

ANALYSIS OF THE PHYSICAL AND CHEMICAL PROPERTIES AND METAL CONTENT OF HOT SPRINGS IN LAMPUNG PROVINCE

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ABSTRAK

Sumber air panas dapat dieksplorasi untuk kegiatan geowisata. Geowisata merupakan bagian dari bidang utama dalam geologi yang dapat berkontribusi pada pembangunan berkelanjutan. Oleh karena itu, sumber air panas dieksplorasi untuk diketahui potensinya berdasarkan sifat fisika dan kimianya. Ada tiga tempat yang diteliti yaitu pemandian Way Belerang Kalianda, pemandian air panas di Natar, serta pemandian air panas di Banjir, Way Kanan. Sifat fisika dan kimia sumber air panas yang diukur secara in situ meliputi total padatan terlarut, oksigen terlarut, pH dan suhu, sedangkan konsentrasi logam total ditentukan dengan ICP-AES. Nilai pH yang terukur berkisar antara 5,2-8,1, suhu rata-rata yang terukur berkisar 37-52°C. Nilai DO tertinggi dan terendah berturut-turut sebesar 9,1 mg/L dan 5,5 mg/L. Nilai rata-rata TDS dan TSS di tiga lokasi sampel berturut-turut sebesar 3620 mg/L dan 16,7 mg/L. Konsentrasi logam Al, Ba, Cu, K, Ni, Pb tertinggi terdapat di Natar, Lampung Selatan, sedangkan konsentrasi B, Co, Li, Na tertinggi di Way Kanan, Lampung Utara. Konsentrasi Mg, Mn, Ca tertinggi terdapat di Way Belerang, Kalianda, Lampung Selatan. Konsentrasi logam yang lainnya umumnya rendah dan serupa di titik sampel sumber air panas yang diteliti. Dengan tingginya kandungan mineral yang tidak berbahaya dalam sumber air panas, maka pemandian air panas dapat dieksplorasi untuk kegiatan geowisata.

Kata kunci: Air Panas, ICP-AES, Kalianda, Natar, Way Kanan

ABSTRACT

Hot springs can be explored for geotourism activities. Geotourism is part of the main field in geology that can contribute to sustainable development. Therefore, hot springs are explored to determine their potential based on their physical and chemical properties. There were three places studied, namely Way Sulfur Kalianda baths, hot springs in Natar, and hot springs in Banjir, Way Kanan. The physical and chemical properties of hot springs measured in situ include total dissolved solids, dissolved oxygen, pH and temperature, while total metal concentrations are determined using ICP-AES. The measured pH value ranged from 5.2-8.1, the average measured temperature ranged from 37-52°C. The highest and lowest DO values were 9.1 mg/L and 5.5 mg/L respectively. The average TDS and TSS values at the three sample locations were 3620 mg/L and 16.7 mg/L respectively. The highest concentrations of the metals Al, Ba, Cu, K, Ni, Pb are found in Natar, South Lampung, while the highest concentrations of B, Co, Li, Na are in Way Kanan, North Lampung. The highest concentrations of Mg, Mn, Ca are found in Way Sulfur, Kalianda, South Lampung. Concentrations of other metals were generally low and similar at the hot spring sample points studied. With the high content of harmless minerals in hot springs, hot springs can be explored for geotourism activities.

Keywords: Hot springs, ICP-AES, Kalianda, Natar, Way Kanan

INTRODUCTION

Hot springs are used as bathing places that are believed to cure skin diseases and joint pain, and are used for geotourism activities. Geotourism is a tourism activity in locations that have geological attraction (Newsome & Dowling 2006) and is one of the main fields in geology that can contribute to sustainable development, so we can indirectly conserve these natural resources for the future. Therefore, geotourism is often used in determining policies.

One type of eco-friendly tourism is hot springs (Erfurt-Cooper 2010). In general, hot springs are warm water that comes out to the earth's surface regularly, where the ambient temperature is different from the soil temperature (Dash et al. 2013; Sherpa et al. 2013). Hot springs can be divided into three groups, namely the first group of hot springs comes from volcanic rocks, the second comes from metamorphic rocks, and the third comes from shallow groundwater mixtures (Guo, et al, 2020). Non-volcanic hot springs are not always related to volcanism. For medium hot springs, the heat is caused by the high geothermal heat generated from volcanism, but the water source is purely meteoric. Volcanic-related hot springs are characterized by the presence of excess heat, mineral content, and water that partly comes from volcanic sources (Amanuel M. Ghilamical, et al. 2017).

