuazhen and Wumishan. The chemical characteristics of the two reservoirs are below:

2.1 Chemical characteristics of Minghuazhen geothermal fluid

Minghuazhen geothermal fluid has obvious zoning rules from south to North in horizontal in the region. The chemical type is SO_4 · Cl-Na, Cl · SO_4-Na, Cl · HCO_3-Na (see Figure 1). Salinity also increased from 1400mg/L to 2400mg/L from north to south.

In Tuanbo New Town, the reservoir is general distribution. The reservoir rock is sandy mudstone and sandstone. The exposed reservoir roof depth is 420 ~ 561 m, with a thickness of 484.5 ~ 710m and a water depth of 73 ~ 85 m. The flow of single well is about 80 m^3/h and the wellhead flow temperature is about 60℃.The water type is SO_4 • Cl-Na. The TDS is about 2700 mg/l. The pH value is 7.8 ~ 8.8, belonging to the weak corrosive water. But because of the influence of underlying strata missing, in most areas in Tuanbo New Town, there is a direct contact between Minghuazhen group and bedrock, the water of Minghuazhen is deteriorated (Li J.F., et al, 2012).

Table 1 shows in a period of 10 years that the whole content of each ion changes little. The concentration of Na^+ changes between 774~842 mg/L. The anions of SO_4^{2-} and Cl- change between 802.1~1018 mg/L and 581.4~634.6 mg/L. The TDS is of 2356.2~2852.2 mg/L.

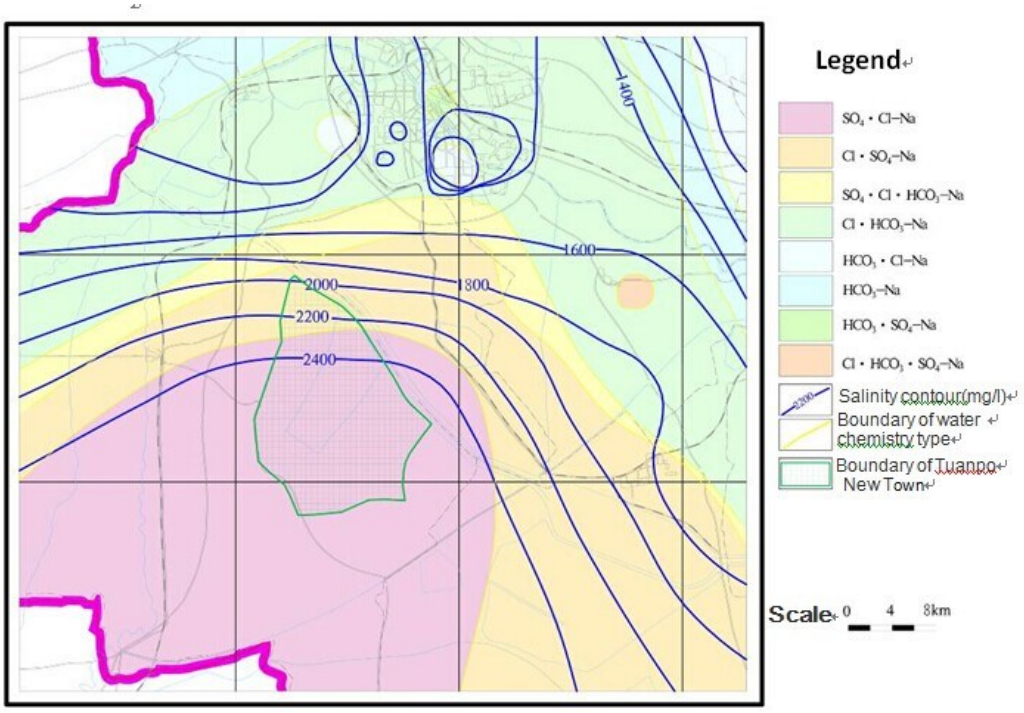

Figure 2: chemical zoning map of Neogene Minghuazhen geothermal fluids.

