The Malaysian Journal of ANALYTICAL SCIENCES ISSN 1394-2506

DETERMINATION OF HOT SPRINGS PHYSICO-CHEMICAL WATER QUALITY POTENTIALLY USE FOR BALNEOTHERAPY

(Penentuan Kualiti Fizik-Kimia Air Kolam Air Panas Yang Berpotensi Digunakan Untuk Balneoterapi)

Zaini Hamzah[1]*, Nurul Latiffah Abd Rani[1], Ahmad Saat[2] and Ab Khalik Wood[1]

[1]*Faculty of Applied Sciences,*
[2]*Institute of Science (IOS),*
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

**Corresponding author: zaini648@salam.uitm.edu.my*

Abstract

Hot springs areas are attractive places for locals and foreigners either for excursion or for medical purposes such as for healing of various types of diseases. This is because the hot spring water is believed rich in salt, sulfur, and sulfate in the water body. For many thousands of years, people have used hot springs water both for cozy bathing and therapy. Balneotherapy is the term used where the patients were immersed in hot mineral water baths emerged as an important treatment in Europe around 1800's. In view of this fact, a study of hot springs water was performed with the objective to determine the concentration of Na^+, K^+, Ca^{2+}, S, SO_4^{2-} and Cl^- in hot springs water around the State of Selangor, Malaysia. Energy dispersive X-ray Fluorescent Spectrometry (EDXRF) was used to measure the concentrations of Na^+, K^+, Ca^{2+} and S meanwhile for SO_4^{2-} and Cl^- anion, Ion Chromatography (IC) was used. The concentration of Na^+ obtained for filtered and unfiltered samples ranged from 33.68 to 80.95 and 37.03 to 81.91 ppm respectively. Meanwhile, the corresponding concentrations of K^+ ranged from 1.47 to 45.72 and 1.70 to 56.81 ppm. Concentrations of Ca^{2+} ranged from 2.44 to 18.45 and 3.75 to 19.77 ppm. The concentration of S obtained for filtered and unfiltered samples ranged from 1.87 to 12.41 and 6.25 to 12.86 ppm. The concentrations for SO_4^{2-} and Cl^- obtained ranged from 0.15 to 1.51 ppm and 7.06 to 20.66 ppm for filtered samples. The data signified higher concentration of salt and other important nutrients in hot spring water.

Keywords: hot springs water, balneotherapy, elemental, anions

Abstrak

Kawasan air panas merupakan tempat tarikan penduduk tempatan dan antarabangsa sama ada untuk pelancongan ataupun mengubati pelbagai jenis penyakit disebabkan oleh kandungan garam, sulfur, dan sulfat di dalam air panas tersebut. Semenjak beribu-ribu tahun, manusia telah menggunakan air panas ini bagi tujuan mandi dan rawatan. Balneoterapi adalah istilah yang digunakan untuk menggambarkan pesakit berendam di dalam kolam air mineral panas dan telah menjadi sebagai satu rawatan penting disekitar tahun 1800 di Eropah. Objektif kajian ini adalah untuk menentukan kepekatan Na^+, K^+, Ca^{2+}, S, SO_4^{2-} dan Cl^- di dalam air panas di Negeri Selangor, Malaysia. Analisis Serakan Tenaga Pendaflur Sinar-X (EDXRF) telah digunakan untuk mengukur kepekatan Na^+, K^+, Ca^{2+} dan S sementara untuk anion SO_4^{2-} dan Cl^-, kaedah ion kromatografi telah digunakan. Kepekatan Na^+ yang diperolehi untuk sampel dituras dan tidak dituras dalam julat 33.68 hingga 80.95 dan 37.03 hingga 81.91 ppm masing-masing. Sementara itu, kepekatan K^+ dalam julat 1.47 hingga 45.72 dan 1.70 hingga 56.81 ppm Kepekatan Ca^{2+} dalam julat 2.44 hingga 18.45 dan 3.75 hingga 19.77 ppm. Kepekatan S yang telah diperolehi untuk sampel dituras dan tidak dituras dalam julat 1.87 hingga 12.41 dan 6.25 hingga 12.86 ppm. Sementara itu, kepekatan untuk SO_4^{2-} dan Cl^- yang diperolehi adalah 0.15 hingga 1.51 ppm dan 7.06 hingga 20.66 ppm bagi sampel yang telah dituras. Data menunjukkan kepekatan garam dan nutrien lain yang tinggi di dalam air panas.