The mineral content in hot springs can cure skin diseases and joint pain, one type of water that is used for medical purposes, especially for skin therapy due to the presence of sulfur and sulfate ions in hot springs (Lund, 1996). Soluble minerals such as calcium, bicarbonate, silicates, iron compounds, sodium, magnesium, sulfur, metals and selenium are found in hot springs resulting from the interaction of water with geological materials (Seite 2013). The salt content in hot springs is believed to also cure various skin diseases (Norbert Simon, et al. 2019).

The relationship between mineral content in the geological environment and human health has been extensively studied, especially in the context of the role of essential minerals such as calcium, magnesium, and zinc that have been shown to contribute to various physiological functions of the body, including metabolism, immune system, and bone health (Zeng et al., 2019). However, the presence of heavy metals such as lead (Pb), mercury (Hg), and cadmium (Cd) in the environment is also a serious concern because of their toxic properties that can cause neurological disorders, organ damage, and even carcinogenicity if accumulated in the human body (Tchounwou et al., 2012). Therefore, a thorough evaluation of the types and concentrations of minerals and heavy metals is very important in the context of utilizing geological potential for the development of health-based geotourism.

Total Dissolved Solid (TDS) is a residual material in which water evaporates and is dehydrated at a certain temperature (APHA, 1989). TDS consists of several impurities in the form of fine sand or mud that dissolves in water due to soil erosion which then enters the water. As a result of the high TDS in the water, it will cause turbidity in the water. Total Suspended Solid (TSS) is the presence of impurities that are not dissolved in the water due to soil erosion around the water. The size of the particles suspended in water is $>45\mu\text{m}$. The suspended impurities were measured using a millipore sieve with a diameter of $> 1\mu\text{m}$. (Asa, Hanifah, & Kuat, 2018).

Research on the potential and benefits of hot springs has not received much attention. There is only one study that explores the balneotherapeutic potential of hot springs (Hamzah et al., 2013). Therefore, this study aims to analyze the physical and chemical properties and metal content of three hot springs in Lampung Province, namely Way Belerang, Kalianda, South Lampung, Natar hot springs, South Lampung, Way Kanan hot springs, North Lampung, so that the potential of hot springs can be explored and the benefits for health can also be known from their mineral content.

In situ parameters measured: pH, temperature, total dissolved solids, and dissolved oxygen. For total metal parameters and total solid suspensions are carried out in the laboratory. The characteristics of hot springs can be seen from their physical properties and can be known for their health benefits from their mineral content.

METHOD

In situ parameters measured: pH using pH meter HANNA HI 98107 (Romania, Europe), temperature (Alla France Thermometer, Cat. 5150T110-qp), total dissolved solids (TDS Meter Type TDS-3), total insoluble solids (TSS Meter 740 Partech, 750W2) and dissolved oxygen (DO-Meter 5509, Lutron). Meanwhile, the total metal parameters using ICP-OES 715ES (EPA 2007 Revised 5 method) and total solid suspensions (Millipore-Kit, Sigma-Aldrich) were performed in the laboratory. The coordinates at each sampling location were measured with a GPS application.

Sampling

Water samples were taken from three different places and very far apart, each place being taken at two location points. One point is taken from the main source of hot water and the other from the composite of the bathing pool. The sample is placed in a clean 1-liter plastic sample

bottle and the bottle is rinsed with water to be taken before filling the sample to the fullest. For samples used for total metal testing, the samples are preserved with a 5% HNO₃ solution of 1 ml per 1 liter of sample, then all samples are stored in a refrigerated box and stored in a refrigerator.

Sampling Location

In this study, samples were taken at three different points, namely the first location at the Way Belerang hot spring, located at the foot of Mount Rajabasa in Way Belerang Village, South Lampung, Kalianda District, Lampung Province. The first location is a hot spring that contains natural sulfur, This location is open to the public and well maintained and managed by the local tourism office. For the second location is at the Juku Batu hot spring in Banjit District, Way Kanan Regency, North Lampung, the Juku Batu hot spring is on the banks of the Umpu river, this location is managed by the local Association of Forest Farmers Groups (Gapoktanhut).

