ISSN 001-6002/52/2/96-101
Acta Médica Costarricense, ©2010
Colegio de Médicos y Cirujanos

Original

Arsenic Determination in Water Supplies for Human Consumption of the Province of Cartago, Costa Rica

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Abstract

Aim: To disclose scientific knowledge about hydroarsenicism in Latin America, as well as to determine the presence of arsenic in water used for human consumption in risk areas of Costa Rica, specifically at the Central, Oreamuno, Paraíso and Alvarado counties of the province of Cartago.

Methods: Quantification of inorganic arsenic by hydride generation and flame atomic absorption, according to method 7062 of the US Agency of Environmental Protection.

Results: None of the analyzed samples surpassed the maximum limit of 10 µg/L allowed by the present Costa Rican legislation.

Conclusion: Even though sampled areas are of volcanic nature and therefore of arsenic risk, the population consumes water of direct underground origin with a great superficial influence and little or no contact to deeper volcanic rock, thus not contaminated with arsenic.

Keywords: arsenic, drinking water, chronic hidroarsenicism.

Received: *July 28th, 2009* **Accepted:** *December 1st, 2009*

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Abbreviations: US EPA, United States Environmental Protection Agency
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SupportSources: financingby Vicerrectoría de Investigación y Extensión del Instituto Tecnológico de Costa Rica.

Issues related with chemical substances in drinking water are mainly because these chemical substances may affect health negatively, after long periods of exposure.[1]
The pollutants with cumulative toxic properties as carcinogenic substances and heavy metals (e.g. arsenic) are of particular concern to the World Health Organization (WHO).[2]
Arsenic doesn't decompose in the environment. It forms naturally and is located on the ground, particularly in the volcanic rocks, forming 0,00005% of the Earth's crust.[3]

Due to natural geological reasons, in certain areas of the world the waters of volcanic origin, which may be consumed by some populations, contain high concentrations of inorganic arsenic. It has been reported in Argentina, Bolivia, Peru, Chile, Mexico, Nicaragua, El Salvador, Canada[4, 5] and US in large quantity[6] as well as, in Pakistan, China, Taiwan, Bangladesh and India, among others.[5]

In some Latin America countries important cases have also been reported; nonetheless, they are related to mining and accidental pollution, as in Chile, Dominican Republic and Cuba.[7]

Another common problem is pollution with the heavy metals that are employed in treatment techniques of materials. In the process of preserving wood, for example, commercial preservative solutions are applied. One solution is the CCA-C mix with high concentrations of copper, chromium and arsenic salts,[8] along with highly toxic elements for all trophic chains. Apart from the direct effect on the ground, this kind of pollution could be extended to the layers of surface water, underground water, or reservoirs of water for human consumption by leaching if is not properly contained.

Arsenic is one of the chemical elements presented in the water for human consumption that has been less studied in the country[9] and that is important for health of the population in the long term. The province of Cartago is considered a high-risk zone by the considerable volcanic influence.

The natural presence of arsenic in Latin America surface water and groundwater is associated with tertiary and quaternary volcanism, hot springs and geothermal phenomena linked to the circumpacific volcanism of the so-called "Pacific Ring of Fire", as shown in Figure 1. This volcanic activity has also exerted influence on some features of these waters: high pH, variable alkalinity, low hardness, moderate salinity and presence of boron, fluorine, silica, and vanadium.[7]

Even though it is a very widespread problem in Latin America, with large number of cases in Nicaragua, in the area of Matagalpa[10, 11] which has similar geological characteristics to the ones in Costa Rica, the country has not reported cases of diseases directly correlated with arsenicism (arsenic disease). It is unknown if it happens either because the injuries are not recognized (since they might be confused with other diseases) or because there are no arsenic contaminated aquifers or wells associated with mass consumption of water.

Figure 1.Pacific Ring of Fire.Areas of significant volcanic activity in Latin America.

