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The Characteristic and Classification of Hot Springs in Thailand

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ABSTRACT

There has not any proper hot spring management in Thailand yet. This could post some serious problem on improper management of hot spring sites, where its environment has been put into jeopardy. This study aims to provide a way to classify the hot springs in Thailand. The result of this study help in the classification of hot spring sites for official planning improvement of administration and sustainable development of natural resources of the country.

The study makes use of the Department of Mineral Resources (DMR). GIS data of a total of one hundred and fourteen hot springs in the attempt to set up a classification system of hot springs in Thailand. These data include surface temperature, conductivity, alkalinity, acidity, TDS, pH values, H_2S, Ca, Cl, F, Fe, K, Mg, Mn, Na, NH_3, SiO_2, SO_4 contents, their locations, usages and other relevant information.

The surface temperature of hot springs are between 32^{o}C – 99^{o}C and SiO_2 geothermometer shows estimated reservoir temperature range from 73^o C – 202^o C. Most of the water from these hot springs are relatively transparent, colorless and their composition is sodium bicarbonate. The hot springs in the northern part of the country generally exhibit high SiO_2 and F content; strong smell of sulfur. The reverse is true for those located in the southern part of the country. In addition, there are nine hot springs located next to the sea show high concentration of Cl, Ca, Na, K and Mg.

There are three major criteria used in the classification system in this study, temperature, pH and their usage. On the basis of temperature, there are two classes of hot springs in Thailand: hyperthermal spring (62 %, 50-99^o C); thermal spring (38%, 30-50^o C). There are three classes achieved on the basis of pH values: 68 % of hot springs exhibit weak alkaline (7.5-9), 24% shows neutral (6-7.5) and 8% are alkaline (9-10) springs. There are 4 types of usage classification: power plant, Tourism, consumption and unutilized. There is only 1 geothermal power plant (300 kW binary cycle) in the north of the country. About 43% are used in tourism, about 17% is for consumption and 39% is unutilized.

1. INTRODUCTION

There are increasing of usage of natural resources due to the population growth rate and convenient instruments used in every day life. So there will be serious problems on sustainability and environment. Geothermal resources are one of natural resources, thus sustainable management and wise-used are needed.

It is necessary to have an information of all geothermal resources in the country. These data provided by DMR (Government agency, its activities are center of geological resources knowledge, planning and presenting geological resources policies) and to help scholars to know and apply in various field of knowledge.

This paper will informs geothermal activities in Thailand, geological settings, geology, chemical characteristics of hot springs and some classifications of hot springs in Thailand.

2. GEOTHERMAL ACTIVITIES IN THAILAND

Geothermal energy has been studied in Thailand since 1946 and systematic exploration and study of geothermal resources had been carried out by working group of Chiang Mai University (CMU), Electricity Generating Authority of Thailand (EGAT) and Department of Mineral Resources (DMR) since 1977.

At first, they focused the exploration and study in the northern part of Thailand. By the year 1981, the cooperation between EGAT and French Agency for Energy Management (FAEM) studied Fang hot spring for geothermal power plant and 300 kW of binary cycle geothermal electricity generation has been generated in 1989. There were any others collaboration in geothermal study in Thailand such as Japan International Cooperation Agency (JICA), United Nations Development Program (UNDP) and Geotermica Italiana.

The last geothermal activity in Thailand is to correct and create geothermal data by the cooperation of Coordinating Committee for Coastal and offshore Geoscience Programmes in East and Southeast Asia (CCOP) under Digital Compilation of Geoscientific Map phase IV(DCGM-IV) programmes.

3. GEOLOGY AND TECTONIC SETTINGS

Geology and tectonic settings of Thailand has been under many researchers (Mitchell, 1981; Tapponnier et al., 1982; Bunopas and Vella, 1983). Following is a summary of geology and tectonic settings taken from Tulyatid, 1997.

