Preliminary Study on the Environmental Geochemistry of Radon Springs at Xifeng, Guizhou Province

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Abstract

The Xifeng hot spring in Guizhou Province is a famous health resort. The spring water has a temperature ranging from 53° to 56°C with a constant flow of more than 1,000 tons per day. All the spring vents emerge on both sides along a normal fault in the Dengying limestone of Sinian age.

Water analysis shows that the spring water contains a number of mineral components beneficial to human health. The concentrations of Hg and F are relatively high, but render no immediate harm to human body. Radon contents in fresh spring water and steam are 11.14 and 32.73 maches respectively, as determined by a FD-105 Type electrometer calibrated with a radium standard source. The radium content in the spring water is only 3.66×10^{-13} g/l, indicating that radium occurs in the free state rather than as a product of radium decay. On the basis of tritium content data and environmental geochemical investigations, the spring has not been affected by any nuclear test, and its age is at least 30 yr. The formation of the spring can be explained by perculating surface water down to great depth along fault cracks, being heated as a result of normal geothermal gradient and seeking its way out along the cracks in the Sinian dolomite under the pressure of overlying strata.

Introduction

The Xifeng hot spring, a famous health resort on the Guizhou Plateau, has been developed for more than one hundred years till now.

Many years' clinic experience and medical records by the Workers' Sanatorium at the Xifeng hot spring, especially the systematic analysis of 5,234 typical cases, indicate that the spring water has proved to be very effective on the trfeatment of some chronic diseases, such as chronic rheumatic arthritis, seyuelae of trauma and primary hypertension (Table 1).

Table 1. Curative effects of the spring water on some diseases

Disease	Curative effect (%)	Disease	Curative effect (%)
Chronic rheumatic arthritis	93.5	Primary hypertension	89.0
Sequelae of trauma	90.1	Coronary heart disease	89.0
Strain of lumbar muscles	94.4	Chronic gastritis	97.6
Sciatica	91.2	Chronic Pb, Hg, As-and Mn-poisoning	94.6

In 1942,g eologist Yue Senxun made a tour-investigation to the hot spring and published a brief report. In 1946, Mr. Zhu Xuefan determined the spring water, designating it as a carbonic acid spring. After liberation, much work was successively done by the Hydrographic Team and the Laboratory of the Geological Bureau of Guizhou Province, the Quarantine Station of Guizhou Province, and the Department of Geology, Engineering Institute, Guizhou Province. To ascertain the composition of mineral water from the Xifeng hot spring, the authors have gone to the spot for many times to conduct environmental geochemical investigations and water quality analysis.

Environmental Geochemistry and Water Quality

The Xifeng hot spring is located at the foot of the Mt. Tiantai (about 700 m above sea level), more than 40 km northeast of Xifeng County and 116 km from Guiyang city. The annual mean temperature is 15.6°C and the annual mean rainfall is about 1,100 mm. The discharge of spring water is comparatively large with a constant flow-out of naturally heated water being more than 1,000 tons per day. According to repeated determinations, the water temperature has generally kept at 53°—56°C for the past decades, except for flood seasons. The Xifeng hot spring is situated at the north end of the Qianzhong Rise. The region is simple in lithology, with Sinian dolomites and Cambrian sandy shales and limestones predominantly exposed. Of the strata, the greyish siliceous dolomite of the Sinian Dengying Formation is the main water-bearing stratum. Spring vents all emerge on the dolomite fracture zone in the Dengying Formation lying on both sides of the Heitanhe normal fault with a NNW strike. Since this region lies in the junction of the Heitanhe normal fault system and the Shixunshan reversed fault system, the rocks there are quite fragmentary due to frequent tectonic movements, thus providing favourable channels for hot groundwater to expose on the surface. Phosphorus and mercury ores occurring near the hot spring may have some influence on the water quality.

Previous water quality analysis indicates a constant chemical composition for the spring water in the past decades. In this work we have only determined the contents of some major and trace elements in spring water samples. The average values are listed in Table 2.

