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Authors

Wickliffe, Jeffrey
Lichtveld, Maureen
Steenland, Kyle
et al.

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Arsenic Concentrations in Household Drinking Water: A Cross-Sectional Survey of Pregnant Women in Tacna, Peru, 2019

Diego Fano[1], **Cinthya Vásquez-Velásquez**[1], **Julio Aguilar**[2], **Matthew O. Gribble**[3], **Jeffrey K. Wickliffe**[4], **Maureen Y. Lichtveld**[4], **Kyle Steenland**[3], **Gustavo F. Gonzales**[1]

[1]Laboratorio de Endocrinología y Reproducción. Facultad de Ciencias y Filosofía. Universidad Peruana Cayetano Heredia, Lima, Peru.

[2]Universidad Nacional Jorge Basadre Grohmann, Tacna, Peru.

[3]Department of Environmental Health, Rollins School of Public Health at Emory University, Atlanta, Georgia, USA. Emory University

[4]School of Public Health & Tropical Medicine, Tulane University, New Orleans, Louisiana

Abstract

The World Health Organization (WHO) estimates that around ~150 million people in 70 different countries have been consuming water with arsenic levels higher than the recommended limit of 10 μg/L. Here we describe the concentrations of inorganic arsenic in drinking water in homes of pregnant women living in the province of Tacna, near the southern border of Peru. 161 pregnant women were enrolled in their second trimester of pregnancy. A total of 100mL drinking water was collected in each household from the source of most common use. Inorganic arsenic was categorized into 3 levels with a commercial kit. Thirty percent of women had drinking water ≤10 μg/L (the WHO recommended level), 35% had 25 μg/L, and 35% had greater than 50 μg/L. Low

Correspondence: Name: Cinthya Vásquez Velásquez, Address: Av. Honorio Delgado 430, Urb. Ingeniería, San Martín de Porres, Lima, Phone: (+511) 319-0000 ext: 233213, cinthya.vasquez.v@upch.pe.

Authors contribution

Diego Fano contributed to study design, data collection and analysis, interpretation and writing of first and subsequent drafts of the paper. Cinthya Vásquez-Velásquez contributed to study design, data collection and analysis, interpretation and writing of first and subsequent drafts of the paper. Julio Aguilar contributed with the coordination and management of the permits with the local government, and with the writing of the first draft. Matthew O. Gribble contributed to the study design, data analysis, interpretation and writing of the drafts. Jeffrey K. Wickliffe contributed to the study design and writing of the final draft of the paper. Maureen Y. Lichtveld contributed to the study design, interpretation and writing of the final draft of the paper. Kyle Steenland contributed to the study design, data analysis, interpretation and writing of the first and subsequent drafts of the paper. Gustavo F. Gonzales contributed to contributed to the study design, data analysis, interpretation and writing of the first and subsequent drafts of the paper.

Ethics statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Free and informed consent of the participants or their legal representatives was obtained and the study protocol was approved by the appropriate Committee for the Protection of Human Participants “Institutional Research Ethics Committee”, by the Universidad Peruana Cayetano Heredia, Lima, Peru, Protocol 102434, December 10th 2018.

Disclosure

The authors declare that they have no conflict of interest.

arsenic levels were found in the southernmost homes, supplied by groundwater, while high levels were found in the northern and metropolitan homes supplied by river water.

Keywords

Arsenic Poisoning; Reproductive Health; Environmental Health; Exposure Assessment; Medical Geology

Introduction

The World Health Organization (WHO) estimates that ~ 150 million people in 70 different countries have been consuming water with arsenic levels higher than the suggested WHO limit of 10 μg/L (WHO, 2011), of which 4.5 million correspond to South America inhabitants exposed to levels above 50 μg/L, with Mexico, Argentina, Chile, Bolivia and Peru the most affected countries (McClintock et al., 2012).