Kata kunci: air panas, balneoterapi, elemental, anion

Introduction

Term of balneotherapy comes from the Latin's word: balneum (bath) which is used for bathing in thermal or mineral waters [1]. Balneotherapy is the practice of using natural mineral hot spring water for the treatment and cure of disease. This therapy has been practiced all over the world from early history [2, 3]. People have used geothermal water and mineral water for cozy bathing, medical purposes and cooking, as being implemented previously in New Zealand, North America and other areas [4]. Presence various of elements and ions, especially sulphur (S) and sulphate ion (SO_4^{2-}) make hot springs water suitable for medical purposes especially for skin therapy. Sulphur is a chemical element and may be present in sulfurated waters as free or combined ion. It may comprise of various combinations of sulphur ions, water and other ions [5]. Initially sulphur and sulphate ion are produced from hydrogen sulphide (H_2SO_4) in underground hot springs water. Meanwhile, sulphide (S^{2-}) will be oxidized when the water rise to the surface [6]. The sulphate ion (SO_4^{2-}) may be originated from the weathering of pyrite or the leaching of other sulphide (S^{2-}) by hypothermal waters of deep origin [7]. The sulphide (S^{2-}) in the form of pyrites (FeS_2) that consist in the hot springs water can react chemically with water to produce H_2S and heat. The H_2S rises with the heated groundwater and gives it the strong odours like a rotten egg [8].

Besides S and SO_4^{2-}, other nutrients and minerals in hot springs water are also important for therapeutic properties. Generally, thermal waters vary greatly in chemical composition depending on geography and geology of the sites. Mineral waters are characterized by physico-chemical dynamism which is based on the study done by Javed *et. al*. (2009) [4], the hot spring water loses most of its ethereal properties when removed from the source. On top of that, the mineral composition of the thermal waters also reflects the geological formations found at the site and the depth of its origin [9]. This paper is focusing on the analysis and data interpretation of Na^+, K^+, Ca^{2+}, S, SO_4^{2-} and Cl^- that present in the hot springs water located around the State of Selangor, Malaysia.

Materials and Methods

Samples of hot springs water were collected from various hot springs in the State of Selangor, Malaysia. The positions of hot springs water were determined using Global Positioning System (GPS) and the coordinates are listed in Table 1. As depicted in Figure 1, the study area lies in the western part of the Peninsular Malaysia. Almost all the hot springs water in the Selangor State are located along the Main Range Granite Batholith but some of the hot springs water located within the area of the granite body and close to sedimentary rock The hot springs water within the granite body give the high concentration of Na^+ as acidic rocks such as sandstone and granitic rocks contain little amount of Ca^{2+} and large amount of Na^+ [10].

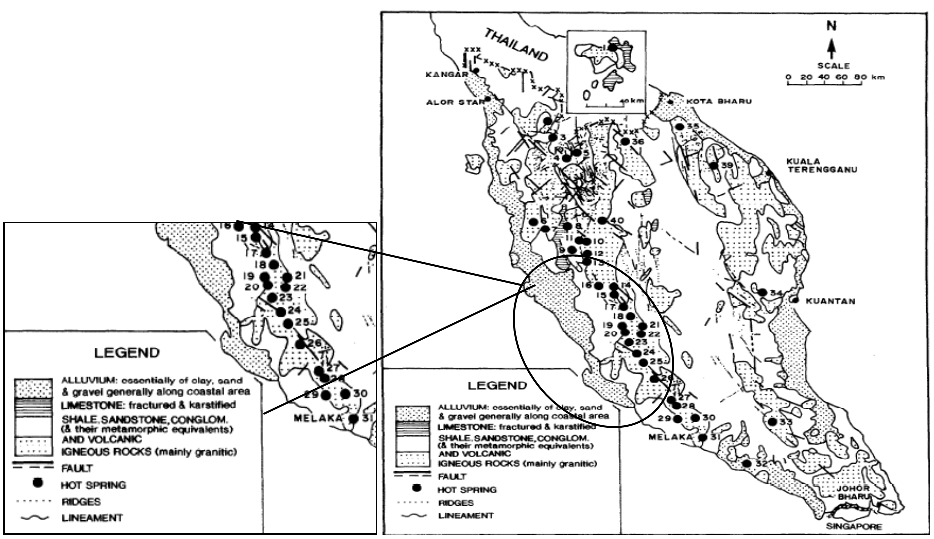

Figure 1. Geological map of the Selangor state, Malaysia hot springs water areas
Source: Abdul Rahim Samsudin *et al*., (1997) [11]

Common parameters such as dissolved oxygen (DO), conductivity, pH, total dissolved solid (TDS) and salinity were measured using calibrated YSI Portable Multi Probes Meter to determine the quality of the hot springs water. The temperature and turbidity of hot springs water were measured using high temperature thermometer and turbidity meter. Water samples for further laboratory analyses were collected from the sampling site in 20 L pre acid-cleaned polyethylene containers.

