Seasonal effects in arsenic levels in drinking water in the Lagunera region

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Abstract. Changes in arsenic content in the drinking water in the Lagunera Region in northern Mexico are presented here. Arsenic and water conductivity were measured both before and after the yearly irrigation cycle and also before and after a river bed that is usually dry, received water in a 2010, a wet year. The results were processed with a Geographic Information System (GIS) to understand better the changes in relation to the dry riverbed. The present work can evolve towards a real-time, sensor-based system.

Keywords: Arsenic, Hydroarsenicism, Geographic Information Systems.

1. Introduction
Arsenic (As) is a toxic element. It may cause serious health problems even when ingested in low quantities for a prolonged time. Hence the relevance of monitoring its levels in drinking water. Its health effects go from simple skin alterations to cancer of the bladder, skin, kidneys, lungs, liver and prostate [1]. When arsenic enters the organism through the digestive system it stays in the blood for a short time as it spreads to the liver, kidneys and digestive tract. A fraction of the arsenic is excreted in urine both in its inorganic and its methylated form. However, some of it stays in the body and may accumulate overwhelming the detoxification mechanisms of the body [2].

2. Hydroarsenicism
There are several places on the planet where hydroarcenicism is present. It arises due to a particular geology or because of human activities such as mining and other industries activities and also as a response to aquifer depletion. The Lagunera Region in north-central Mexico, in the states of Durango and Coahuila, is one of these regions.

Recent research has found that the origin of the arsenic present in groundwater in the Lagunera Region responds to aquifer depletion. This in turn is caused by the damming and diversion of its rivers and a concurrent overdraft of groundwater [3]. The Lagunera Region is one of the driest in Mexico (annual rainfall is 260mm) [4]. Being in the center of the vast Chihuahuan Desert, it has scarce water resources that include the Nazas and Aguanaival rivers, both of them Endorheic Rivers that used to form vast seasonal lagoons that no longer exist. Most of the extracted groundwater is destined to grow

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alfalfa and other forage crops. This responds to the Lagunera Region being the main milk-producing region in Mexico.

The presence of arsenic in groundwater in the Lagunera Region has been recognized since the 1970s [5]. In 2007, López-Uriostegui found arsenic levels in drinking water that far exceeded the Mexican norm of 25 µg/L. The highest value in a well was found in the Holanda Ranch, 10 km south of the city of Tlahualilo, Durango with an arsenic content of 643 µg/L [6].

Irrigation agriculture is dominant in the Lagunera Region. During the irrigation season, water is released from the dams and it flows through the normally dry riverbeds. While moving through the riverbed some water infiltrates to the aquifer. Later, water is moved through cement-paved canals to the fields. Irrigation itself allows for further infiltration of water from the fields to the aquifer. It is expected that during this time “young” water with low arsenic levels may have an effect on arsenic levels in the groundwater. Furthermore, the rain season occurs between May and October, coinciding with the irrigation cycle. Rain may also have a similar effect on arsenic levels in the aquifer.

3. Methods

Fifty samples of drinking water were taken in different points of the metropolitan area of the Lagunera Region (in the cities of Gómez Palacio, Lerdo and Torreón). The sampling dates were selected to bracket both the rainy and the irrigation season. According to data supplied by the National Water Commission, the rainy season occurs between May and October as in the rest of the Mexican highlands. During these dates the dams release water for irrigation in well-defined periods. Samples were taken in April and then again in October. For every sample, latitude and longitude data were registered with a GPS-III personal apparatus (Garmin International Inc., Olathe, Kansas).

The aquifer is expected to receive water both through the riverbed before the water reaches the canals and then through the irrigated fields. Showers that may occur locally during this time also contribute to the recharge of the aquifer.

4. Laboratory analyses

Arsenic levels were analyzed in the Toxicology lab at the Medical School of the Durango Juarez State University using atomic absorption spectrometry with a coupled hydride generator. As a complement, conductivity was measured in each of the samples as a way of seeing the effect of overall salt content. Conductivity was measured using a NEO-2 portable precision conductivity meter (Mesa Laboratories, Lakewood, Colorado) capable of measuring conductivities from 0.001 mS/cm to 1 µS/cm.