Thailand is located in south-east Asia and lies between latitude 5°37′ N and 20° 27′ N and longitudes 97° 22′ E and 105° 37′ E. Southeast Asia is located to the northeast and west of the still active convergent, Indian-Eurasian Plate boundary and to the southeast of the Himalayas. Recent paleogeographical reconstructions and paleomagnetic studies show that SE Asia comprises a complex assembly of allochthonous continental blocks and fragments of island arcs and ophiolites. These principal terranes include: Sinoburmalaya (Shan-Thai), Indochina (Indosinia), East Malaya and South China (Metcalfe, 1991)

Thailand is situated approximately 600-800 km. Northeast Sunda Trench, at which the indian Plate is subducting obliquely the Eurasian Plate (Mitchell, 1989; Bunopas and Vella, 1983). Subduction in this zone become increasingly oblique from southeast to northwest: thus, where as there is a substantial component of N-S convergence beneath Sumatra, plate interaction is almost purely strike-slip to the west of Myanmar. The convergence of there plate resulted in Eocene-to-present collision of the Indian subcontinent with Eurasian continental lithosphere (Tapponnier et al., 1986). The Indian-Eurasian collision appears to be the cause not only of the strong shallow seismicity across the East Asia continent (Tibet, South China and Indochina; Molnar and Tapponnier, 1975) but also of profound changes in the arrangement, structure and shapes of the various blocks which compose its lithoshhere (Tapponnier et all., 1982). (Fig.1)

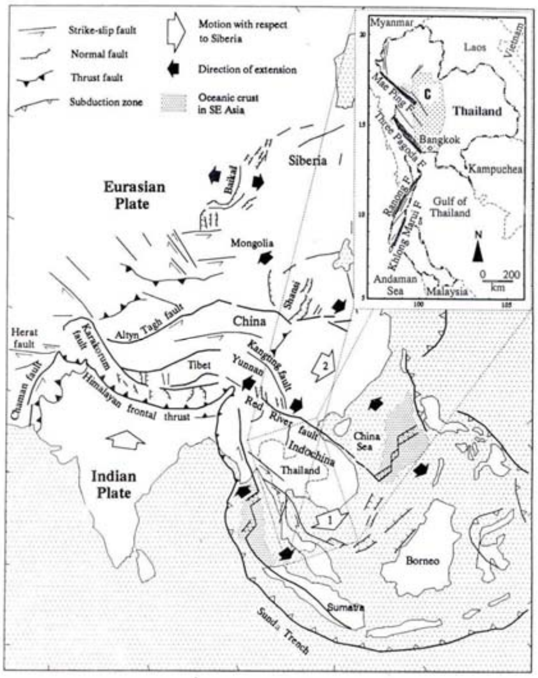

Figure 1: Extrusion tectonics and present-day plate configulation in east Asia (modified after Tapponnier et al., 1982 in Tulyatid, 1997).

Several authors have reviewed the geology of Thailand (Suensilpong et al., 1978; Chonglakmanee et al., 1983; Bunopas, 1981 and DMR, 1987). A summary of geology taken from Tulyatid, 1997) shows that the western mountainous terranes contain a variety of igneous, metamorphic and sedimentary rocks of varying ages (Figure 2). Precambrian metasediments and early Paleozoic sandstone and limestone are exposed in the western part only. Thick middle Paleozoic sedimentary and volcanic rocks crop out in the eastern part (Bunopas, 1981). Permo-Triassic sedimentary and volcanic rocks are widespread in the northeastern part of the western mountain range as well as in east-central and southern parts of Thailand. Triassic and post-Triassic granite plutons are found to have intruded Precambrian metasediments and early Paleozoic rocks in the western mountain terrain. These rocks also crop out in the eastern and southern parts of the country. Thick Triassic marine sedimentary sequences are also found in the eastern and western parts of the mountain range.