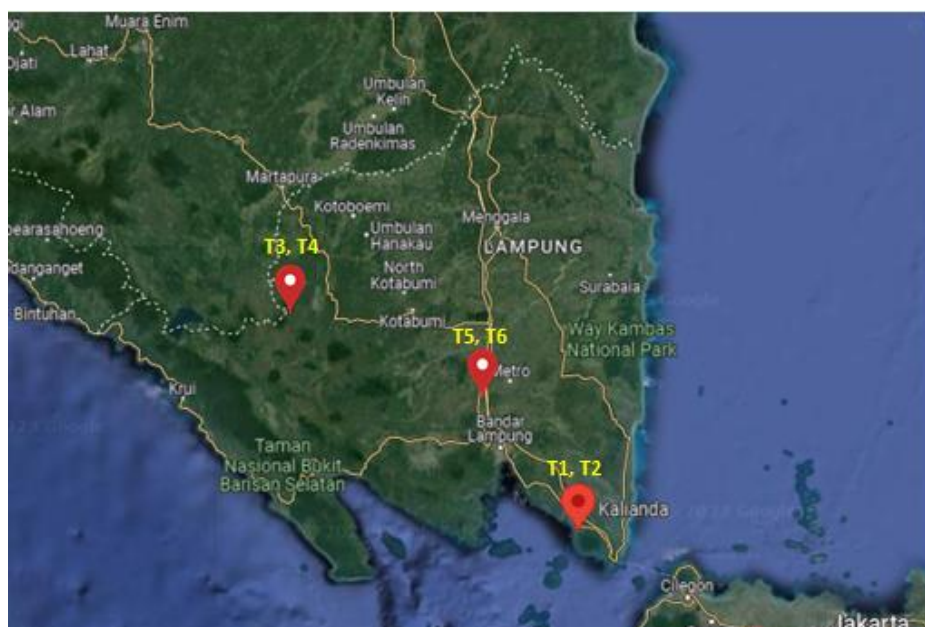


Figure 1. Research location

The third location is a hot spring located in a rice field area in Cisarua Village, Muara Putih Village, Natar District, South Lampung Regency. This third location belongs to an individual indigenous leader of South Lampung Natar, Takim Jaya Taruna.

Table 1. Sampling coordinate point

Sample Code	Location	Coordinates
T1	Squirt	-5,7506301,105,6041348
T2	Squirt	
T3	The Right Way	-4,853749,104,440094
Q4	The Right Way	
Q5	Fields	-5,3004000,105,1929861
T6	Fields	

RESULTS AND DISCUSSION

Hot springs are known to have a variety of health benefits due to their high mineral content, such as sulfur, calcium, and magnesium. These minerals can help relieve muscle pain, improve blood circulation, and help with relaxation and skin health. However, it is also important to understand that excessive exposure to certain metals or minerals in hot water, such as iron, arsenic, or other heavy metals, can pose health risks, especially if used regularly without supervision. To keep the benefits optimal and avoid side effects, the duration of bathing in hot springs should be limited. Generally, a safe duration ranges from 15 to 30 minutes, depending on the temperature of the water and the individual's health condition. Taking a long bath in hot water at high temperatures can lead to dehydration, increased blood pressure, or skin irritation, especially for people with certain health conditions such as high blood pressure or heart disease. Therefore, it is important to conduct regular water quality tests and provide clear information to visitors regarding the mineral content and the safe time limit for bathing in the hot springs (Harada, 2009).

Several studies show that the mineral content in hot water can help improve blood circulation, relieve muscle and joint pain, and provide a psychological relaxation effect (Matsumoto *et al.*, 2018;). However, the higher the temperature and solubility, the greater the potential for water to dissolve heavy metal compounds, such as arsenic, aluminum, and lead, which can cause toxic effects if exposed in excess amounts or over a long period of time (WHO, 2017).

The three hot springs in Lampung were measured in temperature, pH, dissolved oxygen (DO), total suspended solid (TSS), and total dissolved solid (TDS) as shown in Table 2. The

highest temperature in the Juku Batu bath in Way Kanan shows hyper-thermal properties and pH values that tend to be alkaline are also shown in the bath.