The presence of arsenic-contaminated water acquires greater significance in regions with important agricultural and livestock activity since water is used not only to supply towns but also to serve as an irrigation mean and a livestock drink. It takes special importance the fact that specific arsenic-contaminated wells have been described without finding adjacent contaminated wells.[7]

In Latin America it has been seen that with similar arsenic levels but under different conditions (weather, nutrition and others), the clinical involvement level in people is different and generally it is considered "a disease of poverty".[7]

The International Agency for Research on Cancer (IARC) has classified arsenic in group I because there is enough evidence available of its carcinogenicity on human beings.[12]

According to toxicological and epidemiological studies, children are more affected than adults with the same intake of arsenic by means of the exposure routes of ingestion and inhalation, mainly through the drinking water, which causes the hidroarsenicism.[13, 14]

Arsenic in water is found in the form of arsenate, and it can be absorbed easily in the gastrointestinal tract, in a proportion between 40% and 100%.[13] The ingested inorganic arsenic passes into the bloodstream, where it binds to hemoglobin and in 24 hours it can be found in the liver, kidneys, bladder, lungs, spleen and skin.[15, 16] Larger storage organs are skin, bone and muscle. Its accumulation in the skin is related to its reaction on proteins which have sulfhydryl groups.[12]

The development of arsenicism regarding to the time of intake, according to the WHO, is as follows:

- Pre-clinical State: the patient shows no symptoms, but the arsenic can be detected in urine and tissue samples.
- Clinical: it shows darkening of the skin (melanosis) commonly observed in the palm of the hand, dark spots on the chest, back, limbs, and gums. A more serious symptom is keratosis or hardening of the skin in the form of nodules in the plants of the feet and hands (Figure 2).
- Complications: more pronounced clinical symptoms, internal organs affectation, inflammation of the liver, kidneys, and spleen have been reported; in this stage it is also linked to conjunctivitis, bronchitis, and diabetes.
- Malignancy: development of tumors, lung or bladder, liver and kidneys.

If the patient replaces the source of drinking water by arsenic-free during the first two stages, recovery is almost complete. In the third stage the damage may be reversible, but in the fourth it is no longer possible.[2]

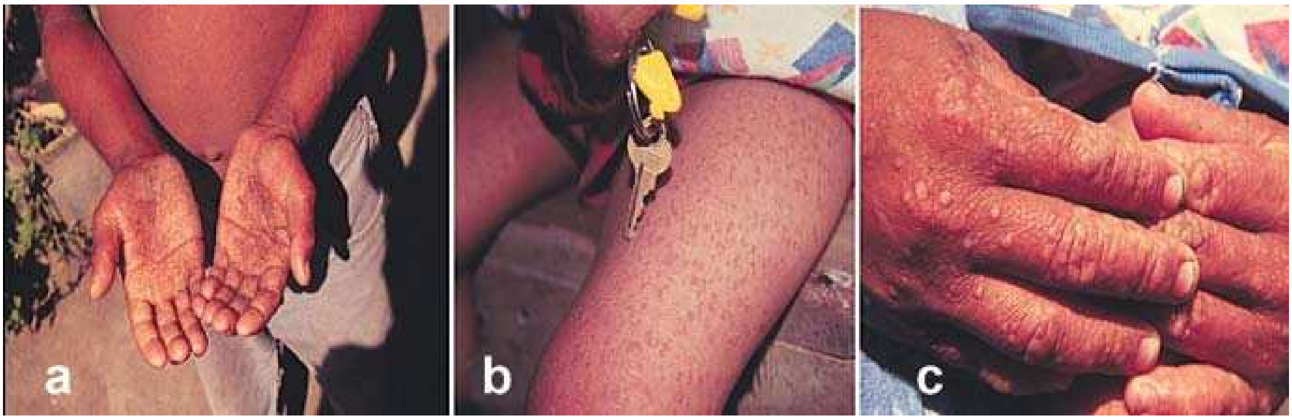

Figure 2. Dra. Alina Gómez Cuevas' patientsfrom El Zapote in Valle de Sebáceo, Department of Matagalpa, Nicaragua. These patients ingested 1320 µg/L of arsenic from water consumption of a crafted well for two years. A- Palmar hyperkeratosis punctata in a 14-year-old boy. B- "Raindrop" hipermelanosis in a one-year- and- a-half child. C- Verrucous papules in the dorsum of the hand on a female patient of approximately 25 years

Materials and methods

The development of this project involved four stages:

1. Geographical delimitation of the study area: it was worked by counties for the appropriate identification and sampling of the water sources used by town councils in the supply of their communities.