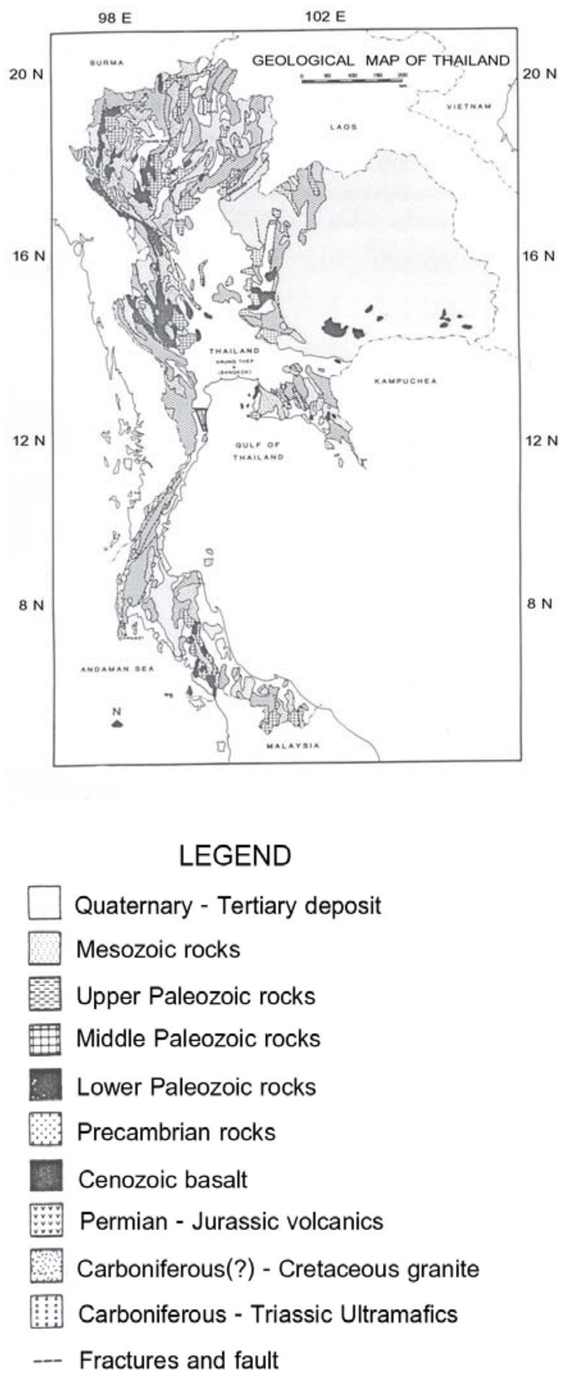

Figure 2: Simpliplified geological map of Thailand(modified after Suensilpong et al., 1978 in Tulyatid, 1997).

To the east of the Central mountain, Mesozoic rocks of Jurassic and Early Cretaceous red sandstone cover the Khorat Plateau). The Khorat Plateau is described as a series of Late Triassic – Cretaceous continental sedimentary sequences (Ward and Bunnag, 1964; lwai et al., 1966). Thick sandstones of the Khorat Group form long and high escarpments along the southern and western edges of the plateau (Bunopas, 1981). The low-lying sandstone rages are characterised by flat-top mountains (buttes) and mesas.

The Cenozoic rocks are non-marine sedimentary sequences, coal and oil bearing shale and sandstone, and continental volcanic rocks. These rocks are widespread in the northern, central and eastern parts of Thailand. Tertiary sedimentary rocks are restricted to fault bounded basins and believed to be lacustrine and lagoon deposits. Quaternary deposits cover about 40% of the land surface. These deposits include sedimentary units which may be subdivided into fluviatile, marine, aeolian and lateritic and interbedded alkaline basalts.

Major Tertiary sedimentary basins in Thailand include a number of basins located within the Central Plain and the Gulf of Thailand, all of which are potentially significant sources of petroleum.

4. CHEMICAL CHARACTERISTICS AND DISTRIBUTION

There are a total of 114 hot springs in Thailand. The assay of these hot springs consist of surface temperature, conductivity, alkalinity, acidity, TDS, pH values, H_2S, Ca, Cl, F, Fe, K, Mg, Mn, Na, NH_3, SiO_2 and SO_4 contents. The detail of some items is as follow;

4.1 Surface Temperature

The temperature measured from a total of 109 hot springs range between 32^o C and 99^o C. The average temperature is 58^o C. The Standard deviation (SD.) is 17 and median (or 50^{th} %) is 53^o C. The hot springs which, temperature are higher than 53^o C mostly located in northwestern part, probably related to the fault system in the North. In the middle of southern part of the country, high temperature of hot springs related to NE-SW Ranong fault zone. The range of temperature in the North is between 32^o C and 99^o C, whereas the temperature in the central, west though the south are 34^o C to 80^o C.

