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Arsenic in the Drinking Water of the City of Antofagasta: Epidemiological and Clinical Study before and after the Installation of a Treatment Plant

by José Manuel Borgoño,* Patricia Vicent,* Hernán Venturino,* and Antonio Infante*

This is a second report of epidemiological and clinical investigation, related to the arsenic health problem, unique in the world, occurring in the city of Antofagasta, Chile. The arsenic problem originates in the chronic contamination of water supply in the city during 12 years. This phenomena, investigated clinically and epidemiologically and first reported in 1971, prompted the installation of a water treatment plant. This report aims to evaluate the working efficiency of the plant.

The study was carried out through the examination of arsenic content in hair and nail clipping samples of the inhabitants of Antofagasta and the determination of this element in cultivated vegetables and carbonated beverages. Also a clinical study in school children, looking for cutaneous lesions attributed to arsenicism, was made.

Results are encouraging. They reveal that contamination persists but in significantly lower levels.

Introduction

Antofagasta, a city of 130,000 inhabitants, received a water supply containing high quantities of arsenic (0.8 ppm) between 1958 and 1970.

The source of the high arsenic content water was the Toconce River, whose waters come from the Andes Mountains at an altitude of 3000 ms and are brought over 300 km to Antofagasta.

At the beginning of the 1960's the first dermatological manifestations were noted, especially in children (Table 1). Several systemic cases attributed to arsenicism (bronchiectasis, Raynaud's syndrome and other peripheral vascular phenomena, ischemia and myocardial infarction, mesentheric thrombosis), including a few fatal ones were sent to Santiago's hospitals.

*Servicio Nacional de Salud, Ministerio de Salud Publica, Republica de Chile, Santiago, Chile.

The magnitude and the interest of the problem motivated sanitary authorities to carry out a complete study. The prevalence of cutaneous lesions attributed to arsenicism in the general population

Table 1. Clinical manifestations among 180 Antofagasta inhabitants relative to skin pigmentation (Antofagasta, Chile, 1969).

	Abnormal skin pigmentation (n = 144), %	Normal skin (n = 36), %
Bronchopulmonary disease history	15.9	6.2
Hyperkeratosis	43.7	3.1
Chronic cough	38.8	3.1
Lips herpes	14.5	3.1
Cardiovascular manifestations		
Raynaud syndrome	38.8	9.3
Acrocyanosis	24.3	12.5
Angina pectoris	4.1	0.0
Hypertension	6.2	0.0
Chronic diarrhea	40.9	0.0
Abdominal pain	39.1	28.1

and arsenic content in hair, nail clippings, and urine samples, were determined for inhabitants of Antofagasta and Iquique. The latter city did not have an arsenicism problem and was used as control group (Table 2).

Also determinations of arsenic in water and carbonated drinks were made in Antofagasta.

Table 2. Hair arsenic among 103 Antofagasta and 26 Iquique inhabitants relative to skin pigmentation.

	No. of persons	(As mean value), mg/100 g
Antofagasta	103	0.42
Normal skin	10	0.32
Abnormal pigmentation	93	0.61
Iquique	26	0.00
Normal skin	26	0.08
Abnormal pigmentation	0	0.00

Measurements of arsenic in water drinks revealed values between 0.6 and 0.8 ppm. Carbonated drinks also contained high values, between 0.30 and 0.70 mg/l.

These findings showed a probable cause-and-effect relationship between high arsenic content in water supply and dermatologic lesions noted in a high percentage of Antofagasta's inhabitants. A water treatment plant, that started to operate in 1970, was built to solve the problem.

The present report aims to evaluate the actual state of the arsenicism problem in the city of Antofagasta 6 yr after the plant began operation. It was carried out by a clinical and epidemiological approach and with the determinations of arsenic content in hair and nail clippings of the general population and in school children 6 years of age or less. These children were probably not exposed to the intoxication risk.

Material and Methods

Materials

Arsenic determinations in hair and nail clippings samples were carried out on 411 subjects, 200 of whom were 6 years of age or less and perhaps not exposed to arsenicism since birth, and 200 subjects over 6 years that were born and lived continously in Antofagasta.

The sample for studies of cutaneous lesions comprised 645 school children; 306 under 6 years and 339 over that age (Table 3).

Table 3. Age distribution of school children examined to determine cutaneous lesions (Antofagasta, Chile, 1976).

Age, yr	Children No.	Children %
0–2	40	6.2
3–4	147	22.8
5–6	119	18.4
7–8	3	0.5
9–10	26	4.0
11–12	19	2.9
13–14	216	33.5
≥15	75	11.6
Total	645	100.0

Method

Arsenic content was determined in carbonated beverages, cultivated vegetables, and biologic products (hair and nails) by using the diethyldithiocarbamate method.

Clinic examination (by a physician) of a representative sample of school children population was carried out to establish the presence or absence of cutaneous lesions attributed to arsenicism.

Results

The results are summarized in Tables 4–10.

Table 4 shows that cutaneous lesions are not found in school children younger than 6 years.