Chronic Arsenic exposure has been linked to several health effects such as cardiovascular diseases, skin disorders, intellectual function (Naujokas et al., 2013), and also with carcinogenic effects, being classified as a Group I human carcinogen (IARC, 2012). There is some evidence associating inorganic arsenic (iAs) exposure with pregnancy outcomes such as spontaneous abortion, low birthweight and preterm birth (Quansah et al., 2015).

In the southern part of Peru, high levels of arsenic have been found in surface and groundwater in several districts, especially in the southern highlands in Puno (George et al., 2014). According to reports made by the Regional Health Directorate of Tacna, more than 60% of population centers of the province of Tacna (a sub-division of the region) are exposed to levels higher than 10 μg/L (Dirección Regional de Salud de Tacna, 2017). The goal of this study was to evaluate the magnitude of exposure to arsenic among pregnant women in Tacna.

Materials and Methods

Study Design

The present study is cross-sectional environmental exposure assessment, in which 161 pregnant women living in the province of Tacna were recruited for an epidemiological study of arsenic and birthweight. The pregnant women attended their prenatal care regularly in the health establishment (Establecimiento de Salud, or ES) corresponding to their area of residence.

Study Population

The province of Tacna is divided into 10 districts. We recruited pregnant women from a total of 16 Health Establishments (ES) from within the 5 most populated districts of Tacna, using a list of pregnant women maintained by each ES. These districts of Tacna Province were La Yarada, Gregorio Albarracín Lanchipa, Tacna, Alto de la Alianza, Ciudad Nueva and Pocollay, with Tacna district the most populated. In these districts, there were 20 health establishments; the 16 nearest health establishments to the city of Tacna were included in

this survey. The 158 pregnant women were recruited during the months of February and March 2019, representing 18% of the pregnant population in two months in the Tacna province.

Women were required to have lived in the province of Tacna for at least the previous 5 years, be between the ages of 18 and 40 years old, and be at ≤ 24 weeks of gestation. All procedures were performed after signing the informed consent. The recruitment was done by telephone, during which the home visit was scheduled to conduct surveys and the sampling of drinking water.

Each ES gave us access to the Pregnant Women Record Book, and potential participants were selected according to the criteria described above. Afterwards, the pregnant women that matched the criteria were contacted and recruited by telephone call.

There were 382 eligible pregnant women but only 364 had a valid telephone number. Six extra women whose telephone number did not appear in the book were approached in the ES in coordination with the obstetrician, so we contacted 370 women, and 161 (44.23%) participated. Three women decided to withdraw from the study, so 158 pregnant women were included in this study, representing the 43.0% of the original targeted population.

The 161 pregnant women were recruited from the six districts of Tacna as follows: n=2 from La Yarada, n=50 from Gregorio Albarracín, n=58 from Tacna, n=18 from Ciudad Nueva, n=24 from Alto de la Alianza, and n=9 from Pocollay. The participation rate in these districts were 25%, 45%, 47%, 30%, 51% and 60%, respectively.

Measures

The exposure variable, concentration of arsenic in drinking water, was obtained by qualitative colorimetric analysis of home drinking water. The analysis of total iAs in drinking water was conducted at the Universidad Nacional Jorge Basadre Grohmann in Tacna. Approximately 100 ml of tap water was collected from the faucet in the homes of the pregnant women. Samples were stored in coolers at 4°C and immediately taken to the laboratory for processing, if the samples could not be analyzed in the same day, they were stored at −20°C, and thawed at 4°C before analysis. The water samples were collected during the months of February and March, 2019.

To quantify the iAs in the drinking water samples, the MQuant® Arsenic Kit (Merck, Lima) was used. In brief, 60mL of tap water were poured into the reaction bottle, and then 2 drops of reagent As-1 were added and swirled. Once a homogeneous color was obtained, a full spoon of As-2 reagent was added and dissolved entirely, followed by As-3 reactant. The reaction bottle was immediately closed with the test strip previously put, and left to stand for 20 minutes. The cap was removed, and the strip cleansed with distilled water. Finally, the strip color was compared to the kit references. The kit detects the total concentration of inorganic arsenic based on the sum of the As^{III} and As^{V} concentrations, giving a qualitative result based on colors that identify the concentrations of 0, 5, 10, 25, 50, 100, 250 and 500 μg/L of arsenic.