Table 2. Characteristics of hot springs in the study area

Yes	Sample Code	Temperature °C	Ph	DO (mg/L)	TDS (mg/L)	TSS (mg/L)
1	T1	39	5,2	5,5	6970	20
2	T2	37	5,2	5,7	7000	20
3	T3	52	7,6	7,6	2330	10
4	Q4	42	8,1	6,6	2250	10
5	Q5	49	6,7	9,1	1580	10
6	T6	38	6,8	8,3	1590	30

The lowest temperature is in Way Belerang, Kalianda, South Lampung (37-39°C), while the highest temperature is in hot springs in Way Kanan, North Lampung (42-52 °C). According to Putri, Irawan, and Yudono (2022), the temperature of hot springs in Kalibeber Village, Central Java is 39°C. The temperature of hot water that is beneficial to our body ranges from <40 °C, meaning that the hot water temperature in the T3, T4, and T5 samples is still quite high. The temperature of the hot water is influenced by the conditions around it, such as the season, day and night weather, the place or location. The varying depth of water circulation also plays an important role in the heat acquisition of a hot spring. (Hang Pe, et al, 2023)

The measured pH value ranges from 5.2-8.1, indicating that hot springs are weak acidic to weak alkaline. When compared to research conducted by Yuliandini and Putra (2013), the pH of hot water in 5 points in the South Solok area, West Sumatra is around pH 8. The measured pH value can be an indicator of whether the quality of the hot water being studied is good or not. If the pH value = 7, then the hot water studied is neutral, if the pH is < 7, the hot water studied is acidic, and if the pH is > 7, then the hot water is alkaline. According to the requirements of clean water, a good pH for hot springs ranges from 6.5-9. So it can be known that the hot water at the T1 and T2 locations (Kalianda) does not meet the pH value requirements for clean water. Water with a low pH can cause irritation to the skin and eyes. pH can also be affected by the fluid-mineral interaction arena during the transport of hydrothermal fluids in the subsurface environment of hot water (Seewald, et al, 2019).

Based on table 2, the highest DO value was in the T5 sample of 9.1 mg/L, while the lowest was in the T1 sample of 5.5 mg/L. The level of dissolved oxygen (DO) in the water reflects the abundance of aquatic life. It is also an important measure of water quality and can vary

substantially over time (Zhi, et al (2021). If the DO value in the water is high, then the water quality will be better. On the other hand, if the DO value is low in the water, then the water can be said to have been contaminated. The amount of dissolved oxygen can be affected by several factors. Higher water temperatures will reach the saturation point 100% faster than colder water. Second, higher salinity levels of water will reduce the amount of DO that will be contained at the same pressure and temperature. Third, the more water pressure increases, the more DO will also increase. For every decrease of 1 meter of water, the reduction of DO that can be contained will be reduced by 10%.

The average TDS value in the three sample locations was 3620 mg/L. The maximum TDS value was in the T2 sample which was 7000 mg/L. The lowest TDS value was in the T5 sample which was 1580 mg/L. According to Ipi and Kurniawan (2019), the TDS value of hot water in the South Bangka area was 22 mg/L. This shows a very significant difference with the TDS value in this study. TDS indicates the amount of dirt/solids dissolved in the water. Usually solids can be found in nature in dissolved form and then decompose into positive and negatively charged ions. The content of dissolved solids can increase the value of salinity and conductivity as salinity is a measure of the amount of salt in water and conductivity is the ability of water to conduct an electric current with dissolved ions as conductors (Dahaan et al., 2016). High TDS levels in hot water can increase the risk of cardiovascular diseases, such as coronary heart disease and heart failure. Increased concentrations of certain minerals and salts in hot water can affect the functioning of the body's organs. For example, high levels of calcium or magnesium can contribute to the formation of kidney stones. (Rani and Retnaningdyah, 2015; Siswoyo and Nicola, 2015).