Table 1. The latitude, longitude and altitude of study areas

Locations	**Latitude (N)**	**Longitude (E)**	**Altitude (m)**
Kerling	03^{o}36.603'	101^{o}36.539'	69
Kuala Kubu Baru	03^{o}33.910'	101^{o}38.753'	68
Hulu Tamu	03^{o}27.838'	101^{o}41.814'	75
Hulu Yam	03^{o}25.549'	101^{o}40.991'	99
Selayang	03^{o}15.542'	101^{o}38.766'	82
Batu 9,Gombak	03^{o}15.246'	101^{o}43.430'	73
Setapak	03^{o}11.384'	101^{o}42.816'	81
IKBN, Hulu Langat	03^{o}08.215'	101^{o}50.072'	59
Sg Serai, Hulu Langat	03^{o}05.445'	101^{o}47.677'	75
Batu 16, Hulu Langat	03^{o}08.343'	101^{o}50.172'	60
Semenyih	03^{o}02.532'	101^{o}52.348'	67

Water samples were then acidified to pH less than 2 using 6 M nitric acid. This was done to prevent any loss of ions fractions by adsorptions onto the wall of containers [12]. Then the water samples were divided into two portions which is filtered and unfiltered. The filtration was done through the 0.45 µm cellulose nitrate membrane filter to separate suspended matter from dissolved portions of the water as suspended solids which has size greater than 0.45 µm retained on filter paper. Elements of Na^+, K^+, Ca^{2+} and S were determined using Energy Dispersive X-ray Fluorescence Spectrometer (EDXRF) (model PW4030) meanwhile SO_4^{2-} and Cl^- were determined using Ion Chromatography (IC) (model ICS-2000).

For elements determined by using EDXRF, 5 mL of filtered and unfiltered samples were pipette into special cups (sample holders) which has a 1.5 µm thin mylar film underneath. The X-ray beam is filtered through an Al-thin filter for determination of K and Ca, kapton filter for S and default for Na. Each sample was analyzed at every 100 s and the spectrums of elements were analyzed by using MiniPal/MiniMate software to determine the elemental concentration.

For anions determined by using IC, 1 mL of sample was injected into the IC column. Eluent used was KOH while SRS (Self-Regenerating Suppressor) was used as suppressor. The function of suppressor is to reduce the conductivity of the eluent and increase the conductivity of the analytes. They are delivered to the conductivity cell in a form that increases response [13].

Results and Discussion

Table 2 shows the value of hot spring water quality parameters in Selangor. Based on the measured parameters as depicted in Table 2, it can be inferred that most of the data comply with the requirement needed for bathing and other body contact activities (Class II B). Nevertheless, some of the water quality parameters values do not conform to water quality guidelines needed as potable water (class I). Salinity for all locations is not fulfilling the requirement needed for class I as the value obtained is above 0.05 mg/L. Similarly, Selayang C and IKBN, Hulu Langat shows the pH and turbidity values that do not fulfil the requirement for with value above 8.5 and 5 NTU respectively.

Apart from immersion in hot springs water, the beneficiary of drinking hot springs water also has been investigated by Dupuy *et al*., (1999)[14] for treatment of dermatologic conditions. Dupuy and his co-workers found out that drinking of low-salt Avene (France) hot spring water (sodium, 4.9 mg/L; magnesium, 22.5 mg/L; calcium, 44.3 mg/L; bicarbonate, 234.8 mg/L) for a period of 18 days was reported to normalized the intestinal permeability in patients with atopic dermatitis. However for the Malaysian hot springs water, it is advice not to drink the water as the water is not meeting the potable water standard as specified in the National Water Quality Standard for Malaysia.