Table 1: Comparison table of ion concentration in a Minghuazhen geothermal well

Sampling Date	ion concentration (mg/l)						TDS (mg/l)	Water Quality Type
	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-		
2003.3	794.8	76.2	12.2	620.4	975	219.7	2743.2	SO_4·Cl-Na
2003.12	776.4	42.1	12.2	606.2	853.4	213.6	2676.7	
2009.11	789	85.8	10.1	581.4	894	244.1	2647.2	
2013.2	842	78.6	13.9	634.6	1018	219.7	2852.2	

2.2 Chemical characteristics of geothermal fluid in Wumishan reservoir

The water type of Wumishan geothermal fluid in the region mainly is Cl · SO_4-Na, Cl · HCO_3 · SO_4-Na, Cl · HCO_3 – Na. From the north to the south, the TDS is increased from 1800 mg/L to 4200mg/L.

There are 13 geothermal wells of Wumishan reservoir in Tuanbo New Town. The chemistry type of the geothermal fluids are Cl·SO_4-Na and Cl-Na. The TDS is in a range of 2081.1~3200mg/L. The type of water is complex and the change of TDS is relatively large (.Lin L., et al.2000)

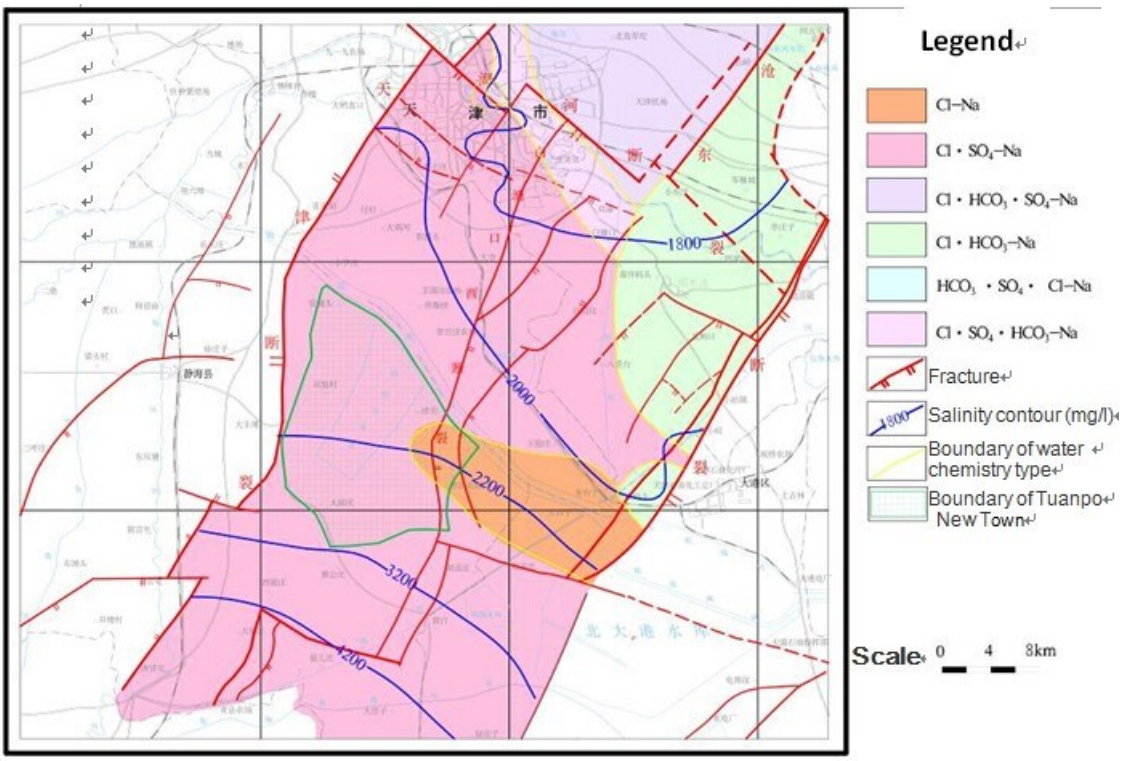

Figure 3: chemical zoning map of Wumishan geothermal fluids.