4.2 Alkalinity (HCO_3)

A total of 83 assay of thermal water show HCO_3 content ranging from 47 to 608 mg/l. The average is 248 mg/l, with an SD. of 116 and the median value of 217 mg/l. Hot springs in the northern part of the country have HCO_3 content higher than the average and the median values. It may have been cause by the chemical reaction while thermal water flow through wall rocks which are limestone, dolometic-limestone and dolomite.

4.3 Acidity ($CaCO_3$)

There are only 21 assay of thermal water ranging from 3.54 to 43.23 mg/l. The average is 20 mg/l, with an SD of 12 and a median value of 23.9 mg/l.

4.4 TDS (Total dissolved solids)

The 86 thermal water samples have TDS contents between 130 and 18,570 mg/l. The average is 1,608 mg/l, the SD is 3,873 and the median is 380 mg/l. Most of TDS in hot springs (about 86 % of hot springs in the country) are less than 750 mg/l, which is the maximum of standard drinking water follows by Groundwater acts in 1991. But some of hot springs (14 % of hot springs) in the south have high TDS (>1,500 mg/l) especially those hot springs located near the sea.

4.5 pH

The pH values of 84 hot springs show a range between 6.35 and 9.5, with an average of 7.6, the SD of 7.9 and the median value of 8. Most of hot springs are weak alkaline.

4.6 H_2S (SULFIDE SATURATED)

A total of 26 thermal water samples were analyzed for H_2S. The results show a range between 0.21 mg/l and 24.6 mg/l, with an average of 5.9 mg/l, an SD of 5.76 and a median value of 4 mg/l. Sulfide smell is slightly strong especially where manifested near granitic rocks.

4.7 Ca, Cl, K , Mg and Na

The Ca content of thermal water has a range between 1.2 and 1,005 mg/l. The average is 108 mg/l., with an SD. of 242 and the median value of 17 mg/l. One of the reasons of high Ca is flowing though gypsum deposits of thermal water (Surat thane Basin) in the south.

The Cl content of thermal waters has an assay 1 to 9,579 mg/l. The average is about 754 mg/l, with an SD. of 2,277 and the median value of 8 mg/l. Following Groundwater acts in 1991; standard drinking has Cl content less than 200 mg/l, brackish water has Cl content about 1,400 – 3,000 mg/l and salty water has Cl more than 3,000 mg/l. Most of hot springs in this country has Cl content less than 200 mg/l.

The K content of thermal water is between 1 and 208 mg/l. The average is about 18 mg/l, with an SD. of 38.7 and a median value of 6.3 mg/l. Most of thermal waters have low K.

The Mg content of thermal water has arrange between 0.01 and 375 mg/l. The average is about 25 mg/l., with an SD. of 65 and the median value of 0.67.

The Na content of thermal water shows ranging from 4 to 5,479 mg/l. The average is 446.7 mg/l, with an SD. of 1,177.2 and the median value of 97.2 mg/l.

The contents of Ca, Cl, K and Mg in thermal water are low, however there are high concentration of these elements in some hot springs in the southern part especially in Surat thanee, Phang-nga, Krabi and Trang provinces. All of these hot springs located near the sea.

4.8 F (fluorine)

A total of 56 assay of thermal water show F content from 0.01 to 21 mg/l. with an average of 6.7, an SD. value of 6 and a median value of 5.9 mg/l. Most of hot springs have high F content, hot springs which have F content more than 15 mg/l are probably near fluorite deposit in the north part of the country. There are only 18 hot springs heaving F content less than 1 mg/l and located in the south.

4.9 Fe (iron)

The Fe content of 53 hot springs has range from 0 to 2.5 mg/l. The average is 0.257 mg/l, the SD is 0.379 and the median is 0.15 mg/l. Most of them have Fe content less than 1 mg/l; this value is the standard drinking water of Groundwater acts in 1991. Only 2 thermal water samples from Mea Hong Son province in the north have Fe content higher than 1 mg/l. To solve high Fe content in the water is to fill oxygen in to water.

4.10 Mn (manganese)

The Mn content of 44 hot spring samples range from 0 to 0.58 mg/l. The average is about 0.1 mg/l, the SD is 0.13 and the median value equals to 0.04 mg/l.