The demographic variables considered were: geographic zone, age, years of residence in the province of Tacna, gestational age, smoking and drinking behavior before gestation, pre-gestational BMI, access to public services (electricity, water and sewage), level of education, marital status, ethnicity and occupation. These data were collected via an interview during the first home visit.

Statistical Analysis

The pregnant women were categorized according to the concentration of arsenic present in drinking water. We analyzed whether the demographic variables (listed above) differed by arsenic group. We also separated women into three groups by residential zones.

The ES's were divided in three groups: South, Metropolitan and North, a grouping adopted by the Tacna health authorities. The districts of La Yarada and Gregorio Albarracín belong to the South, Tacna to Metropolitan, and Alto de la Alianza, Ciudad Nueva and Pocollay are located in the North.

The distribution of these variables was considered across arsenic categories (Table 1). One-way ANOVA was used to compare the means of continuous variables. Contingency table analysis was used to test the independence of demographic variables and category of arsenic exposure; for variables where cells contained < 5 observations, Fisher's exact test was used; whereas for variables with cells containing n ≥5 observations, a χ^2-test was used. A $p < 0.05$ was considered nominally significant. Analyses were done using STATA version (15).

Geocoding

Coordinates (latitude and longitude) of the pregnant women homes were collected with the free online application UTM Geo Map. Using the free software R version 3.5.2 and the R libraries leaflet, mapview, shiny, sp, rgeos, raster, mapview, webshot, dplyr, the coordinates were located in an OpenStreetMap map adjusted for the province of Tacna, and colored according to the arsenic exposure category (≤10 μg/L, 25 μg/L or ≥50 μg/L).

Ethical Considerations

Women were offered a gift card to be expended in a local market as an incentive. In addition, they would learn the level of their arsenic in their drinking water, as well as the level of arsenic in their urine. The study was approved by Universidad Peruana Cayetano Heredia IRB, with registration number 602–24-18. The Tacna Health Network granted the corresponding permits for access to the Follow-up Book for Pregnant Women at each ES.

Results

The average age of our whole population was 28.13 ± 6.04 years-old, with an average time of residence in Tacna of 17.11 ± 9.81 years. The gestational age at the time of recruitment was 15.74 ± 4.68 weeks, which is during the second trimester of pregnancy. There was no difference of this parameters between the three exposure groups. Mean BMI in the three groups was above 25 kg/m^2. More than 50% of the population in each group has high school

education, are married or cohabit, and self-identified as Aymara ethnicity (14 women decided not to share information about their ethnicity).

As seen in Table 1, 47 of women had levels ≤10 μg/L, 56 had 25 μg/L, and 55 had levels greater than 50 μg/L. Arsenic was higher in the northern and metropolitan areas, while low levels predominated in the south. Of the 47 women that live in the South, 38 were exposed to a ≤10 μg/L iAs level; in Metropolitan 31 out of 56 to 25 μg/L, and in the North 35 out of 55 women had exposure level ≥50 μg/L.

Among all variables, the only two which were significantly associated with arsenic level was access to basic services, and geographic zone.

Figure 1 shows the spatial distribution of pregnant women with their respective exposure value. Lower arsenic levels in home water supplies were found in the southeast, which corresponds to district Gregorio Albarracín, while higher levels were found in the districts of Ciudad Nueva and Pocollay located in the North.

Discussion

Little is known about Tacna and its situation of arsenic contamination, being this the first study exposure assessment in the pregnant population. We were able to recruit 43% of the target population, with an average age of 28 years; according to data obtained from the Perinatal Information System (Pan American Health Organization, 2018) (Sistema Informático Perinatal in Spanish) of Tacna, the mean age from 2000 – 2018 was 27; in this database average BMI was 25.99 kg/m^2 and 84% were married or cohabiting, similar to our results, 26.57 kg/m^2 and 77%.