The average TSS value at the three sample locations was 16.7 mg/L. The maximum TSS value was in the T6 sample which was 30 mg/L. The lowest TSS value was in the T3, T4, and T5 samples which was 10 mg/L. The height and low Total Suspended Solid (TSS) affected the water clarity level. If the Total Suspended Solid (TSS) value is low, the water clarity level will be higher (Dewa, et al, 2016). High TSS has an impact on the human body which produces toxins because it is not needed by the body. The toxin is an inhibitor of the performance of enzymes so that the process in the metabolism of the human body is interrupted. The process in the body is through the skin, to breathing and to digestion (Ramlia et al., 2018). The turbidity of hot water can be calculated from the TSS content obtained. The quality standard of TSS value in waters based on SNI 06-6989.3-2004 is 400 mg/L. This means that the TSS value in this study meets the quality standard in SNI.

In addition to measuring pH, DO, TDS, and TSS, metal content in the hot springs was also measured. Heavy metals are natural elements of natural waters and some of them such as iron, manganese, zinc, cobalt, molybdenum, and selenium are biologically important in the aquatic environment when present at low concentrations. Heavy metals can enter the waters from various sources, such as the weathering of rocks and soil. Another source of heavy metals is the result of human activities for agriculture, mining, and other manufacturing industry activities.

Table 3. Results Total metal analysis of hot springs

		Sample Code						Quality Standards (SNI)
Metal		T2	T3	Q4	T6	T7	T8	(mg/L)
Ag	mg/L	Td	Td	Td	Td	Td	Td	0,1
Al	mg/L	0,07	0,10	0,01	Td	0,02	0,02	0,2
B	mg/L	0,04	0,04	14,91	15,16	1,59	1,43	1,0
Ba	mg/L	Td	Td	Td	0,01	0,06	0,06	0,1
Cd	mg/L	Td	Td	Td	Td	Td	Td	0,2
Co.	mg/L	0,03	0,04	0,04	0,05	0,04	0,04	0,1
Cr	mg/L	Td	Td	Td	Td	Td	Td	0,1
Cu	mg/L	0,01	0,02	0,01	0,01	0,01	0,01	2,0
Fe	mg/L	Td	Td	Td	Td	Td	Td	0,2
K	mg/L	17,52	13,91	42,66	45,24	56,79	53,99	-
Li	mg/L	Td	-0,01	2,96	3,14	2,65	2,65	-
Mg	mg/L	27,57	27,57	0,42	0,36	7,75	8,03	150
Mn	mg/L	1,34	1,41	0,11	0,09	0,18	0,20	0,4
Na	mg/L	62,31	47,43	658,52	656,01	444,43	449,20	-
Ni	mg/L	0,01	0,01	0,01	0,00	0,03	0,01	0,02
Pb	mg/L	0,01	0,04	Td	0,06	0,09	0,05	0,01
Zn	mg/L	Td	Td	Td	Td	Td	Td	3,0
Ca	mg/L	173,08	166,93	35,26	31,96	53,76	104,55	-

*) TD : Undetectable

The highest concentration of Al, Ba, Cu, K, Ni, Pb metals is found in Natar, South Lampung. The concentration of B, Co, Li, Na is highest in Way Kanan, North Lampung. The highest concentration of Mg, Mn, Ca is in Way Sulfur, Kalianda, South Lampung. Other metal concentrations are generally low and similar at the hot spring sample points studied, which can be seen in Table 3. When compared to the quality standards according to SNI, the metal content in the three hot spring areas in this study meets the standards so that it is safe for the health of living beings. The minerals contained in hot water are highly valued because they are believed to be effective in killing germs. Soaking in this hot spring can relieve pain, heal wounds, lower

blood pressure, and take care of the skin. Soaking in hot springs is also very effective in relieving muscle and joint pain, relieving flu, and curing chronic skin pain (Wiyatasari, 2021).

All of the healing properties of course differ from one hot spring to another, and this depends on the mineral content. Different minerals will provide different health benefits. For example, hot springs with sulfur, calcium, sodium, and other temperatures in the range of 25 to 40°C are effective in curing various diseases, such as rheumatism, high blood pressure, diabetes, and various skin diseases (Wiyatasari, 2021). With the high mineral content in hot springs used as hot springs in this study, hot springs can be explored for geotourism activities. Further research can be developed to apply the potential contained in these hot springs.