4.11 NH_3 (ammonia)

The NH_3 value of 8 hot springs show a rang between 4 and 5,479 mg/l (analyzed by Geotermica Italiana, 1984). The average is about 446.7 mg/l with an SD of 1,177 and a median value of 97 mg/l.

4.12 SiO_2 (silica)

A total of 87 assay of thermal water show SiO_2 content from 2 to 273 mg/l. The average is 72.97 mg/l, with an SD of 36 and a median value of 66 mg/l. Hot springs in the northern part of the country have high SiO_2 content while comparing to hot springs in the South.

4.12 SO_4 (sulfate)

The SO_4 content of 84 hot springs has a range between 2 mg/l and 1,328 mg/l. The average is 127.8 mg/l, with an SD. of 286 and a median value of 22 mg/l. The hot springs having high SO_4 are mostly located in the South near the sea especially in Surat thanee, Phang-nga, Krabi and Trang provinces.

Cl-SO_4-HCO_3 triangular diagram (Giggenbach, 1991) in Figure 3, Ca-Na-K equilibrium triangular diagram and Ca-Na-Mg equilibrium triangular diagram (modified from Hen, 1959; Giggenbach, 1991 and Suzan Pasvanoglu et al., 2000) in Figure 4 and Figure 5 present property of thermal water in the country. Cl-SO_4-HCO_3 triangular diagram shows that most of thermal water are bicarbonate. Some of thermal water property is saline water located near the sea in the southern part of the country and a little thermal water are sulfate water which located in the south as well. In Figure 4 and Figure 5 There are approximately 60% of total number of hot springs water samples show high Na content, the others show high Ca content.

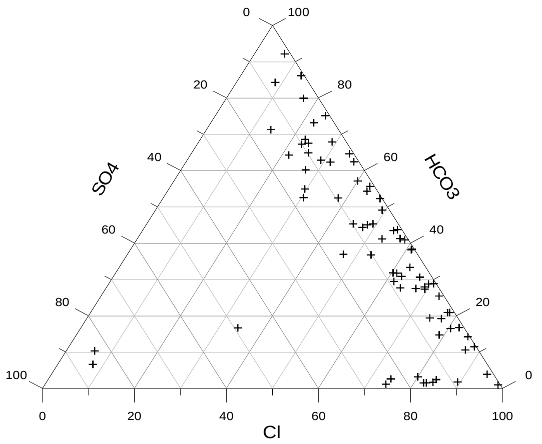

Figure 3: Cl-SO_4-HCO_3 triangular diagram of hot springs in Thailand.

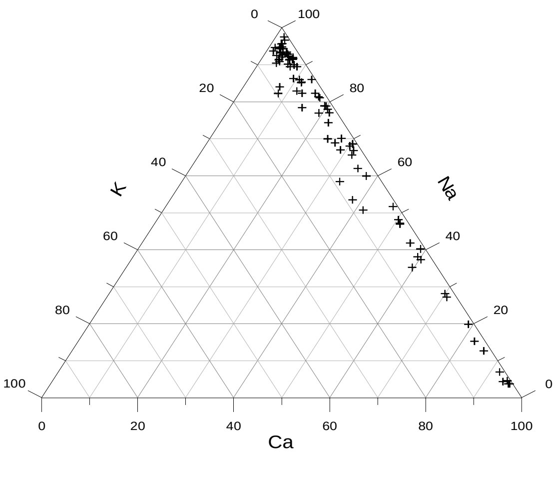

Figure 4: Ca-Na-K triangular diagram of hot springs in Thailand.

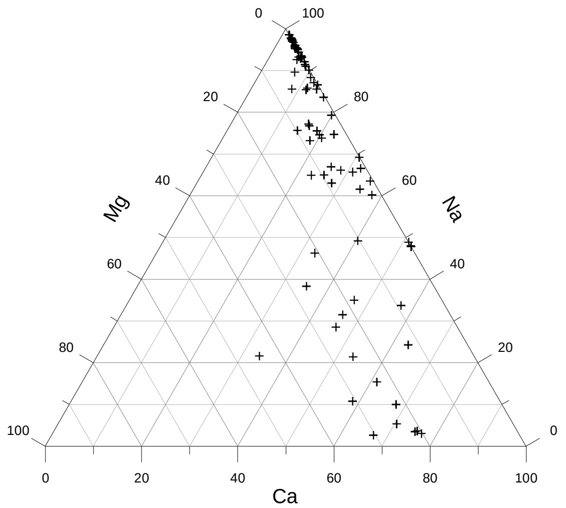

Figure 5: Ca-Na-Mg triangular diagram of hot springs in Thailand.