Table 2. Water quality parameters of hot spring

Locations	Temp (^{0}C)	DO (mg/L)	Conductivity (μS/cm)	pH	TDS (mg/L)	Salinity (mg/L)	Turbidity (NTU)	TSS (mg/L)
Hulu Tamu (A)	51.7	2.93	493	7.60	311	0.23	0.22	0.38
Hulu Tamu (B)	50.6	3.07	485	7.58	307	0.23	0.26	0.15
Gombak (A)	56.9	3.00	495	8.50	311	0.23	0.19	1.04
Gombak (B)	52.30	3.50	493	7.54	311	0.23	0.65	1.26
Batu 16, Hulu Langat	67.90	2.64	369	7.86	228	0.17	0.22	1.49
IKBN, Hulu Langat	36.10	2.99	595	7.34	373	0.28	6.75	8.50
Sg Serai, Hulu Langat	45.40	2.80	560	7.73	343	0.25	1.34	0.71
Semenyih	36.70	4.91	559	7.45	364	0.27	0.83	1.00
Kuala Kubu Baru	40.00	3.94	365	7.33	225	0.16	0.20	1.02
Kerling	40.00	3.47	497	7.14	312	0.23	0.24	0.75
Setapak (A)	45.90	5.27	567	7.36	376	0.28	0.23	1.07
Setapak (B)	55.20	1.97	586	7.27	374	0.28	0.19	1.27
Hulu Yam	55.80	4.50	508	7.45	321	0.24	0.18	0.43
Selayang (A)	53.50	2.63	508	7.68	313	0.23	0.26	1.44
Selayang (B)	49.40	3.58	506	7.98	319	0.23	0.78	0.24
Selayang (C)	54.10	2.92	509	8.98	317	0.23	0.14	0.06
Class I, NWQS	**-**	**7**	**1000**	**6.5 – 8.5**	**500**	**0.05**	**5**	**25**
Class II B, NWQS	**-**	**5 - 7**	**-**	**6 - 9**	**1000**	**-**	**50**	**50**

Water temperature has an important role for the metabolic effects of balneotherapy and had been classified as being “cold” (< 20^{o}C), “hypothermal” (20-30^{o}C), “thermal” (30-40^{o}C), or “hyperthermal” (>40^{o}C) [1, 5]. The temperature is ranging from 36.1^{o}C to 67.9^{o}C. Among others, Batu 16, Hulu Langat shows the highest temperature which is 67.9^{o}C and IKBN, Hulu Langat shows the lowest temperature of 36.1^{o}C. The variation in temperature is indicated the geology of a particular site and also the depth from surface of the hot spring water. In Japan, due to volcanic areas, the hot spring water temperature can be much higher. From the data obtained, most of the hot springs water located in Selangor, Malaysia can be categorised as hyperthermal except for IKBN, Semenyih, Kuala Kubu Baru and Kerling as these hot springs water temperature is ranging from 30-40^{o}C. The highest and the lowest temperature are possibly reflecting the depths of waters penetration along faults system in a crust that had been affected by an anomalous geothermal gradient [15]. According to Lambert [16], the water temperature increases from near the surface to the depth of 1000 m from 15ºC to 35ºC. This shows that the deeper the water flow the higher the temperature of the spring’s water produced.

Temperature plays an important role for balneotherapy. Study done by Ohtsuka *et al*., (1995) [17], 37.6% of body enzyme activity (erythrocyte aldose reductase) increased after immersion in hot water at 42^{o}C for 10 minutes.

Meanwhile, the body enzyme activity decrease by 52.2% and 47.0% after immersion in hot water for 10 minutes at 39^{o}C and 25^{o}C. However, increasing value of this enzyme activity gave negative effect to the diabetic patients and might aggravate diabetic complications. Besides that, according to Pospisil *et al*., (2007) [18], heart rate and diastolic blood pressure in patients with Parkinson's disease had been statistically significant decrease after water immersion (32.5^{o}C) up to level of the heart. Literature reported studies show that variations in temperature of hot springs water gave different effect to the human beings and generally depending on the conditions of the individual.

The pH values were from 7.14 – 8.98. This high alkalinity water is primarily assessed by judging through the concentrations of Ca^{2+}, Na^+ and K^+ (Table 4). The granitic body in the study areas contributed to the high concentrations of Na^+ as acidic rocks such as sandstone and granitic rocks contain little amount of Ca^{2+} and large amount of Na^+ [10].

Pearson correlation had been performed between water quality parameters of hot springs water. There is a good correlation between specific conductivity and total dissolved solid (TDS) with R^2 = 0.9792, and salinity with R^2 = 0.9652. The correlation between TDS and salinity is R^2 = 0.9926. These three parameters were correlated to each other's as there are strong correlations obtained between these three parameters. TDS is solids in water that can pass through a filter (usually with a pore size of 0.45 µm). TDS is a measure of the amount of material dissolved in water. Usually solids can be found in nature in a dissolved form then break into positively and negatively charged ions. The ions include major positively and negatively charged ions such as sodium, (Na^+) calcium (Ca^{2+}), potassium (K^+) and magnesium (Mg^{2+}) for positively charge ions and chloride (Cl^-), sulfate (SO_4^{2-}), carbonate (CO_3^{2-}), and bicarbonate (HCO_3^-) for negatively charge ions. The presence of this dissolved salts directly increase the value of salinity and conductivity as salinity is a measure of the amount of salts in the water and conductivity is the ability of water to conduct an electrical current with dissolved ions as the conductors [19].