Table 4. Age and sex distribution of school children with cutaneous lesions attributed to arsenicism (Antofagasta, Chile, 1976).

Age, yr	Inhabitants with cutaneous lesions attributed to arsenicism: Female No.	Female %	Male No.	Male %
0–6	0	0	0	0
7–8	0	0	0	0
9–10	0	0	1	3.4
11–12	1	4.3	0	0
13–14	18	78.3	19	65.5
≥15	4	17.4	9	31.1
Total	23	100.0	29	100.0

Table 5. Arsenic in hair samples of inhabitants (Antofagasta, Chile, 1968–1970 and 1976).

	1968–1970 No.	1968–1970 %	1976 No.	1976 %
Total samples	204	100	274	100
As levels 0	36	17.4	31	11.3
As ≤0.10 mg-%	0	0	133	48.5
As >0.10 mg-%	168	82.6	110	40.1
Mean values in samples over 0.10 mg-%	0.92		0.27	

Of the persons examined between 1968 and 1970, 82.6% had arsenic levels of hair above normal values (Table 5); in 1976 these values dropped to 40.1%. Mean values also decreased from 0.92 in 1970 to 0.27 mg-% in 1976.

Table 6 shows that 110 hair samples (40.2%) show abnormal values of arsenic content. However, only three samples reach the mean values of the first study.

Table 6. Arsenic in hair samples of inhabitants under and over age of 6 years (Antofagasta, Chile, 1976).

As level mg-%	Under 6 years		Over 6 years	
	No.	%	No.	%
0.00–0.10	62	55.2	102	66.6
0.11–0.20	31	27.6	29	18.9
0.21–0.30	10	6.6	13	8.5
0.31–0.40	9	5.9	5	3.3
0.41–0.50	4	3.3	1	0.7
0.51–0.60	—	—	—	—
0.61–0.70	2	1.9	1	0.7
0.71–0.80	2	1.9	—	—
0.81–0.90	—	—	—	—
0.91–1.00	—	—	—	—
1.01–1.10	1	0.9	—	—
1.71–1.80	—	—	2	1.3

Table 7. Arsenic in nail clipping samples of inhabitants (Antofagasta, Chile, 1968 and 1976).

	1968		1976	
	No.	%	No.	%
Total samples	26	100	273	100
0 As	3	11.5	82	30.0
As ≤0.10 mg-%	0	0.0	64	23.4
As >0.10 mg-%	23	88.5	127	46.6
Mean values in samples over 0.10 mg-%	2.86		1.41	

Table 8. Arsenic in nail clippings samples of inhabitants under and over age of 6 years (Antofagasta, Chile, 1976).

As level mg-%	Under 6 years		Over 6 years	
	No.	%	No.	%
0.00–0.10	34	28.3	111	72.4
0.11–0.50	13	10.8	7	4.6
0.51–1.00	32	26.6	15	9.8
1.01–1.50	12	10.0	15	9.8
1.51–2.00	11	9.1	1	0.7
2.01–2.50	6	5.0	1	0.7
2.51–3.00	3	2.5	1	0.7
3.01–3.50	4	3.3	2	1.3
3.51–4.00	2	1.7	—	—
4.01–4.50	1	0.8	—	—
4.51–5.00	1	0.8	—	—
7.01–7.50	1	0.8	—	—

In 1968, nail clippings samples with abnormal arsenic content constituted 88.5% of all samples collected in Antofagasta; this declined to 46.6% in 1976. Mean values also descend from 2.86 in 1968 to 1.41 mg-% in 1976.

Table 8 shows the range of variation of As values in nail clipping samples.

Table 9. Arsenic in cultivated vegetables (Antofagasta, Chile 1976).

	No.	%
Total samples	15	100
> As levels 0.05 ppm	2	13.3
≤0.05 ppm	13	86.7

Only 13.3% of the cultivated vegetables samples show arsenic contents above normal values (Table 9).

Table 10. Arsenic in soft drinks (Antofagasta, Chile, 1968 and 1976).

	1968	1976
Mean As values, mg/l.	0.24	0.060

Mean values of arsenic content in soft drinks dropped from 0.24 mg/l. in 1968 to 0.06 mg/l. in 1976 (Table 10).

Discussion

In this preliminary study, 6 years after the water treatment plant began operation, the problem had disminished considerably relative to the previous report (1971).

The absence of cutaneous lesions in school children under 6 years suggest two hypotheses: they may have not been produced because of the short period of exposure to arsenic in the drinking water, or that the arsenic content is under the necessary level to produce clinical manifestations.

The fact that the arsenic contamination problem continues, although very diminished, suggests that continued surveillance and continued investigations are desirable to follow up the clinical and epidemiological manifestations of this problem. These manifestations can be cutaneous lesions produced by a cummulative effect of the arsenic ingested, or other systemic clinical manifestations attributed to arsenic consumption and perhaps produced earlier than the cutaneous sign.

Sanitary engineering studies will be necessary to improve the system of water purification, in order further to lower the arsenic content.

With periodic evaluation of the chronic arsenic intoxication problem we will have an integral and complete view of the illness.