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Presence of metals in a ferruginous hot spring in the Cundinamarca region, Colombia

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Abstract

The presence of metals in hot springs has been associated with various adverse health effects. Although some elements are essential for humans, they are dangerous at high levels of exposure.

There have been little studies on the presence of metals in hot springs in Colombia, therefore, laboratory tests were carried out over a period of six months (June to December, 2021), with spot samples every month in a ferruginous hot spring in the Cundinamarca region, Colombia.

Tests were carried out for arsenic (As), chromium (Cr), mercury (Hg), lead (Pb), aluminum (Al), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), nickel (Ni), zinc (Zn), strontium (Sr), and calcium (Ca) in the Laboratory of the Bogota Aqueduct and Sewer Company (in Spanish EAAB). Since there are no regulations in Colombia there is no regulation on the quality of hot springs, the analysis of results was carried out by comparing them with standards for drinking water and swimming pools from countries such as Canada, Germany, and the World Health Organization (WHO) as well as hot springs in Japan. It was observed that iron was the only metal that exceeded the regulations for drinking water and swimming pools.

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Keywords: Colombia; ferruginous; hot spring; metals; standards; regulations

Resumen

La exposición a algunos metales presentes en las aguas termales se ha asociado con varios efectos adversos para la salud. Aunque algunos elementos son esenciales para los humanos, también pueden ser peligrosos a altos niveles de exposición.

Existen pocos estudios sobre la presencia de metales en las aguas termales en Colombia, por lo que se realizaron pruebas de laboratorio durante un período de seis meses (junio a diciembre de 2021), con muestreos puntuales todos los meses en una termal ferruginosa en la región de Cundinamarca, Colombia. Se realizaron pruebas de arsénico (As), cromo (Cr), mercurio (Hg), plomo (Pb), aluminio (Al), cobre (Cu), hierro (Fe), magnesio (Mg), manganeso (Mn), níquel (Ni), zinc (Zn), estroncio (Sr) y calcio (Ca) en el Laboratorio de la Empresa de Acueducto y Alcantarillado de Bogotá (EAAB - ESP). Considerando que en Colombia no existe una regulación sobre la calidad de las aguas termales, el análisis de resultados se realizó comparándolos con estándares de calidad de agua potable y piscinas de países como Canadá, Alemania y la Organización Mundial de la Salud (OMS) y estándares para aguas termales en Japón. Se observó que el hierro fue el único metal que superó las normas para agua potable y piscinas.

Palabras clave: *Colombia; ferruginosas; aguas termales; metales; normas; reglamentos*

1. Introduction

Exposure to some heavy metals has been associated with various adverse health effects, including cancer (US EPA, 1989). Although some elements are essential for humans. They can be dangerous at high levels of exposure. Considering the importance of their toxicological potential, arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), and lead (Pb) are especially considered in this study (García et al., 2012).

Existing studies in the Cundinamarca hot springs have focused on measurements of microbiological parameters of some hot springs, considering molds and yeasts, *Pseudomonas aeruginosa*, mesophilic aerobics, and fecal coliforms, but not metals (INGEOMINAS, 2003).

Therefore, the present study seeks to determine if there is a risk for bathers with the presence of metals in ferruginous hot spring, for which a six-month monitoring of aluminum, arsenic, boron, copper, chromium, iron, magnesium, manganese, mercury, nickel, lead, selenium, Zinc, strontium, and calcium, results that were analyzed with the existing regulations for drinking water, swimming pools, and hot springs.

2. Methodology

The ferruginous hot spring was chosen for the study located in the department of Cundinamarca and with discharge to tributaries that feed the Bogota River. A total of 6 samplings were carried out in the public ferruginous hot spring with a sampling frequency of one sample per month for a period of six months, at the source of the hot spring pool. The sampling schedule was carried out during July to December, 2021. In each of the monitoring, the water sample was taken, based on the protocols established by the EAAB - ESP (in Spanish Empresa de Acueducto y Alcantarillado de Bogotá) (Sanchez, Y., 2023).

Tests are performed using standard methods (SM 3030 E and 3120 B) for aluminum, arsenic, boron, copper, chromium, iron, magnesium, manganese, mercury, nickel, lead, selenium, zinc, strontium, and calcium.

3. Metals in a Ferruginous Hot Spring in the Cundinamarca Region, Colombia

In Colombia, the regulations do not have specific parameters for water quality in hot spring. Article 6 in Decree 554 of 2015, of the Ministry of Health and Social Protection, establishes "*The general physical – chemical, and microbiological parameters of the water will not be required of the ponds that store hot springs and therapeutic uses. The Ministry of Health and Social Protection will define these parameters*" (Colombia, 2015).

However, in the case of hot springs where the bather is exposed to similar conditions to that of swimming pools, the results of the metal parameters measured in the ferruginous hot spring, were compared with regulations for drinking water, swimming pools, and hot springs, as described shows in Table 1 (Sanchez, Y., et al., 2022).