Table 2. Contents of some elemenst in the spring water

Sample locality	Major element (mg/l)				Trace element (μg/l)			
	K	Na	Ca	Mg	Cd	Pb	Cu	Cr
Spring for daily life	4.61	15.43	61.46	23.22	0.04	<0.8	0.4	<0.7
Swimming pool	3.94	13.65	57.53	23.22	0.04	<0.8	0.4	<0.7
Pump room	4.57	14.99	61.46	23.52	0.04	<0.8	0.4	<0.7
Water from the Heitanhe River	—	—	—	—	0.2	<0.8	0.6	<0.7
Water from the Qingshuihe River	—	—	—	—	0.2	<0.8	0.6	<0.7

Note: Trace elements determined by atomic absorption spectroscopy.
Analyst: Piao Hechun.

Radon Content in the Spring Water

Radon (Rn) is a radioactive gas element, one of the intermediate products of uranium decay and the daughter of radium (^{226}Ra). Radon generally finds its way into the blood of human body through its sweat pores of skin, respiratory track and alimentary canal, and then is carried to the whole body through the blood system. According to the available data, it is revealed that when one takes a bath in Rn-bearing mineral water, one will find a thin radioactive membrane of radon spread on one's overall skin, lasting 3—4 hr after bath with continuous emission of α-rays. So it has certain curative effects on human organisms, such as sedation, analgesia, the elimination of inflammation and hyposensitization as well as the adjustment of cardiovascular function and the promotion of hematopoiesis.

α particles resulting from the decay of radon exert strong ionization on air molecules. As the intensity of ionization current is proportional to the concentration of radon, radon content can be detected by determining the intensity of ionization current with highly sensitive instruments. We have made many on-the-spot determinations using a FD-105 Type electrometer (accurately calibrated by the radium standard source), and then calculated the radon content with the following formula (see Table 3):

$$\mathrm{Rn} = \frac{K \cdot J_0}{V} \times 10^{10}(\mathrm{eman}),$$

where V is the volume of sample (in litre), K the correction constant for the instrument (curie/erg/min), and J_0 the intensity of ionization current for the whole radon in the sample (erg/min).

Because radon is an inert gas, its solubility in water is extremely low and the combination ability of its molecules with water molecules is very weak. Therefore, stirring in various ways will facilitate the quick release of radon molecules from mineral water . After mineral water keeps stagnant on the surface for a period of time, or it is diluted with surface water, radon content in the water will decrease significantly. It can be seen from practical measurements that the radon content of fresh spring water on the surface and that of escaped gases are higher than that of mineral water exposed on the surface. For example, the radon content of mineral water from the hydrotherapy pool is 2.59 mache/l due to artificial stirring.

The norms of radon content in hot spring waters for medical treatment formulated in China are: 3 mache/l for therapeatic treatment; if one spring has a radon content as high as 10 mache/l, it will be named a radon spring. According to the norms, the Xifeng hot spr-

Table 3. Radon content in the Xifeng Hot Spring (mache/l*)

Sample locality		Radon content	
		Determined in Dec., 1980	Determined in April, 1981
Fresh spring water just welling onto the surface**		11.14	11.29
Mixed water after being stored	Superficial water not used in the swimming pool	4.34	
	Spring water for daily life stored in the stone caves	4.96	5.83
	Spring water for pumping	4.94	6.19
	Spring water in the hydrotherapy room	2.59	
Cold spring water from the Baishi spring		0.16	
Steam escaping from hot spring water***		32.73	

* 1 eman = 10^{-10} curie/l; 1 mache = 3.64 eman.

** Spring water just welling onto the surface without mixing with previously existing water collected directly with a sampling tube specially designed.

*** Steam escaping from the spring water directly collected with a self-designed sample collector.

Analysts: Wang Junwen and Cheng Zhongli.

ing can be designated to a radon spring of medical interest.