CONCLUSION

The hot springs used for bathing in the three places studied can be classified according to measured pH values ranging from 5.2-8.1, indicating that hot springs are weak acidic to weak alkaline. The lowest temperature is in Way Belerang, Kalianda, South Lampung (37-39 oC), while the highest temperature in the hot springs in Way Kanan, North Lampung (42-52 oC) can be classified as hyper-thermal compared to other hot springs. The highest DO value was in the T5 sample of 9.1 mg/L, while the lowest was in the T1 sample of 5.5 mg/L. The average TDS value in the three sample locations was 3620 mg/L. The maximum TDS value was in the T2 sample which was 7000 mg/L. The average TSS value in the three sample locations was 16.7 mg/L. The maximum TDS value was in the T6 sample which was 30 mg/L. The lowest TDS value was in the T3 sample, T4, and T5 is 10 mg/L.

The highest concentration of Al, Ba, Cu, K, Ni, Pb metals is found in Natar, South Lampung. The concentration of B, Co, Li, Na is highest in Way Kanan, North Lampung. The highest concentration of Mg, Mn, Ca is in Way Sulfur, Kalianda, South Lampung. Other metal concentrations are generally low and similar at the point of the hot spring sample being studied. Based on the analysis of the physical and chemical properties of hot springs in this study, it can be concluded that hot springs in the Lampung Province area are categorized as safe and suitable for use, even the mineral content contained in hot springs can show high potential to provide benefits for health, especially skin health and as a place for geotourism activities. This study expands knowledge about the physical and chemical characteristics of three hot springs in Lampung Province..

Hot springs are natural resources rich in minerals and have various health benefits, such as improving blood circulation, relieving muscle pain, and providing a relaxing effect. The high

mineral content is produced by the process of dissolving rocks due to high water temperatures. However, these temperatures also increase the risk of dissolving harmful metals, such as arsenic or lead, which can be harmful to health if consumed or used in excess. For this reason, the use of hot springs needs to be done carefully by considering the duration of safe use, as well as regular water quality testing.

BIBLIOGRAPHY

- APHA. (1989). *Standard Methods For The Examination of Waters and Wastewater*. Washington, D.C: Water Pollution Control Federation.
- Dahaan, S.A.M.Al, Al-ansari, N. & Knutsson, S. (2016). Influence of groundwater hypothetical salts on electrical conductivity and total dissolve solids. *Engineering*, 8, 823–830
- Dash, A., Palita, S.K. & Patra, H.K. (2013). Physico-chemical analysis of thermal spring of Atri in the district of Khurda, Odisha, India. *International Journal of Chemical Sciences and Applications* 4(2): 97-104.
- Dewa, Charista., Liliya Dewi Susanawati., Bambang Rahadi Widiatmono. (2015). DayaTampung Sungai Gede Akibat Pencemaran Limbah Cair Industri Tepung SingkongdiKecamatan Ngadiluwih Kabupaten Kediri. from <http://jsal.ub.ac.id>.
- Erfurt-Cooper, P. (2010). Geotourism in Volcanic and Geothermal Environments: Playing with Fire? *Geoheritage* 3: 187-193. DOI: 10.1007/s12371-010-0025-6.
- Guo, Liang, et al. (2020). Temperature governs the distribution of hot spring microbial community in three hydrothermal fields, Eastern Tibetan Plateau Geothermal Belt, Western China. *Science of the Total Environment*: S0048-9697(20)31085-8. doi.org/10.1016/j.scitotenv.2020.137574
- Hamzah, Z., Abd Rani, N.L., Saat, A. & Wood, A.K. (2013). Determination of hot springs physico-chemical water quality potentially use for balneotherapy. *The Malaysian Journal of Analytical Sciences* 17(3): 436-444.
- Harada, E. (2009). Therapeutic effects of hot spring bathing for chronic pain and fatigue. *Japanese Journal of Balneology, Climatology and Physical Medicine*, 72(2), 97–104.
- Ipi, dan Kurniawan, W.B. (2019). Kajian Kelayakan Kualitas Sumber Mata Air Panas Non Vulkanik Desa Nyelanding Berdasarkan Parameter Fisika Dan Kimia. *Prosiding Seminar Nasional Penelitian & Pengabdian Pada Masyarakat* ISBN: 978-602-61545-0-7
- Iyer A, Mody K, Jha B. (2005). Biosorption of heavy metals by a marine bacterium. *Mar Pollut Bull*;50:340–3, doi:<http://dx.doi.org/10.1016/j.marpol-bul.2004.11.012>
- Lund, J. W. (1996). Balneological use of thermal and mineral waters in the USA. *Geotherm*, 25, 103–147