Table 1. Regulation of parameters of metals in hot spring

PARAMETER	UNIT	DRINKING WATER						SWIMMING POOL					HOT SPRING
		CANADA			GERMANY	COLOMBIA	WHO	CANADA		GERMANY	CHILE	COLOMBIA	JAPAN
		ONTARIO Reg. 169/03 (a)	GUIDELINE FOR ONTARIO (b)	GUIDELINES FOR CANADIAN (c)	BGBl. I 2016, 476 (d)	Resolution 2115/07 (e)	A global overview of national regulations (f)	Alberta Reg. 204/2014 and Government (g)	Ontario Reg. 565/1990 (h)	DIN 19643 (i)	Decree 209 of 2002 (j)	Resolution 1618/10 (k)	Hot spring Law, 2014 (l)
Aluminum	mg Al/L	-	0.1	< 0.1	0.2	0.2	0,1 - 0,2	-	-	-	-	< 0,2	
Arsenic	mg As/L	0.01	0.025	0.01	0,01	0.01	0.01	-	-	-	-	-	
Boron	mg B/L	5.0	5.0	5.0	1.0	-	2.4	-	-	-	-	-	
Copper	mg Cu/L	-	1.0	2.0	2.0	1	2.0	-	-	-	max 1.5	< 1,0	
Chromium	mg Cr/L	-	-	-	0.05	0.05		-	-	-	-	-	
Iron	mg Fe/L	-	0.3	<= 0,3	0.2	0.3	None set	-	-	-	-	<0,3	>= 10
Magnesium	mg Mg/L	-	-	-	-	36	None specified	-	-	-	-	-	
Manganese	mg Mn/L	-	0.05	0.12	0.05	0.1	0.4	-	-	-	-	-	>= 10
Mercury	mg Hg/L	0.001	0.001	0.001	0.001	0.001	0.006	-	-	-	-	-	
Nickel	mg Ni/L	-	-	-	0.02	0.02	0.07	-	-	-	-	-	
Lead	mg Pb/L	0.01	0.01	0.005	-	0.01	0.01	-	-	-	-	-	
Selenium	mg Se/L	0.05	0.01	0.05	0.01	0.01		-	-	-	-	-	
Zinc	mg Cr/L	-	5	<=5	-	3	None set	-	-	-	-	-	
Strontium	mg Sr/L	-	-	7.0	-	-		-	-	-	-	-	> = 10
Calcium	mg Ca/L	-	-	-	-	60	None specified	-	-	-	-	-	-

[a] (Ontario, 2003). [b] (Ontario, 2003).[c] (Health Canada, 2020). [d] (Germany, 2016). [e] (Colombia, 2015).). [f] (WHO, 2021). [g] (Alberta, 2014). [h] (Ontario, 1990). [i] (Germany, 1997). [j] (Chilean Ministry of Health, 2012). [K] (Colombia, 2007) and (Sanchez, 2011). [l] (Japan, 2014).

In Table 1, it can be seen that in countries such as Canada and Germany, metal parameters are not regulated in swimming pool, except in their drinking water. Considering that Colombia does not have hot spring water quality regulations, a comparison of the results was made with the regulations in Table 1.

Table 2 presents the results for the analysis of aluminum (Al), arsenic (As), boron (B), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn), strontium (Sr), and calcium (Ca).

Table 2. Results of parameters of metals in ferruginous hot spring

PARAMETER		UNIT	JUNE - JULY	JULY - AUGUST	AUGUST - SEPTEMBER	SEPTEMBER - OCTOBER	OCTOBER - NOVEMBER	NOVEMBER - DECEMBER
			30/06/2021 ENTRY	28/07/2021 ENTRY	2/09/2021 ENTRY	3/10/2021 ENTRY	17/11/2021 ENTRY	15/12/2021 ENTRY
Ferruginous Hot Spring	Aluminum	mg Al/L	0.01	N.Q	0.02	0.05	0.05	0.02
	Arsenic	mg As/L	N.Q	N.Q	N.Q	N.Q	N.Q	N.Q
	Boron	mg B/L	N.Q	N.Q	N.Q	N.Q	N.Q	0.03
	Copper	mg Cu/L	N.Q	N.D	N.D	N.D	N.Q	N.Q
	Chromium	mg Cr/L	N.D	N.D	N.D	N.D	N.D	N.D
	Iron	mg Fe/L	6.63	7.95	7.14	8.76	14.28	9.26
	Magnesium	mg Mg/L	N.D	N.D	N.D	N.D	N.D	3.29
	Manganese	mg Mn/L	0.22	0.22	0.25	0.24	0.25	0.29
	Mercury	mg Hg/L	N.Q	N.Q	N.Q	N.Q	N.D	N.D
	Nickel	mg Ni/L	N.Q	N.Q	N.Q	N.Q	N.Q	N.D
	Lead	mg Pb/L	N.Q	N.Q	N.Q	N.Q	N.Q	N.Q
	Selenium	mg Se/L	N.Q	N.Q	N.Q	N.Q	N.Q	N.D
	Zinc	mg Zn/L	0.03	N.Q	0.02	N.Q	0.01	0.01
	Strontium	mg Sr/L	N.Q	N.Q	N.Q	N.Q	0.04	N.Q
	Calcium	mg Ca/L	2.61	2.63	2.98	2.68	2.61	3.23

N.Q = Not quantifiable, N.D = No data.