Table 2: Comparison table of ion concentration in Wumishan geothermal wells

ions(mg/L)	Well 2	Well 3	Well 4
K^+	64.2	71.7	67.6
Na^+	576.6	588.1	578
Ca^{2+}	48	41.3	45
Mg^{2+}	17	14.9	14.9
NH^{4+}	2.39	1.4	1.3
Cu^{2+}	＜0.02	<0.02	＜0.02
Mn^{2+}	0.04	0.04	0.06
Zn^{2+}	＜0.02	<0.02	0.06
T Fe	1.6	0.56	0.8
Cl^-	645.2	586.7	583.2
SO_4^{2-}	377.3	343	377.2
HCO_3^-	384.4	381.4	390.5
CO_3^{2-}	0	0	3
NO_2^-	0.027	0.047	0.016
NO_3^-	1.6	1.38	1.53
F^-	8.2	7.91	8.5

ions(mg/L)	Well 2	Well 3	Well 4
Br^-	1.1	1.2	1.2
I^-	0.15	3.04	0.15
PO_4^{3-}	0.02	0.03	0.04
HBO_2^-	33.21	28.28	31.08
Soluble SiO_2	56	55	57.5
TDS（mg/L） and classification	2168.7	2081.1	2116.9
	Weakly mineralized water	Weakly mineralized water	Weakly mineralized water
pH and classification	8.14	8.3	8.35
	Weak alkaline water	Weak alkaline water	Weak alkaline water
Total hardness and classification（ $CaCO_3$mg/L）	190.2	164.6	174.2
	Hard water	Hard water	Hard water
Fluid chemical types	$Cl{\cdot}SO_4$—Na	$Cl{\cdot}SO_4{\cdot}HCO_3$—Na	$Cl{\cdot}SO_4{\cdot}HCO_3$—Na

2.3 Origin of the geothermal water

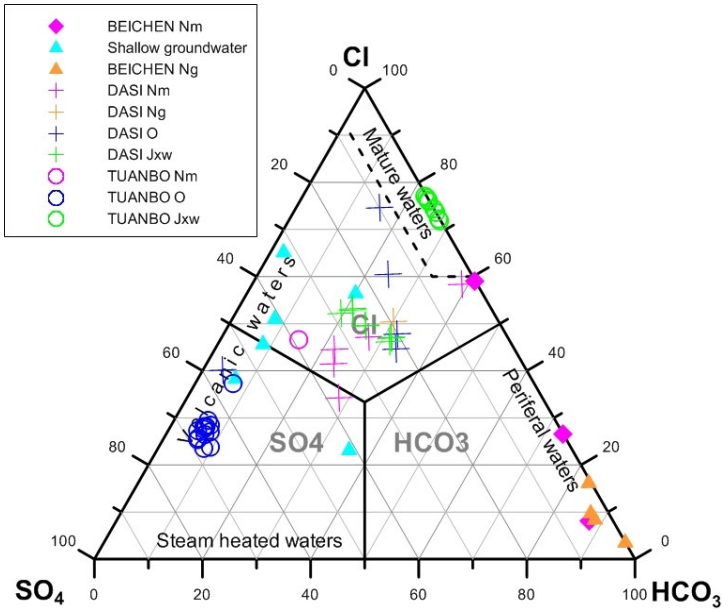

Figure 4: Cl-SO4-HCO3 triangular diagram of geothermal fluids in different areas.

The $Cl\text{-}SO_4\text{-}HCO_3$ triangular diagram (Qian H., 2005) is commonly used for classifying waters of different origin. It not only filters out unsuitable samples for geochemical calculations, but also can provide an initial indication of mixing relationships or geographic groupings.

Figure 4 shows the different origin of the geothermal fluids in Tianjin. Tuanbo Nm, Tuanbo O and Tuanbo Jxw respectively stand for the ion content of geothermal fluids from Minghuazhen reservoir of Tuanbo New Town, Ordovician and Wumishan reservoirs. Compare with the ions content in other area, the geothermal fluids in Tuanbo have different characteristics because of the different origin.

2.3.1 Minghuazhen reservoir

In the Minghuazhen geothermal water of Tuanbo New Town, the concentration of Cl is a bit higher, while the three ions are nearly balanced in DASI and HCO_3 is quiet higher in Beichen. According to the location of the Tuanbo New Town, it is far away from the

recharge area which is in the north of Tianjin. Through a long way to runoff from north to south, it becames mature waters, which leads to the increase of Cl.