We found that ~70% of pregnant women in the province of Tacna are exposed to levels of inorganic arsenic in drinking water ≥25 μg/L, and of these, 35% had drinking water arsenic ≥50 μg/L. We found that there was a greater risk of being exposed to high concentrations of arsenic if one lived in Ciudad Nueva and Pocollay. As seen in Figure 1, each category of arsenic predominates in a specific area of the map. In the case of the South (the district of Coronel Gregorio Albarracín Lanchipa), the population is supplied with water from the underground aquifers, while the other the North and Metropolitan areas are supplied form the rivers Uchusuma, Sama and Caplina (EPS Tacna, n.d.).

In 2014, George et al. found that 77% of a total of 151 water samples from 12 districts of Peru showed arsenic above the WHO limit of 10 μg/L and 41% over 50 μg/L (George et al., 2014). However, districts in that study were mining districts, whereas the arsenic in the water of our study population is of natural origin coming from the Andes plateau (Ocola Salazar, 2015). Interestingly, in this setting it appears that drinking water arsenic was higher in surface water sources (river water), different from other countries such as Bangladesh in which groundwater is highly contaminated with arsenic. This could be due to the leaching of volcanic rock into surface water in Peru (Tapia et al., 2019).

Arsenic concentrations in household drinking water supplies were associated with access to public services such as electricity, water and sewer. There was an inverse association

between access to the three public services and arsenic exposure (≤10 μg/L). This may be because the most recent settlements in Tacna, with least access to public services, were established in Gregorio Albarracín district area in our study (EPS Tacna, n.d.).

A limitation of the study is that the method to quantify the drinking water arsenic concentration is a qualitative one, which it is not a precise measurement of the real exposure. Nonetheless, it gives us an approximation that will be later complemented with urinary arsenic analysis.

In conclusion, a large percentage of the pregnant population in this province is exposed to levels above the WHO limit, and taking into account that there is evidence exposure to high concentrations of arsenic in drinking water is associated with adverse birth outcomes such as low birth weight, spontaneous abortion (Quansah et al., 2015), preterm birth (Milton et al., 2017) and small for gestational age (Mullin et al., 2019; Wang et al., 2018), this population could be facing a major reproductive health threat.

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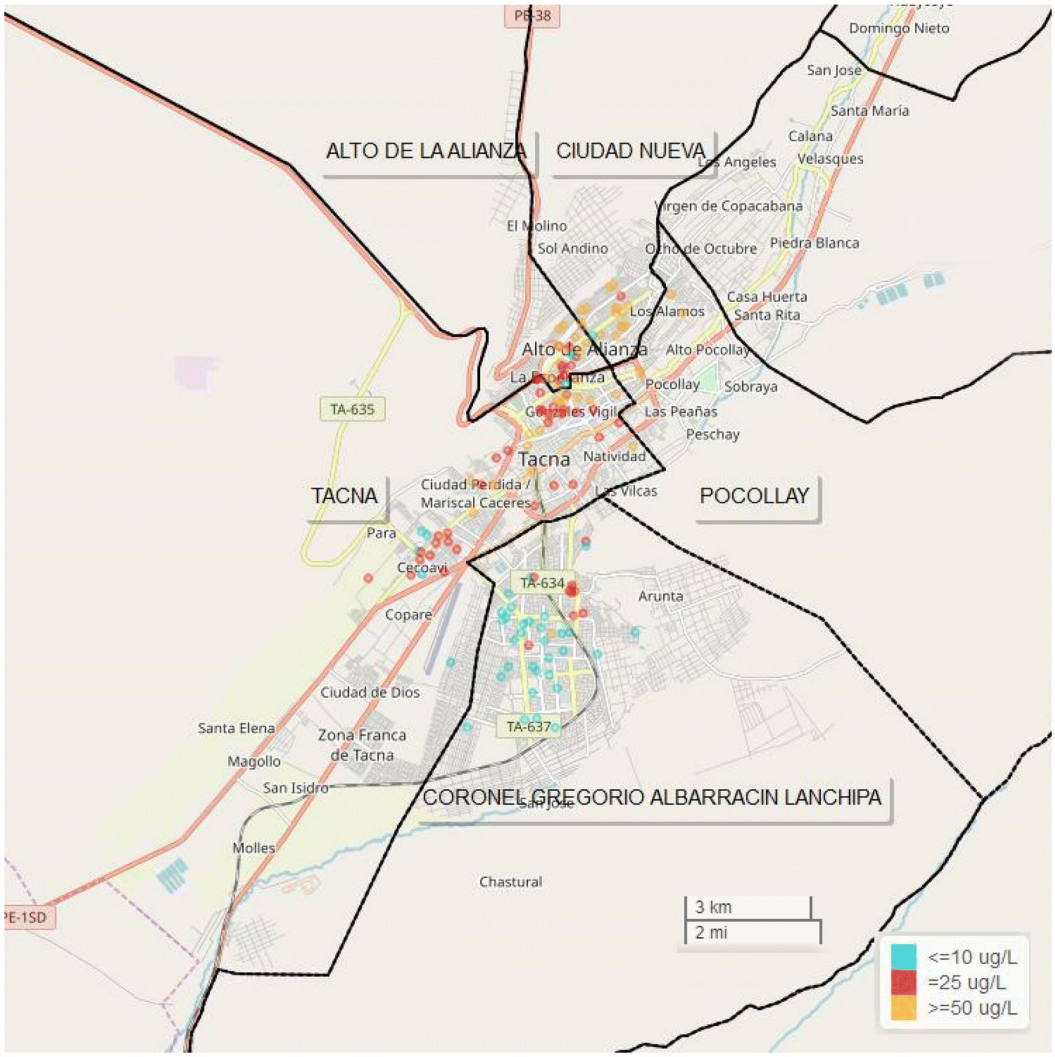