Table 3. Pearson correlation between water quality parameters of hot springs

	Temp.	**DO**	**Cond.**	**pH**	**TDS**	**Sal.**	**Tur.**	**TSS**
Temp.	1							
DO	0.1865	1						
Cond.	0.1404	0.0038	1					
pH	0.2101	0.0723	0.0183	1				
TDS	0.1455	0.0262	**0.9792**	0.0297	1			
Sal.	0.1247	0.0238	**0.9652**	0.0411	**0.9926**	1		
Tur.	0.2331	0.0096	0.1785	0.0378	0.1402	0.1489	1	
TSS	0.1414	0.0180	0.1069	0.0662	0.0855	0.1013	**0.9022**	1

Turbidity and total suspended solid (TSS) also shows strong correlation (R^2 = 0.9022). Turbidity is the measure of the light scattering properties of water and depends on the amount, size and composition of the suspended matter such as clay, silt, colloidal particles, plankton and other microscopic organisms. It is measured in nephelometric turbidity units (NTU) and suspended solids refer to the mass of the suspended matter and are measured as mg/L [20]. According to Mohd Noor Salleh *et al.*, (2011) [21], there are usually a correlation between these two parameters. Other parameters show weak correlation with value of R^2 < 0.5000.

Table 4 showed concentration of Ca^{2+}, Na^+, K^+, S, SO_4^{2-} and Cl^- obtained from the analysis. Ca^{2+}, Na^+, K^+, S were analysed using EDXRF, meanwhile SO_4^{2-} and Cl^- were analysed using IC. Results indicate the values of unfiltered samples for each element consistently higher than filtered for EDXRF analysis. This might be due to the ions that attached to the charged site of the suspended solids have been filtered away. From the results, it also shows that the value obtained for concentration of Na^+ is higher than the concentration of Ca^{2+} in the water samples. This prove that major element composition of the hot water is dominated by Na^+ meanwhile Ca^{2+} is a minor component [22].

Value obtained for S (filtered and unfiltered) is higher compared with SO_4^{2-} (See Table 4). Their low SO_4^{2-} content suggests that these compounds are converted into S by bacterial reduction of magmatic SO_2 or sulfate [23]. Nevertheless, hot springs water contains SO_4^{2-}, initially in the form of H_2S. As the water rises to the surface, the S^{2-} may be oxidized, especially if the path to the surface is the rise of water is slow through rock fractures rather than faults and S, SO_2, or SO_4^{2-} may be produced [6]. It is important to note that sulfur-rich hot spring water has special interest for dermatological effects [1]. Sulfur also interacts with oxygen radicals in the deeper layers of the epidermis, producing sulfur and disulfur hydrogen, which may be transformed into pentathionic acid and this, may be the source of the anti bactericidal and antifungal activity of sulfur water [5]. This was supported by studied that had done by Inoue *et al*., [24] that *Staphylococcus aureus* on the skin surface decreased in number or disappeared after balneotherapy, the hot-spring water was suspected to act against the microorganism. The concentration range obtained for Cl^- is between 7.06 to 20.66 ppm. Hydrogen sulfide gases dissolved in hot springs water that originates in the magma as well as hydrogen chloride. Thus, chloride ion in geothermal waters can be at high concentrations [6].

The results (see Table 5) showed that most of the Ca^{2+}, Na^+, K^+, S, SO_4^{2-} and Cl^- concentrations for each hot spring water locations in Selangor, Malaysia are comparable with other studies that previously used hot springs water for balneotherapy. Difference concentrations of elements obtained as the locations of the hot springs water in Selangor, Malaysia located at different geological position which on granite body, thus the concentrations of Ca^{2+} obtained is lower compared to others elements.