2.3.2 Ordovician reservoir

The Ordovician geothermal fluid of Dasi is mainly Cl ion, but is SO_4^{2-} ion in Tuanbo. It forms an obvious difference distribution. The main reason of that are three points:(1) the lithological differences: depositional environment of Ordovician in two areas are different, which causes the lithological composition differences and affects the water quality in the geothermal fluid; (2) effects of the overlying strata in Ordovician, that is coated with C distribution area, will inevitably lead to the Ordovician geothermal fluid mineralization of especially high SO_4^{2-} content. But as the cut in the geothermal fluid and composition determination of geothermal well, we find out there is also C distributed in the area and its water quality is similar as Wumishan reservoir and Neogene reservoir in the same area. So the formation conditions of SO_4^{2-} are far more complex than ever think.

2.3.3 Wumishan reservoir

Wumishan geothermal fluids of Dasi area and Tuanbo areas are mainly Cl ions. But there are also differences, mainly reflected in the SO_4^{2-} ion content. The content of SO_4^{2-} in Tuanbo New Town is close to zero, which has large difference of SO_4^{2-} in the Ordovician geothermal fluid. But the SO_4^{2-} content in the Wumishan geothermal fluid of Dasi area reached 40%, close to that of Ordovician. It infers that the Ordovician reservoir and the Wumishan reservoir has stronger hydraulic connection in Dasi area.

3. QUALITY ASSESSMENT OF GEOTHERMAL FLUIDS

3.1 Assessment of medical utilization

On the basis of medical hot mineral water standard from "Geologic exploration standard of geothermal resources"(GT5/T1161 2010), the water quality of geothermal fluids in Tuanbo New Town is evaluated.

Table 3: Medical hot mineral water assessment (mg/L)

Ions	Standard concentration of medical mineral water	Reach the standard or not			
		Well 1	Well 2	Well 3	Well 4
Reservoir	/	**Nm**	**Jxw**		
Li	1	/	No	/	/
Sr	10	/	No	/	/
Mn	1	No	No	No	No
Fe^{2+}	10	No	No	/	No
F	2	No	Yes	Yes	Yes
Br	5	No	No	No	No
I	1	No	No	Yes	No
HBO_2	5	Yes	Yes	Yes	Yes
H_3PO_4	5	No	No	No	No
H_2SiO_3	25	Yes	Yes	Yes	Yes
CO_3	250	No	No	No	No
H_2S	1	No	No	/	No

According to the water quality testing report, related indicators situation around the geothermal wells as shown in table 3. In Tuanbo New Town, boric acid and silicate concentration of all the sampling wells reach the medical standards; fluorine and iodine concentration of well 2, well 3 and well 4 reached the medical standards. Obviously, Minghuazhen geothermal fluids can use for medical use of borate and silicate; Wumishan geothermal fluid can use for medical use of boric acid, iodine, fluorine and silicate.

3.2 Analysis of medical efficacy

The geothermal fluid can make body function returned normal. The way is that factors of anionic, cationic, trace elements and radioactive substances steadily stimulate the body sensor inside and out.

And then, the compound stimulus is send to the brain cortex, so that it can change the pathological state of the central nervous system. The mineral water is good for endocrine glands, adrenal gland and gonad (Li Q.2000).

3.2.1 The fluoride ion

The concentration of fluoride ions in geothermal fluids in Tuanbo New Town is about 8mg/L, which is one of the life elements in human body. The water fluoride concentration reached the standard of medical mineral water. The medical efficacies are blow:

(1) Keep children away from dental caries.

(2) Improve the thyroid function:

Fluoride can regulate the iodine metabolism to improve the thyroid function.

(3) Keep the bone normal:

Fluoride plays an important role in the skeletal development by promoting deposition of calcium and phosphorus in bones.

3.2.2 The iodine ion

It is active healthy elements. The content of iodine ion in the geothermal fluid in parts of Wumishan reservoir in Tuanbo Newtown reaches the medical mineral water content which is about 3mg/L.

(1) Improve the thyroid function:

Iodine is closely related with a variety of endocrine glands function. Drinking iodine mineral water can promote metabolism, expansion of blood vessels and improve the thyroid function.

(2) Improve arteriosclerosis:

Iodine mineral fluids can make the serum phospholipids decreased, especially the brain phospholipids decreased significantly; be used to improve arteriosclerosis and prevent thrombosis by bathing and drinking,

(3) Increase the body resistance to hardening and anti-inflammatory effects.

(4) Sterilization: iodine has a strong bactericide. It also has anti-fungal effect. The iodine solution can be used for preventing and improving fungal skin diseases (such as tinea versicolor, erythrasma etc.).

