Traceability of arsenic in agricultural water in Irrigation District 005, Mexico

M.C. Valles-Aragón¹ & M.L. Ballinas-Casarrubias²

¹Faculty of Agrotechnological Science, Autonomous University of Chihuahua, Chihuahua, Chih., Mexico

²Faculty of Chemical Sciences, Autonomous University of Chihuahua, Chihuahua, Chih., Mexico

ABSTRACT: The Irrigation District 005 is an agricultural territory in Chihuahua, Mexico where has been detected As in groundwater. So, the objective was to determine As in agricultural wells, and the metalloid traceability to soil and crops. 119 irrigation wells were sampled, 140 samples of soil, 32 onion and 37 chili plants were collected. The As concentration was determined in all matrices by HG-AAS. 11% of the wells exceeded the maximum permissible level (MPL) in Mexico of As in water for agricultural use ($100 \mu\text{g L}^{-1}$), the highest concentration was $576 \mu\text{g L}^{-1}$. 13% of the soil samples exceeded the MPL for agricultural use (22 mg kg^{-1}), the maximum concentration was 57.7 mg kg^{-1} . The highest As presence in crops was in root, 7.4 mg kg^{-1} in chili and 28.8 mg kg^{-1} in onion. However, 0.16 mg kg^{-1} in chili crop and 0.38 mg kg^{-1} in onion crop were also identified.

1 INTRODUCTION

In Mexico, many rural localities, have water sources contaminated with arsenic (As), among them localities from Chihuahua State (Rivera-Huerta *et al.*, 2008). Several studies support this fact, Espino-Valdes *et al.* (2009) determined at the south-center region of Chihuahua State 72% of the samples exceeded the maximum permissible level (MPL) of As in water for human consumption of $25 \mu\text{g L}^{-1}$ established by the Mexican regulation (SSA 1994). Olmos-Márquez (2011) determined the As concentration in the feeding of 116 plants of reverse osmosis in municipalities of Chihuahua, 73% exceeded the MPL of water for human consumption. Vega-Gleason (2013) estimated the As interval in water between 0.5 and $500 \mu\text{g L}^{-1}$ in the south region of Chihuahua State. González-Horta *et al.* (2015) reported high As levels in water for human consumption, as well as 49% of the sampled people with high levels of As in urine. The Irrigation District 005 (ID005) located in the south-central region of Chihuahua State in Mexico, is a territory that has a representative agricultural economy (INEGI 2013). Due this, it is considered that crops irrigated with contaminated water with As may be a contribution to the daily intake of As (Santra *et al.*, 2013). So, the objective was to determine the As concentration in agricultural wells, and the traceability of this metalloid to soil and plants for human consumption.

2 METHODS/EXPERIMENTAL

2.1 Water, soil and plant sampling

The sampling was conducted in the ID005, two water sampling were performed, the first on summer (Sampling 1) and the second on autumn (Sampling 2). In

the first sampling, water from 65 wells was collected, in the second from 54 wells. For soil sampling, were considered the zones that exceeded the MPL according to Mexican regulations for As in water for agricultural use (CONAGUA 2016). Zones were systematic sampled by quadrants, each quadrant had 24 sampling points at 250 m of distance between them, in an area of 100 ha. Giving a total of 140 soil samples. The plants collection was in the harvest time from May to July. 32 samples of onion, and 37 of chili plant were collected in the same quadrants.

2.2 Sample preparation and As determination

The water samples before the analysis were filtered with Whatman No.2 and Millipore filters. Soil and plant samples were dried at 45°C , and digested in a Mars 6 microwave. EPA-3052 digestion method was used for soil and EPA-3051 for plants. As determination in all matrices was done by a Perkin Elmer AAnalyst700 Atomic Absorption Spectrometry equipment, coupled to FIAS 100 Hydride Generator. The detection limit was $3.12 \mu\text{g L}^{-1}$, samples were analyzed in triplicates, using controls and standards.