Aluminum
The different standards compared in Table 1, in drinking water and swimming pools there is a maximum Al value of 0.1 and 0.2 mg Al/L, where it was observed that the data from the ferruginous hot spring complied with the regulations.

Arsenic
The regulations are shown in Table 1, the maximum value is 0.01 mg As/L for drinking water. In swimming pool is not regulated. The results obtained from the ferruginous hot springs was not quantifiable, which complied with the regulations of drinking water.

Boron
The regulations are shown in Table 1, the values have a maximum value of 1.0 and 5.0 mg B/L for

drinking water. In swimming pool water was not regulated. The results obtained from the ferruginous hot springs was not quantifiable, only one-point data was 0.03 mg B/L, which complied with the regulations of drinking water.

Copper
The regulations are shown in Table 1, the maximum values oscillate between 1.0 and 2.0 mg Cu/L for swimming pool water and drinking water. The results obtained from the ferruginous hot springs was not quantifiable, which complied with the provisions of the limit of the standards.

Chromium
The regulations are shown in Table 1, the limit value for drinking water is 0.05 mg Cr/L and in swimming pool water are not regulated. Only one data point was not quantifiable.

Iron
The regulations are shown in Table 1, the values oscillated between 0.2 and $\leq$ 0.3 mg Fe/L for drinking water. In swimming pool water was not regulated. Only Japan has a specific value in regulation for hot springs, it is $\geq$10 mg Fe/L, where it was observed that the data of ferruginous hot spring, did not fulfill the regulation of drinking water and only one data point was outside the limit values of the regulations of Japan for hot springs.

Magnesium
The standards are shown in Table 1, only the Colombian standard has a limit value of 36 mg Mg^{2+}/L for drinking water. Only one data point of the hot spring was measured and this point fulfilled the regulation.

Manganese
The regulations are shown in Table 1, the maximum values oscillate between 0.05, 0.12, and 0.4 mg Mn/L for drinking water, in swimming pool water was not regulated. Only Japan has a specific value in regulation for hot springs, it is $\geq$10 mg Mn/L, where it was observed that the data from the hot spring fulfilled the regulation.

Mercury
The regulations are shown in Table 1, the maximum values oscillated between 0.001 and 0.006 mg Hg/L for drinking water. In swimming pool water was not regulated. The results obtained from the ferruginous hot spring was not quantifiable, which complied with the provisions of the limit of the standards.

Nickel
The regulations are shown in Table 1, the maximum values oscillated between 0.02 and 0.07 mg Ni/L for drinking water. In swimming pool water was not regulated. The results obtained from the ferruginous hot spring was not quantifiable, which complied with the limit standards.

Lead
The regulations are shown in Table 1, the maximum values oscillated between 0.005 and 0.01 mg

Pb/L for drinking water. In swimming pool water was not regulated. The results obtained from the ferruginous hot springs was not quantifiable, which complied with the provisions of the limit standards.

Selenium
The regulations are shown in Table 1, the maximum values oscillated between 0.01 and 0.05 mg Se/L for drinking water. In swimming pool water was not regulated. The results obtained from the ferruginous hot spring was not quantifiable, which complied with the limit standards.

Zinc
The regulations are shown in Table 1, the maximum values oscillated between $\leq$ 5 mg Zn/L and 3.0 mg Zn/L for drinking water. In swimming pool water was not regulated, where it was observed that the data from the ferruginous hot springs fulfilled the regulation.

Strontium
The regulations are shown in Table 1, the maximum values established by the Canadian Guidelines for drinking water is 7 mg Sr/L. In swimming pool water are not regulated. Only Japan has a specific value in regulation for hot springs is $\geq$10 mg Sr/L, where it was observed that the data from the ferruginous hot spring fulfilled the regulation.

Calcium
The regulations are shown in Table 1, Colombian drinking water regulation established that there is a limit value of 60 mg Ca^{2+}/L. In swimming pool water was not regulated, where it was observed that the data from the ferruginous hot spring fulfilled the limit values of the Colombian drinking water regulations.

Analysis of samples from ferruginous hot springs indicates that they generally meet drinking water standards. The one exception is high iron levels, as studies conducted at geothermal springs in Soutpansberg, Limpopo Province, South Africa, found trace metal concentrations from geothermal springs and wells to be within allowable drinking water guidelines by the South African National Standards (SANS) and the World Health Organization (WHO), with the exception of mercury (Hg), which is high in the summer season. (Durowoju et al., 2020).

4. Conclusions

The results of the samples analyzed from ferruginous hot springs comply with the drinking and swimming pool water standards for most of the metals evaluated. Only high values of iron were presented, which becomes more of an aesthetic problem of the water, typical of its characteristic ferruginous hot spring.

The same results were obtained as those performed at the geothermal springs in Soutpansberg, Limpopo Province, South Africa, where trace metal concentrations were within the allowable drinking water guidelines set by the South African National Standards (SANS) and the World Health Organization (WHO).

Most of the results of the sampling of heavy metals were not quantifiable.

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