In addition. we have determined the radium (the direct parent of radon) content of spring water samples and found that it is 3.664×10^{-13} mg/l in fresh mineral water, being within the normai range. Determination results show that radon in the spring water seems unlikely to have come from radium decay in the water, but from radon gas originally accumulated in the fractures of rocks at depth, which was dissolved in groundwater under high pressures and then carried to the surface. Hence no radioactive radium harmful to human body exists in the spring water at all.

F and Hg Contents in the Spring Water

Both F and Hg are major trace elements in the nature, which are closely related to human health. Therefore, it is of great significance in further exploiting and utilizing the Xifeng hot spring to find out the definite contents of F and Hg in the spring water. The contents of F and Hg determined with fluoelectrode method and cold atomic absorption technique are listed in Table 4.

Table 4. The contents of F and Hg in the spring water

Sample locality	F* (mg/l)	Hg** (μg/l)
Spring for daily life	1.34	1.2
Swimming pool	1.28	1.4
Pump room	1.28	1.8
Water from the Heitanhe River	0.118	0.2
Water from the Qingshuihe River	0.27	0.2
Running water	—	0.2
Boiled spring water	—	0.3

* Analysts: Chen Qingmu and Liu Yulan.

** Analyst: Chen Yecai.

F is one of the essential elements for human life, and its content in drinking water will directly affect the health of human body. According to the available data, it is known that if one drinks the water for a long time, in which F content is less than 0.5 mg/l, one would suffer from dental caries; when F content in the drinking water is greater than 1.5 mg/l, F-etched teeth will come out due to large accumulation of F in human body, even occurs chronic F poisoning in serious cases (e.g. skeletal malformation).

It can be seen from Table 4 that F content in river water is very low, indicating no F pollution in this area. The higher F concentration in the spring water is mainly attributed to the fact that the spring water derived from greater depths has dissolved part of F when passing through some F-bearing strata (e.g., phosphate-ore bed in the Sinian Doushantuo Formation) along the fractures of rocks upwards to the surface. F is an element widely distributed in the nature and present in various water bodies. Because F-bearing minerals can be more easily dissolved in hot water than in cold water and, therefore, the F concentration in hot spring water is generally higher.

In China, the hygienic norms for daily drinking water stipulate that the optimum concentration of F in drinking water is 0.5—1.0 mg/l. Systematic studies on F by some researthersdemonstrate that the F concentration in drinking water cannot be regarded as the only basis for hygienic norms. Many other factors should be taken into consideration, such as the intake of F from food and the local climatic temperature before we can make an accurate assessment of its influence on the health of local inhabitants. With reference to some related literature on hot spring waters both at home and abroad (Table 5), we have found that their F contents all exceed the F concentration in Xifeng hot spring water. Although the F content of water from the famous Vichy hot spring in France is 5.50 mg/l, the bottled apollinasis spring water sells well on foreign markets. We have also made investigations on the local inhabitants in the neighbourhood of the Xifeng hot spring and found no one suffering from F-caries due to drinking this spring water. It is evident that Xifeng hot spring water is not harmful to human body though its F concentration seems higher.

Table 5. F content in some hot spring waters

Spring type	Sulphur spring, Tengchong, Yunnan	Hot spring, Huailai, Hebei	Yangbajan, Xizang	Xiaotangshan, Beijing	Hot water well, Beijing Railway Station	Hot spring, Zunhua, Hebei	Mineral spring, Vichy, France
F (mg/l)	18.22	8.30—14.9	13.00	7.0	5.42	10.0	5.50

Hg is a highly toxic element harmful to human body. Organic mercury is particularly harmful to human health. Hg may enters human body through its respiratory tract, alimentary canal and skin, and is continuously accumulated and concentrated in the internal organs, frequently resulting in the diseases affecting the central nervous system because it is not easily drained.