On the basis of result from the chemical analysis of SiO_2 , Na, K and Ca, the geothermometers were then calculated to estimate reservoir temperature (Fournier, 1981).

The equations for calculating geothermalmeter are as follow;

Quartz no stream loss

$$t \circ C = \frac{1309}{5.19 - \log Sio2} - 273.15 \qquad (1)$$

Quartz maximum stream loss

$$t \circ C = \frac{1522}{5.75 - \log Sio2} - 273.15 \qquad (2)$$

Na/K

$$t \circ C = \frac{1217}{\log(Na/K) + 1.483} - 273.15 \qquad (3)$$

Na-K-Ca

$$t \circ C = \frac{1647}{\log(Na/K) + \beta[\log(\sqrt{Ca}/Na) + 2.06] + 2.47} - 273.15 \qquad (4)$$

$t < 100^o$ C, $\beta = 4/3$

$t > 100^o$ C, $\beta = 1/3$

The estimated reservoir temperatures from the equations above are summarized in Table 1. Estimated temperature from quartz no stream loss is approximately the same as the temperature obtained from quartz maximum stream loss, where as Na-K-Ca geothermometer shows higher estimate temperature and the highest estimate temperature is Na/K geothermometer,

Table 1: Summarization of estimated reservoir temperature from 4 types of geothermometer .

Geothermometer	Range	Average	SD.	Median
Qtz no	73-202	116	22	115
Qtz Max	77-186	115	19	114
Na/K	87-460	196	65	184
Na-K-Ca	98-220	156	25	152

Note: unit = C

5. CLASSIFICATION OF HOT SPRING.

There are many criteria to classify hot springs such as temperature, pH, chemical composition etc. These criteria depend on purpose or object of classification. The object of these classifications is to sustainable management and development.

5.1 Temperature Classification

There are 4 types of hot springs classified by surface temperature as follow;

cold spring < 20^{o} C

20^{o} C $\le$ hypothermal spring < 30^{o} C

30^{o} C $\le$ thermal spring < 50^{o} C

50^{o} C $\le$ hyperthermal spring

The one hundred and nine data of hot springs in Thailand indicated that 41 hot springs (37%) are thermal springs, where as 68 hot springs (63%) are hyperthermal springs (Figure 6).

5.2 pH Classification

The classification of thermal water based on pH is divided into 6 classes as follow;

strong acid spring pH < 2

acid spring $2 \le$ pH < 4

weak acid spring $4 \le$ pH < 6

neutral spring $6 \le$ pH < 7.5

weak alkaline spring $7.5 \le$ pH < 9

alkaline spring $9 \le$ pH

Hot springs in Thailand are divided into 3 classes on the basis of pH (Figure 7). These are neutral, weak alkaline and alkaline. Twenty-four percents of hot springs show neutral (pH = 6–7.5). Weak alkaline hot springs, which have pH between 7.5 and 9 are found 68% and 8% are alkaline hot springs (pH = 9–10).

5.3 Usage Classification

There are 4 types of this classification: power plant, Tourism, consumption and unutilized. Geothermal resource in Thailand are classified in medium enthalpy (United Nations Development Program, 1984). There is only one geothermal power plant (300 kW binary cycle) in the north of the country (Fang Geothermal area, Chiang Mai Province). There are approximately 43% of hot springs used in tourism purpose. The consumption of hot springs in Thailand is approximately 17%, where 39% of hot springs in the country is unutilized. It is useful to know status of all hot springs, if sustainable development of geothermal are needed.