Table 4. Concentration of Ca^{2+}, Na^+, K^+, S, SO_4^{2-} and Cl^- analyse using EDXRF and IC

Samples	**Ca^{2+} (mg/L)**	**Ca^{2+} (mg/L)**	**Na^+ (mg/L)**	**Na^+ (mg/L)**	**K^+ (mg/L)**	**K^+ (mg/L)**	**S (mg/L)**	**S (mg/L)**	**SO_4^{2-} (mg/L)**	**Cl^- (mg/L)**
	F	**Un-F**	**F**	**Un-F**	**F**	**Un-F**	**F**	**Un-F**	**F**	**F**
Hulu Tamu (A)	2.44 ± 0.01	5.18 ± 0.02	39.51 ± 0.87	42.40 ± 0.68	1.55 ± 0.04	1.70 ± 0.07	1.87 ± 1.27	6.25 ± 7.02	0.55 ± 0.64	14.19 ± 0.31
Hulu Tamu (B)	2.48 ± 0.02	3.75 ± 0.09	47.68 ± 0.79	52.66 ± 0.40	1.47 ± 0.02	7.82 ± 0.06	11.92 ± 1.35	11.94 ± 1.08	0.79 ± 0.02	20.66 ± 0.43
Gombak (A)	9.53 ± 0.14	10.38 ± 0.19	51.95 ± 0.37	53.86 ± 0.40	18.17 ± 0.05	20.04 ± 0.71	6.78 ± 3.68	8.81 ± 1.44	1.46 ± 0.43	7.06 ± 1.22
Gombak (B)	10.44 ± 0.05	11.31 ± 0.04	37.96 ±0.199	41.15 ± 0.49	3.46 ± 0.07	6.37 ± 0.07	10.96 ± 0.07	11.58 ± 0.17	0.51 ± 0.11	14.66 ± 1.84
Batu 16, Hulu Langat	2.90 ± 0.06	4.73 ± 0.01	55.08 ± 0.38	81.73 ± 0.91	2.75 ± 0.06	2.60 ± 0.05	8.59 ± 0.94	10.11 ± 0.28	0.56 ± 0.37	16.66 ± 1.28
IKBN, Hulu Langat	4.13 ± 0.02	5.61 ± 0.08	61.11 ± 0.62	69.49 ± 0.71	19.35 ± 0.04	24.98 ± 0.93	11.60 ± 1.28	11.02 ± 0.57	0.40 ± 0.01	16.79 ± 0.45
Sg Serai, Hulu Langat	12.60 ± 0.14	15.92 ± 0.13	80.95 ± 0.02	81.91 ± 0.35	13.22 ± 0.02	19.01 ± 0.75	11.53 ± 0.27	11.89 ± 0.80	1.51 ± 0.48	14.05 ± 0.22

Semenyih	14.13 ± 0.13	17.77 ± 0.16	59.69 ± 0.85	60.23 ± 0.68	45.72 ± 0.04	56.81 ± 0.72	7.64 ± 5.66	9.04 ± 4.40	0.76 ± 0.25	9.78 ± 0.19
KKB	9.31 ± 0.02	10.97 ± 0.05	45.23 ± 0.81	46.08 ± 0.97	23.84 ± 0.02	25.27 ± 0.66	10.01 ± 0.56	11.23 ± 0.64	0.23 ± 0.09	12.60 ± 0.19
Kerling	14.82 ± 0.13	16.55 ± 0.15	60.00 ± 0.03	64.94 ± 0.26	20.81 ± 0.09	29.78 ± 0.68	11.58 ± 0.77	11.65 ± 1.30	0.32 ± 0.02	12.13 ± 0.10
Setapak (A)	7.08 ± 0.11	7.83 ± 0.10	66.41 ± 1.27	67.71 ± 0.28	2.85 ± 0.037	8.21 ± 0.07	5.33 ± 1.35	9.33 ± 0.55	0.48 ± 0.09	15.48 ± 0.25
Setapak (B)	7.04 ± 0.03	7.81 ± 0.05	70.33 ± 0.88	71.03 ± 0.53	3.28 ± 0.06	5.97 ± 0.06	10.53 ± 1.30	11.22 ± 0.49	0.16 ± 0.01	20.12 ± 0.39
Ulu Yam	5.67 ± 0.05	6.48 ± 0.07	43.93 ± 0.56	52.22 ± 0.80	2.04 ± 0.02	2.20 ± 0.01	10.39 ± 0.05	11.32 ± 1.14	0.19 ± 0.01	11.78 ± 0.30
Selayang A	17.80 ± 0.06	19.17 ± 0.07	44.30 ± 0.13	48.66 ± 0.67	14.05 ± 0.03	15.16 ± 0.02	11.17 ± 0.01	11.69 ± 0.08	0.15 ± 0.003	11.96 ± 0.34
Selayang B	17.93 ± 0.15	19.77 ± 0.05	40.85 ± 0.02	45.24 ± 0.56	14.53 ± 0.01	15.54 ± 0.01	12.41 ± 0.25	12.86 ± 0.28	0.16 ± 0.02	11.43 ± 0.33
Selayang C	18.45 ± 0.14	18.55 ± 0.12	33.68 ± 1.10	37.03 ± 0.09	2.74 ± 0.02	3.69 ± 0.07	12.38 ± 0.75	12.51 ± 0.37	0.36 ± 0.05	10.09 ± 0.18