After arsenic and conductivity measurements were done, the results were analyzed using the ArcGIS geographic information system (ESRI, Redlands, California). This analysis allowed the visualization of the probable distribution of arsenic in groundwater.

5. Results

Images of the probable distribution of arsenic in groundwater in the metropolitan area of the Lagunera Region were produced. These images were made using sample information before and after the irrigation cycle and the rainy season. This study was done only for the urban area. A satellite photograph of the urban area was used as the base layer of the image as seen in figures 1-2. A second layer included the sampling points. A third layer was a raster that results from the spatial interpolation of the arsenic levels found in each one of the fifty samples. Red areas correspond to levels higher than the Mexican norm of 25 µg/L [7]. It is worth noting that the World Health Organization recommends an arsenic content of no more than 10 µg/L [8].

Figure 1 shows the resulting image built from the samples of April 2010 prior to the irrigation cycle. For this period the highest value was 43.325 µg/L of arsenic in sample 8, the lowest value was 8.625 µg/L of arsenic in sample 34. The mean of all 50 samples was 23.25 µg/L of arsenic.
Figure 1. Probable arsenic levels of groundwater in the metropolitan area of the Lagunera Region in April, 2010.

Figure 2 shows the image that results from the samples taken in October 2010, after the irrigation cycle. For this period the highest value was 70.960 µg/L of arsenic in sample 25, the lowest value was 11.075 µg/L of arsenic in sample 49. The mean of all 50 samples was 26.65 µg/L of arsenic.

The results of the conductivity studies are shown in Figures 3 and 4. Although there is not a mention of conductivity in the Mexican norms regarding drinking water, we found that the zones with the highest conductivity coincide with the zones with the highest arsenic levels. This can be a cross-check of sorts as conductivity stands for overall salt content including arsenic salts. This zone is in the northeastern part of the image and is located in the city of Gómez Palacio in the state of Durango.

In figures 3 and 4 the difference between the resulting April and October images do not show a stark contrast as is the case with the arsenic images. This may point to the fact that arsenic salts are not the dominant component of conductivity in the groundwater of the Lagunera Region. And therefore, that there is not a seasonal effect in conductivity.
6. Conclusions

From figures 1 and 2 it can be noted that the irrigation cycle had an effect in diminishing arsenic levels in the eastern part or the metropolitan area but increasing it in the western part. It is interesting to note that the dry bed of the Nazas River coincides with the eastern limit of the red zone in figure 2, this the zone where arsenic above 25 µg/L is present. In 2010 there was rainfall above the average that forced the authorities to release water in a normally dry portion of the Nazas river in addition to the water moved through the canals. Since 1968 when the Francisco Zarco dam was completed, this has only
happened in 1992 and 2008. The rise in arsenic levels is counterintuitive as “new” water brought by rain and the river (through the normal irrigation cycle and the extraordinary 2010 flood) is expected to dilute arsenic levels in the aquifer.

The 2010 flood and the ensuing passage of the water through the normally dry riverbed may have provoked a violent local recharge of the aquifer and a corresponding alteration of the phreatic layers that may have caused the arsenic to rise. This effect may have manifested with special force near the riverbed but not in zones farther from it, i.e. the eastern portion of the metropolitan area. Another explanation is that the floodwaters may have been laced with arsenic. There are a number of mines (and their tailings dams) in several tributaries of the Nazas upstream from Torreon.

7. Recommendations
Arsenic in drinking water is a public health issue. Furthermore, it is problem that has been worsening as time passes as the main cause of it, the overdrafting of groundwater is accelerating. It is therefore necessary that this problem be addressed even when it will take time to revert to an earlier state when arsenic in water was not an issue as drafting was kept below recharge.

More analyses are needed both from events in the future but also from data from previous years. This would help build a more complete picture of the recharge dynamics of the local aquifer. However, the present work justifies further studies towards the development of sensor-based, automatic monitoring systems that can evaluate arsenic levels both in the aquifer and the water for irrigation coming from the dams on a daily basis. This would help detect illegal toxic spills from mines upstream, take aquifer management decisions more speedily, and communicate risk to the 1.5 million inhabitants of the metropolitan area of the Lagunera Region regarding the safety of tap water.

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