Analyses demonstrate that the Hg content in the spring water is slightly higher than that formulated in accordance with the hygienic norms. Hg in the water comes mainly from Hg-bearing ore beds of Cambrian age. Historical data show that Hg was mined at Shixunshan near the hot spring in the past, as indicated by a number of waste pits and slags which are still seen on the site. Hot groundwater, when flowing through the Hg-bearing ore beds, would dissolve part of Hg and carry it to the surface.

According to the hygienic norms for drinking water as mentioned above, the Hg concentration of any drinking water is not allowed to exceed 1 μg/l, and so it is improper to take a cold drink from the spring water. However, it has been found that the Hg concentration of the spring water after being boiled decreases to 0.3 μg/l, because Hg in the water may be adsorbed on boiler scale as precipitant in the process of boiling,, and part of Hg may also evaporate under high temperatures. So drinking the boiled mineral water will exert no harm on human health.

Preliminary Exploration on the Genesis of Xifeng Hot Spring

Hot spring is a natural exposure of geothermal water on the surface; generally two mechanisms of genesis can be distinguished: one is that when infiltrating surface water comes in contact with the not yet cooled rock bodies, it will take its way by convection towards the surface along the fractures of the rock bodies in the form of geothermal water or steam, forming hot springs or steam springs; the other is that when surface water permeates deeply along the fault system in a region far away from magmatic heat source, it will be warmed up under normal geothermal gradient conditions and form, as the carrier of geothermal energy, hot springs on the surface.

According to the geological data from this region it should be assigned to a region far away from magmatic heat source. The formation of the Xifeng hot spring is: when surface water permeates downwards to great depths along the fault system, it will be heated by geothermal heat and well onto the surface under ground pressures along fractures of the dolomite. It is evident that the Xifeng hot spring is a pressure-loaded fracture-type hot spring.

The Tritium Laboratory of the Institute of Geochemistry, Academia Sinica has determined the tritium content of the spring water with electrolytic concentration technique, coupled with a liquid scintillating counter. The results are given in Table 6.

Table 6. Tritium content in the spring water

Sample locality	Spring for drinking	Swimming pool	Pump room	Baishi spring	Qingshuihe River
Tritium (*TU*)*	<2	6.6	3.8	36.8	47.9

* *TU* is the unit of tritium content; $1TU = T/H \times 10^{-18}$.
Analysts: Wei Keqin, Lin Reifeng and Wang Zhixiang.

Results of the determination indicate that the tritium content of spring water for daily life is very low, and this is because the spring water has not been contaminated by artifical tritium released by thermal nuclear tests since 1953. All this demonstrates that it will take more than thirty years for Xifeng hot spring water to complete one-round circulation from water supply to artesian effusion on the surface. The tritium content in the river water is 47.9 *TU*, corresponding to that in local precipitation. The tritium content in the Baishi spring (a cold water spring) adjacent to the Xifeng hot spring is lower than that in the river water, indicating that the latter has been heavily polluted by artificial tritium and that its circulating period is only a few years. Although spring waters in the swimming pool and the pump room have the same source of groundwater as the spring water for daily life, the tritium content of the former is slightly higher than that of the latter due to mixing with a small amount of river water or shallow-layer water.

Conclusions

1. Repeated on-the-spot determination of water quality shows that the Rn content of Xifeng hot spring water is 11.14 mache/l and that of hot steam is 32.73 mache/l. Thus, it can be concluded that the Xifeng hot spring is a Rn spring with higher curative effects.

2. Major and trace elements in the spring water are within the normal range. Although the F and Hg contents seem to be higher, the concentration of F is still in the normal range, so far as its water quality is concerned, and the concentration of Hg, after being boiled, decreases significantly. Therefore, both F and Hg in the spring water would exert no harm on human body.

3. The Xifeng hot spring is of pressure-loaded fracture-type. The circulating period of the spring water from water supply to exposure on the surface is over thirty years.

4. All the spring vents in this region have the same groundwater source. Before welling onto the surface the spring water has not generally been mixed with surface cold water.

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