* F- Filtered, Un-F - Unfiltered

Table 5. Comparison concentration of Ca^{2+}, Na^{+}, K^{+}, S, SO_4^{2-} and Cl^{-} with other studies

Locations	**Ca^{2+} (mg/L) Unfiltered**	**Na^{+} (mg/L) Unfiltered**	**K^{+} (mg/L) Unfiltered**	**S (mg/L) Unfiltered**	**SO_4^{2-} (mg/L) Filtered**	**Cl^{-} (mg/L) Filtered**	**References**
Kusatsu Hot Spring Water, Japan	72.00	53.70	16.00	-	611.00	343.00	Inoue *et al.*, (1999)[24]
Sulfur baths, Austria	-	-	-	7.30	-	-	Leibetseder *et al.*, (2004) [25]
Atatürk Balneotherapy & Rehabilitation Center, Turkey	91.90	222.50	23.00	-	277.00	2.20	Yurtkuran *et al.*, (2005) [26]
Northern Part of Limpopo Prov., South Africa	1.31-13.73	10.59-156.31	0.99-4.25	-	2.98-53.17	19.47-168.97	Olivier *et al.*, (2011) [27]

Saratoga Spa State Park, USA	32.20 - 872	2.00 –3820	0.15 – 340	-	22.00	4.80 – 6030	Lund., (1996)[3]
Present study Hot springs water in Selangor, Malaysia	**3.75 – 19.77**	**37.03 – 81.91**	**1.70-56.81**	**6.25 – 12.86**	**0.15 – 1.51**	**7.06 – 20.66**	

Conclusion

Hot Springs water all over State of Selangor, Malaysia contains Na^+, K^+, Ca^{2+}, S, SO_4^{2-} and Cl^- which are good for balneotherapy. Chemical composition consist in hot springs water has its own beneficial for the human's health where it generally can increase metabolism, accelerate healing, soothe muscles, improve blood circulation and detoxify the body's lymphatic system [4]. The data shows that hot springs water located in Selangor, Malaysia are suitable for bathing and body contact activities but unsuitable as potable water. The composition and physical properties of various hot springs waters are vary in term of salt, sulphate and chloride content. Generally, the concentrations of chemical compositions of the hot springs water are comparable with literature reported studies and this indicated that the hot springs water in Selangor are potentially qualified for balneotherapy.

Acknowledgement

The authors would like to thank Universiti Teknologi MARA Malaysia particularly the UiTM's Research Management Institute for providing grant, Research Excellence Fund 600-RMI/DANA 5/3/RIF (1/2012) and support to carry out this study.

References

1. Nasermoaddeli, A., and Kagamimori, S., (2005). Balneotherapy in Medicine: A Review. *Environmental Health and Preventive Medicine* 10: 171–179.
2. Kristmannsdóttir, H., and Björnsson, G. O., (2003). Balneological prospects in Iceland using geothermal resources. *International Geothermal Conference, Reykjavík,* 3: 19-26.
3. Lund, J. W., (1996). Balneological use of thermal and mineral waters in the U.S.A. *Geothermics* 25(1): 103-147.
4. Javed, A., Iqbal, J., Asghar, U., Khan, F. A., Munshi, A. B., and Sddiqui, I., (2009). A study to evaluate therapeutic properties of minerals of Manghopir Hot Spring, Karachi. *J.Chem.Soc.Pak* 31(3): 396-401.
5. Matz, H., Orion, E., and Wolf, R., (2003). Balneotheraphy in dermatology. *Dermatologic Theraphy.* 16: 132-140.
6. Hodder, A. P. W., (1999).Geothermal Waters: A Source Of Energy and Metals. *Unit Department of Earth Sciences, University of Waikato .XIII-Water-A-Geothermal;* 1-10.
7. Drogue, C., Cat, N. N., and Dazy, J., (2000). Geological factors affecting the chemical characteristics of the thermal waters of the carbonate karstified aquifers of Northern Vietnam. Hydrology and Earth System Sciences 4(2): 332-340.
8. Thompson, G. R., and Turk, J., (2005). *Earth science and the environment*. Third edition. Brooks/Cole, Thomson Learning, USA.
9. Olivier, J., Niekerk, HJ., and Walt, I., (2008). Physical and chemical characteristics of thermal springs in the Waterberg area in Limpopo Province, South Africa. *Water South Africa* 34(2): 163-174.
10. Homma, A., and Tsukahara, H., (2008). Chemical characteristics of hot springs water and geological environment in the northernmost area of the Itoigawa Shizuoka tectonic line. *Bull. Earthq. Res. Inst. Univ. Tokyo.* 83: 217-225.
11. Abdul Rahim Samsudin., Umar Hamzah., Rakmi Ab. Rahman., Chamhuri Siwar., Mohd Fauzi Mohd. Jani., and Redzuan Othman., (1997). Thermal springs of Malaysia and their potential development. *Journal of Asian Earth Sciences.* 15: 275-284.