   The project included the counties of Alvarado, Central, Oreamuno and Paraiso from the province of Cartago, as shown in the map of Figure 3.

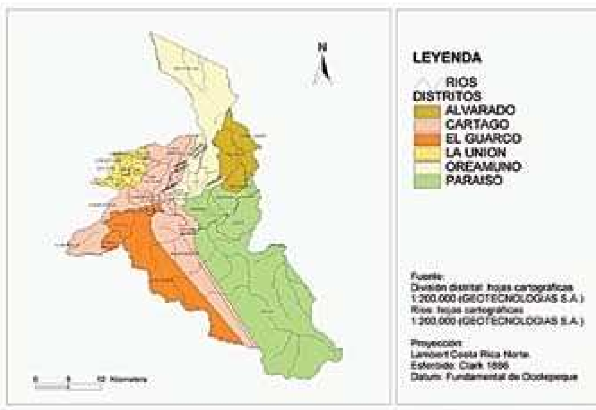

Figure 3. Geographic location of study areas

2. Touring schedule: the collection of samples was coordinated with owners of town councils' aqueducts, corresponding to winter and summer seasons to determine possible differences in levels of arsenic.

3. Determination of the correct methodology for the quantification of the metal in water, at concentrations required at traces range (µg/L): a reproducible, high sensitivity, well-known and reliable methodology was used i.e., the determination of arsenic in its trivalent form through generation of volatile metal hydride by flame atomic absorption; double beam Perkin Elmer equipment model 3300 AA with photomultiplier detector and hydrides generator analytical system with four step continuous flow injection (FIAS) and 193,7 nm wavelength. The USEPA 7062 methodology was employed.

   In the method's validation a cuantification limit of 5 µg/L and a experimental detection limit of 1,4 µg/L was obtained, according with established methodology by Miller and Miller.[17]

4. Analyte measurement: samples were collected at the water springs sites, preserved with nitric acid and then quantified.

Results

The names that appear in Table 1 are the water springs used officially for the consumption of the counties' studied population. The samples correspond to dry and rainy seasons (marked as summer and winter) to determine possible differences in the quantification levels of the studied arsenic.

After processing and analyzing the 118 of the spring water samples indicated in Table 1, it was determined that none of them contained measurable amounts of arsenic (III) by not exceeding the used method's 5 µg/L limit of quantification, but there were indeed samples that did exceed the detection limit.

Discussion

The results presented reinforce what was previously supposed and are consistent with what is expressed in literature; populations consuming water contaminated with arsenic in Latin America do it from wells, which contrast with what is found in the province of Cartago, where city councils -in their great majority- use water from springs.

Health effects caused by repeated exposure and by long-term natural contaminants, related to specific hydrogeological conditions, are little known and studied in this medium. Regarding the specific case of arsenic in Costa Rica, there are

Table 1. Springs sampled in the study, used by the municipalities of Oreamuno, Cartago's Central Canton, Paraíso and Alvarado, for consumption by the population, shown name and location.