3.3.3 Metasilicate

The concentration of metasilicate concentration of Wumishan geothermal fluids in Tuanbo New Town is about 30mg/L, which reachs the standard of medical mineral water concentration.

Metasilicate in geothermal fluids has the health care functions on the cardiovascular, stomach, skeletal growth. It has a softening effect on human aortic. It also has the function of health care of heart disease, hypertension, arteriosclerosis, nerve function disorder, gastritis and peptic ulcer. In addition, it contributes to the bone calcification to promote children growth and prevent senile osteoporosis.

3.3.4 Boric acid

The concentration of boric acid in Wumishan geothermal fluids in Tuanbo New Town has reached the medical mineral water concentration.

Boron in water can participate in vitamins E and effect adrenal, thyroid and other endocrine function. Boric acid water is helpful to arethritis and the diseases caused by boron deficiency such as atherosclerosis.

4. CONCLUSION: ANALYSIS OF PROSPECTS FOR THE DEVELOPMENT AND UTILIZATION OF GEOTHERMAL IN TUANBO NEW TOWN)

The hot spring tourism gathering the leisure, fitness and tourism together is becoming a hotspot of tourism and resorts. In recent years, hot spring tourism has become one of the fastest growing sectors. The advantages of the development of hot spring tourism in Tuanbo New Town are following:

4.1 Regional location

Tuanbo New Town is located between Beijing and Tianjin City. The Beijing- Shanghai railway and Beijing-Shanghai High Speed Railway are across the town from North and South. The Beijing-Shanghai, Tianjin-Cangzhou and other highways are around the city. The traffic is very convenient.

4.2 Abundant geothermal resources

Tuanbo New Town is in Wanglanzhuang geothermal field, and the geothermal resources are extremely rich. With the shallow reservoir depth buried and the high temperature of the fluids, the resource conditions are very nice. Among them, the depth of Minghuazhen reservoir is 600 ~ 900m and the water temperature is 30 ~ 60 ° C; the depth of Wumishan reservoir is 900 ~ 2500m and the water temperature is 74 - 83 ° C.

In addition, geothermal fluid of Tuanbo New Town is rich in lithium, strontium, boron and other 24 kinds of trace elements beneficial to human body. It belongs to the composite medical mineral water resources with physical, rehabilitation, health characteristics.

4.3 The development and utilization of various forms

The development and utilization of geothermal resources in Tuanbo New Town is in various forms. It is widely used in building heating, physiotherapy, planting and breeding and other fields. A spring hotel and an agricultural ecological park have been built with high visibility. It promotes both the economic and social development and improves the living conditions of the residents. (Wang K., 2003)

Though the development and utilization of geothermal resources in Tuanbo New Town started late, the geographical position is superior and is rich in geothermal resources. With large flow, high temperature, the geothermal fluids here has a great development potential. In addition, as the "Chinese spring city", Tuanbo New Town is an important part of building "China hot spring" of Tianjin city. With the economic construction, the development of hot spring tourism here will have broad prospects for development and utilization of the geothermal.

REFERENCE

Li J.F., Li X.M., Lin J.W. et al. The analysis of composition of sedimentary geothermal fluid in Tianjin. [J]. hydrogeology and engineering geology, 39(2012), 137-143.

Li Q. Medical mineral water and its utilization. [J]. Sichuan Journal of geology, 20 (2000), 311-316.

Lin L., Wang K., Lin J.W. et al. The city of Tianjin deep geothermal survey report[R], Tianjin Geothermal Exploration and development and Design Institute, (2000), 77-94.

Lu R., Li S.C., Gao W.Q. et al. Tianjin city and Wanglanzhuang geothermal field exploration report [R], Tianjin Geothermal Exploration and development and Design Institute, (1988), 31-44.

Qian H., Ma Z.Y., hydrogeochemistry [M](2005). Beijing: Geological Publishing House.

Wang K., Li M.L., Xu P. Sustainable utilization of geothermal resource in Tianjin city.[J]. Resource survey and environment, 24 (2003), 7-13.

Zhang B.M., Lin L., Zhao S.M. [J]. Hydrogeology and engineering geology, Analysis on Mechanism of Tianjin Geothermal 33 (2006), 28-107.