12. Kovacs, T., Mate, B., Somlai, J., Kavasi, N., and Jobbagy, V., (2010). Radiochemistry characterization of springs water in Balaton Upland, Hungry, estimation of radiation dose to members of public. *Microchemical Journal* 94(2): 159-165.
13. Dionex., (2010). *Eluent suppressors for ion chromatography*.
14. Dupuy, P., Casse, M., Andre, F., Dhivert-Donnadieu, H., Pinton, J., and Hernandez-Pion, C., (1999). Low-Salt Water Reduces Intestinal Permeability in Atopic Patients. *Dermatology 1999;*198:153–155.
15. Cinti, D., Pizzino, L., Voltattorni, N., Quattrocchi, F., and Walia, V., (2009). Geochemistry of thermal waters along fault segments in the Beas and Parvati valleys (north-west Himalaya, Himachal Pradesh) and in the Sohna town (Haryana), India. *Geochemical Journal*. 43,65-76.
16. David Lambert Group (2007). *The field guide to geology*. Library of Congress Cataloging. pg 29.
17. Ohtsuka, Y., Yabunaka, N., Watanabe, I., Noro, H., Fujisawa, H., and Agishi, Y., (1995). Thermal strees and diabetic complications. *International Journal of Biometeorology*.38(2): 57-59.
18. Pospisil, P., Konecny, L., Zmeskalova, M., Srovnalova, H., Rektorova, I., Nosavcorova, E., Sosikova, M., Dobsak, P., and Siegelova, J., (2007). Balneotherapy in Patients with Parkinson's disease. *SCRIPTA MEDICA (BRNO)* – 80 (5): 233–23.
19. State Water Resources Control Board, Division of Water Quality (2002). Electrical Conductivity/Salinity. *The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment; 1-5*.
20. National Land and Water Resources Audit., (2008). Turbidity/Suspended Particulate Matter in Aquatic Environments. *Australian Government* 1-9
21. Mohd. Noor Salleh and Zaki Zainudin (2011). Potable Water Quality Characteristics. *JURUTERA; 21-27.*
22. Bucher, K., Zhang, L., and Stober, I., (2009). A hot spring in granite of the Western Tianshan, China. *Applied Geochemistry* 24: 402–410
23. Gebresilassie, S., Tsegab, H., Kabeto, K., Gebreyohannes, T., Sewale, A., Amare, K., Zerabruk, S., Mebrahtu, G., Gebrehiwot, K., and Haile, M., (2011). Preliminary study on geology, mineral potential and characteristics of hot springs from Dallol area, Afar rift, northeastern Ethiopia: implications for natural resource exploration.. *Mekelle University*. 2: 17-3.
24. Inoue, T., Inoue, S., and Kubota, K., (1999). Bactericidal Activity of Manganese and Iodide Ions against Staphylococcus aureus: A Possible Treatment for Acute Atopic Dermatitis. *Acta Derm Venereol,* 79: 360-362.
25. Leibetseder, V., Strauss-Blasche, G., Holzer, F., Wolfgang Marktl, W., and Ekmekcioglu, C., (2004). Improving homocysteine levels through balneotherapy: effects of sulphur baths. *Clinica Chimica Acta* 343: 105– 111
26. Yurtkuran, M., AlevAy and Karakoç, Y., (2005).Improvement of the clinical outcome in Ankylosing Spondylitis by balneotherapy. *Joint Bone Spine* 72:303–308
27. Olivier, J., Venter, J. S., and Jonker, C. Z.,(2011). Thermal and chemical characteristics of hot water springs in the northern part of Limpopo Province, South Africa. *Water South Africa* 37:427-436