3 RESULTS AND DISCUSSION

3.1 As in water

During sampling 1, 9% of the wells exceeded the MPL of As for agricultural water of $100 \mu\text{g L}^{-1}$ (CONAGUA 2016) and 38% the MPL for human consumption ($25 \mu\text{g L}^{-1}$) (SSA 1994), the maximum concentration was $335 \mu\text{g L}^{-1}$. In Sampling 2, 13% of the wells exceeded the MPL for agricultural irrigation and 33% the one for human consumption. The maximum concentration of As was $576 \mu\text{g L}^{-1}$ (Table 1).

Table 1. Arsenic in water of the Irrigation District 005.

Samples	MPL agricultural use >100 $\mu\text{g L}^{-1}$	MPL human use >25 $\mu\text{g L}^{-1}$	Not detectable <3 $\mu\text{g L}^{-1}$	Interval $\mu\text{g L}^{-1}$
Global n=119	11% n=13	36% n=43	43% n=51	<3–576
Sampling 1 n=65	9% n=6	38% n=25	45% n=29	<3–335
Sampling 2 n=54	13% n=7	33% n=18	41% n=22	<3–576

Table 2. Arsenic in soil in the Irrigation District 005.

Samples	MPL agricultural >22 mg kg^{-1}	Interval mg kg^{-1}
Global n=140	13% n=18	4.3–57.7
MM33 n=24	8% n=2	4.4–57.7
MM35 n=24	0% n=0	4.3–15.6
MM38 n=24	0% n=0	5.8–13.5
MR14 n=24	17% n=4	7.9–35.6
MJ01 n=20	10% n=2	8.3–23.5
MJ02 n=24	42% n=10	8.7–47.5

Table 3. Arsenic in chili and onion plants.

Crop	Root	Stem	Leaf	Chili/onion
Jalapeño	0.3213	0.2236	0.5325	0.1583
Serrano	7.4327	0.0000	0.6992	0.0546
Chilaca	1.2110	0.2143	1.1862	0.0000
Onion	28.8492	0.8069	–	0.3814

3.2 As in soil

The soil results were done in 6 sampling sites classified as: MJ01, MJ02, MM33, MM35, MM38 and MR14. The soil with the highest As concentrations was MJ02 with 42% of the samples that exceeded the MPL of 22 mg kg^{-1} (SEMARNAT/SSA 2004), for As in agricultural land (Table 2). However, it was observed that in all soil samples, there was As presence, which evidences the accumulation of it by water irrigation. However, it is emphasized that the global average of As concentration in soil is 6.83 mg kg^{-1} (Kabata-Pendias 2011).

3.3 As in plant

The analysis of chili of different species jalapeño, serrano and chilaca showed a higher As concentration in root with 0.32, 7.4 and 1.2 mg kg^{-1} of As, respectively. In leaf with an average concentration of 0.53, 0.7 and 1.2 mg kg^{-1} , respectively. Although, the edible part of chili presented the lowest As levels, with an average of 0.16 and 0.05 mg kg^{-1} in jalapeño and serrano, without presence in chilaca (Table 3).

The analysis of onion showed the existence of a higher As concentration in root with an average of

28.8 mg kg^{-1} . However, it was observed that it was accumulated in the onion bulb in a greater quantity than in the chili plants. An average As concentration of 0.38 mg kg^{-1} was determined (Table 3).

4 CONCLUSIONS

As is an element present in the ID005, it is at levels that can cause an agricultural risk for production, it can even mean a public health risk, especially if it is used as water for human consumption for agricultural communities. The As presence in soil is relevant although in most cases the MPL are not exceeded, evidences the traceability of the metalloid from water to soil. Moreover, being As present in water and soil, it can be absorbed by the plant; although it is mostly concentrated in the root of the plants, chili and onion can store arsenic in the edible part too.

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