- Matsumoto, S., Yasukouchi, A., & Ishii, N. (2018). Effects of hot spring bathing on health: A literature review. *Journal of Integrative Medicine*, 16(1), 12–16.
- Newsome, D. & Dowling, R.K. (2006). The scope and nature of geotourism. In *Geotourism*, edited by Dowling, R.K. & Newsome, D. Massachusetts: Elsevier ButterworthHeinemann. pp. 3-25.
- Norbert Simon, et al. (2019). Physico-chemical Characterisation and Potential Health Benefit of the Hulu Langat Hot Spring in Selangor, Malaysia (Pencirian Fiziko-kimia dan Potensi Manfaat Kesihatan bagi Mata Air Panas Hulu Langat Selangor, Malaysia). *Sains Malaysiana* 48(11)(2019): 2451–2462 <http://dx.doi.org/10.17576/jsm-2019-4811-15>.
- Peng He, et al. (2023). Geological and hydrochemical controls on water chemistry and stable isotopes of hot springs in the Three Parallel Rivers Region, southeast Tibetan Plateau: The genesis of geothermal waters. *Science of the Total Environment*: 906(2024)167648
- Putri, V.C.P, Irawan, A.B, & Yudono, A.R.A. (2022). Karakteristik Air dan Perkiraan Suhu Reservoir Panas Bumi di Desa Kalibeber, Kecamatan Mojotengah, Kabupaten Wonosobo, Provinsi Jawa Tengah. *Prosiding Seminar Nasional Teknik Lingkungan Kebumihan Ke-IV*
- Ramlia, Amir, R., & Djalla, A. (2018). Uji Kandungan Logam Berat Timbal (Pb) di Perairan Wilayah Pesisir Pare-Pare. *Jurnal Ilmiah Manusia dan Kesehatan*, 256-257.
- Schmitt D, Saravia F, Frimmel FH, Schuessler W. (2003). NOM-facilitated transport of metal ions in aquifers: importance of complex-dissociation kinetics and colloid formation. *Water Res*; 37(15):3541–50.
- Seite, S. (2013). Thermal waters as cosmeceuticals: La Roche Posay thermal spring water example. *Clinical, Cosmetic and Investigational Dermatology* 6: 23-28.
- Seewald, et al. (2019). Geochemistry of hot-springs at the SuSu Knolls hydrothermal field, Eastern Manus Basin: Advanced argillaceous alteration and vent fluid acidity: *Geochimica et Cosmochimica Acta* 255 (2019) 25–48
- Siswoyo, M. M., & Nicola, F. (2015). TDS (Total Dissolved Solid) DAN TSS (Total Suspended Solid) Dengan Kadar Fe 2+. *Seminar Nasional Kimia*, 159–164.
- Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. *Experientia Supplementum*, 101, 133–164.
- Wei Zhi, et al. (2021). From Hydrometeorology to River Water Quality: Can a Deep Learning Model Predict Dissolved Oxygen at the Continental Scale. *Environmental Science & Technology*: [dx.doi.org/10.1021/acs.est.0c06783](https://doi.org/10.1021/acs.est.0c06783).
- Wiyatasari, Reny. (2021). Kebudayaan Onsen dan Eksistensinya di Jepang. *Jurnal Ilmiah Kajian Antropologi*: E-ISSN: 2599-1078.
- World Health Organization (WHO). (2017). *Guidelines for drinking-water quality: Fourth edition incorporating the first addendum*.
- Yuliandini, A. and Putera, A. (2013) Pengaruh Formasi Batuan Terhadap Karakteristik Hidrokimia Lima Sumbermata Air Panas Di Daerah Sapan, Pinang Awan, Kecamatan

Alampauah Duo, Kabupaten Solok Selatan, Jurnal Fisika Unand, 2(4), pp. 212–219. doi: 10.25077/jfu.2.4.

Zeng, H., Uthus, E. O., & Combs Jr, G. F. (2019). Mechanistic aspects of the interaction between selenium and arsenic. *Journal of Inorganic Biochemistry*, 203, 110871.