Sample	Spring	Place	Canton	Sample	Spring	Place	Canton
1	Paso Ancho	Paso Ancho	Central	31	Boquerón	Finca Milton Garro	Paraíso
2	Lankaster	Paso Ancho	Central	32	Albertano	Peñas Blancas	Paraíso
3	San Blas	San Blas	Central	33	Volio	Volio	Paraíso
4	La Misión	Tierra Blanca	Central	34	Chilamate	Cachí	Paraíso
5	Rafael Calvo	Banderillas	Central	35	Peñas Blancas	Peñas Blancas	Paraíso
6	Banderillas	Banderillas	Central	36	Jorge Obando	Peñas Blancas	Paraíso
7	Río Loro	Ochomogo	Central	37	Urazca	Rancho Urazca	Paraíso
9	La Ortiga	Corralillo	Central	39	Guzmán	El Calvario	Paraíso
10	Padre Méndez	San Rafael	Central	40	José Castro	Barrio Los Ángeles	Alvarado
11	Ladrillera	Lourdes	Central	41	Julio Gámez	Barrio Los Ángeles	Alvarado
12	Río Claro	Río Claro	Central	42	Marcos Pele	Barrio Los Ángeles	Alvarado
13	Toño Meneses	Mata e Mora	Oreamuno	43	Aníbal Barquero	Llano Grande Pt Alta	Alvarado
14	Mario Ivancovich	Mata e Mora	Oreamuno	44	Coto	Llano Grande Pt baja	Alvarado
15	Villalta (Aguacate)	Mata e Mora	Oreamuno	45	Minor	San Martín	Alvarado
16	Mario Ivancovich (Aguacate)	Mata e Mora	Oreamuno	46	More	San Martín	Alvarado
17	Mario Ivancovich (Poza)	Mata e Mora	Oreamuno	47	Martín Montero	Buenos Aires	Alvarado
18	La Regina	Chinchilla	Oreamuno	48	Pinita Montero (Lalo Leandro)	Barrio Lourdes	Alvarado
19	Carlos Gómez #1	Chinchilla	Oreamuno	49	La Tica	Barrio Lourdes	Alvarado
20	Carlos Gómez #2	Chinchilla	Oreamuno	50	Enciernillos (Rubén Montero)	Enciernillos	Alvarado
21	Carlos Gómez #3	Chinchilla	Oreamuno	51	Vicente Serrano	Las Parcelas	Alvarado
22	Carlos Gómez #4	Chinchilla	Oreamuno	52	Coliblanco	Coliblanco	Alvarado
23	Franco Fernández	Chinchilla	Oreamuno	53	Bajo Rojas	Santa Teresa	Alvarado
24	INA	Chinchilla	Oreamuno	54	Palmital	Santa Teresa	Alvarado
26	Capira	Cipreses	Paraíso	55	Vaca Negra	Santa Teresa	Alvarado
27	Parruas	San Francisco	Paraíso	56	Callejón	Bajos de Abarca	Alvarado
28	Guayabal	Calle Mero	Paraíso	57	Buena Vista # 1	Buena Vista	Alvarado
29	Mero	Calle Mero	Paraíso	58	Buena Vista # 2	Buena Vista	Alvarado
30	Bosque	Calle Mero	Paraíso	59	María Cristina	Barrio Lourdes	Alvarado

no studies of populations at risk. Until this work it was not determined that in researched areas there are not water springs with arsenic III quantities of more than 5 µg/L (being that the national standard) or the maximum allowed for arsenic with a total of 10 µg/L.

Despite the fact that the study areas correspond to volcanic origin zones, where the likelihood/odds of finding arsenic of natural origin could be as high as in many Latin American countries, the wide water supply of the outlined studied counties'/cantons' framework and the existence of areas with the relative protection circling the recharged zones of water springs make the water consumed by these populations free of this heavy metal.

The study did not take into consideration deep wells that, even when it is well-known that they exist in these counties, they are not directly employed by city councils for consumption of their inhabitants.

It would be useful to determine the situation in other Costa Rican areas with volcanic influence, like the ones surrounding the Guanacaste Volcanic Ridge, which has less water supply comparatively to the province of Cartago and areas with a lot of deep wells supplying the population.

The contribution of studies like this is that by quantifying a little-known toxic substance, it creates the opportunity to advance pathologies with clinical pictures already established and their malignancies. As well, and in this case in particular, early hidroarsenicism in the population could be detected.

Thanks and collaborations

A special thanks to the Vicerrectoría de Investigación and ExtensióndelInstitutoTecnológico de Costa Rica for funding the Project.

To Dra. Alina Gómez Cuevas, Nicaraguan dermatologist, for providing photographs of her patients with skin manifestations of arsenicism.

To the Central, Oreamuno, Alvarado and Paraíso city councils, from Cartago province, because of their permission and cooperation with water spring sampling.

To Mr. José Isaías Arias Picado for his assisstance work.To BC. Ricardo Coy Herrera, for reviewing the values within the limits of detection and quantification of the determination.

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Translated by: Luis Leonardo Chacón Prado