Fig 1.

Geolocation of pregnant women and identified according to arsenic exposure level (≤10 μg/L, 25 μg/L and ≥50 μg/L). In the district of Gregorio Albarracín Lanchipa predominates arsenic concentrations ≤10 μg/L, while in the subsequent districts it can be seen an increase in the arsenic levels. Because the arsenic analysis test is colorimetric (categorical), there are no continuous values between the arsenic level groups. Each colored circle represents a diameter of 130 meters.

Table 1:

Sociodemographic characteristics of the population according to the category of arsenic exposure.

Characteristics	Description	iAs category (μg/L)			*p*
		≤10	25	>25	
	N	47	56	55	-
Participants	%	29.75	35.44	34.81	-
	South	38	13	1	
Geographic Zone	Metropolitan	7	31	19	<0.001
	North	2	12	35	
Age	Years-old	28.97	28.93	26.68	0.97
Living in Tacna	Years	15.39	18.52	17.18	0.15
Gestational age	Weeks	15.1	16.15	15.75	0.64
	Smoke	0	1	4	0.09
Pre-gestational habits	Alcohol	1	5	8	0.09
Pre-gestational BMI	Mean (kg/m^2)	27.13	25.93	26.58	0.80
	Underweight	0	2	1	
	Normal	18	23	17	
Categorized BMI[¥]					0.61
	Overweight	17	21	20	
	Obesity	12	10	17	
	At least 1	9	1	1	
	At least 2	5	0	1	<0.001
Basic services access (Electricity, water, sewer)	All	33	55	53	
Education	Elementary	2	4	4	0.77
	High School	29	31	27	
	Higher	16	21	24	
	Single	7	16	13	
Marital Status					0.35
	Married or cohabiting	40	40	42	
	Aymara	24	27	30	
Ethnicity[¥]	Quechua	7	8	2	
	Mestizo	7	20	19	
	Housewife	28	33	29	
Occupation	Worker	16	21	25	0.63
	Student	3	2	1	

Categorical variables are presented as counts, and continuous variables as means.

Chi^2 test of association was used for categorical variables except in cells with counts under 5, for those, Fisher's exact test was calculated.

Oneway ANOVA was employed for continuous variables Age, Living in Tacna, Gestational age and Pre-gestational BMI.

[¥]Columns do not add to totals due to missing values.