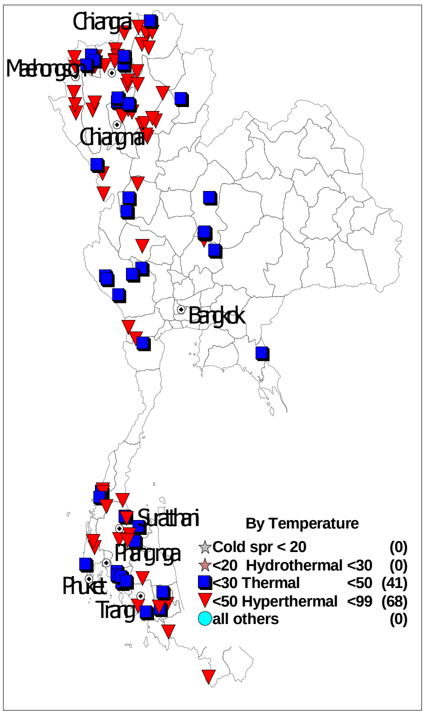

Figure 6: Classification of hot springs in Thailand on the basis of surface temperature.

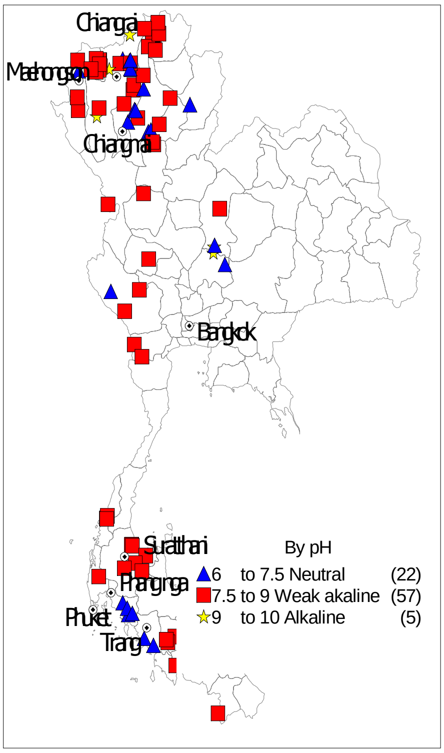

Figure 7: Classification of hot springs in Thailand on the basis of pH.

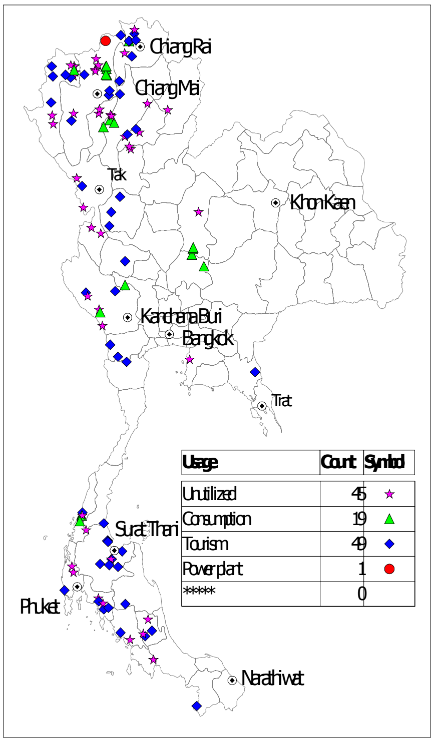

Figure 8: Classification of hot springs in Thailand on the basis of usage.

6. CONCLUSION

Most of hot springs in Thailand are classified in sodium bicarbonate, some of them are calcium bicarbonate and others are saline water. In the northern part of the country thermal water generally exhibits strong smell of sulfur and high SiO_2 and F contents, the reverse is true for those located in the South. The surface temperature is between 32^{o}C – 99^{o}C. The SiO_2 geothermometer shows estimated reservoir temperature range from 73 ^{o} C – 202 ^{o} C.

There are three types of hot spring classification system; temperature, pH and geothermal usage. On the basis of temperature, there are two classes of hot springs in Thailand: 62 % of hot spring are hyperthermal spring (50-99^o C) and 38% show thermal spring (30-50^o C). There are three classes achieved on the basis of pH values: 68 % of hot springs exhibit weak alkaline (7.5-9), 24% show neutral (6-7.5) and 8% are alkaline (9-10) springs. The last classification is geothermal usage. They are classified in 4 types: power plant (only one hot spring), tourism (43%), consumption (17%) and unutilized (39%).

The most popularity use of hot spring trend in Thailand is hot spring spa business.

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