DOI: 10.24850/j-tyca-2025-03-08

Articles

Fluoride concentration in groundwater of the Jalisco Highlands, Mexico

Concentración de fluoruros en aguas subterráneas de los Altos de Jalisco, México

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Abstract

The main source for the drinking water supply in most of the administrative regions of the state of Jalisco (Mexico) is underground aquifers, which in many cases are hydrothermal origin, characterized by supply potentially harmful chemical compounds for human and animal consumption. The study area of this work is located in the northeast of the state of Jalisco, comprising 10 municipalities in two administrative regions. The objective of this study is to determine the trend of fluoride concentration in deep wells that supply drinking water to the municipalities of the study area, based on two evaluations carried out during the years 2021 and 2022. In the results it is possible to observe an increasing trend in the fluoride concentration of most of the wells analyzed in the periods studied, the highest concentrations are reported in the towns of Tepatitlan, Arandas, Mexticacan and San Miguel el Alto, as well as in the municipalities of Valle de Guadalupe and Canadas de Obregon, so that the intake of water from these areas represents a greater risk to the health of the local population, likewise an increasing trend in the concentration of fluorides in the groundwater extracted from the study area is ratified, one possible cause being the continuous decrease in the dynamic level of extraction that most of the wells evaluated. It is necessary to implement programs and strategies to guarantee the sustainability of this vital resource in this and other regions of the country.

Keywords: Fluorides in water, Groundwater, Jalisco Mexico.

Resumen

La principal fuente de abastecimiento de agua potable en la mayoría de las regiones administrativas del estado de Jalisco (México) son los acuíferos subterráneos, que en muchos casos son de origen hidrotermal, los cuales se caracterizan por la presencia de compuestos químicos potencialmente nocivos para la salud humana y animal. El área de estudio de este trabajo se ubica en el noreste del estado de Jalisco, que comprende 10 municipios en dos regiones administrativas. El presente estudio tiene como objetivo determinar la tendencia de la concentración de flúor en pozos profundos que abastecen de agua potable a los municipios del área de estudio, a partir de dos evaluaciones realizadas durante los años 2021 y 2022. En los resultados se puede observar una tendencia creciente en la concentración de flúor de la mayoría de los pozos analizados en los periodos estudiados; las mayores concentraciones se reportan en las localidades de Tepatitlán, Arandas, Mexticacán y San Miguel el Alto, así como en los municipios de Valle de Guadalupe y Cañadas de Obregón; el uso de estas fuentes como agua potable representa un mayor riesgo para la salud de la población local, lo que ratifica, asimismo, una tendencia creciente en la concentración de fluoruros en las aguas subterráneas extraídas del área de estudio; una posible causa es la continua disminución en el nivel dinámico de extracción que presentan la mayoría de los pozos evaluados. Es necesario implementar programas y estrategias para garantizar la sostenibilidad de este recurso vital en ésta y otras regiones del país.

Palabras clave: agua subterránea, Altos de Jalisco, fluoruros en agua.

Received: 04/05/2023

Accepted: 10/04/2024

Published online: 03/05/2024

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Introduction

In Mexico, the natural content of fluoride compounds in groundwater varies from 0.001 to 25 mg/l. The states of the Mexican republic that present the highest concentrations of fluorides are mainly those located in the center, north and northwest. In the northeast of the country, precisely these are the regions that report a high prevalence of dental and skeletal fluorosis (Varela *et al*., 2013). The main Mexican cities where drinking water has excess fluorides are Aguascalientes, Chihuahua, Durango, Hermosillo, Salamanca and San Luis Potosí (Leyva & Martinez, 2019).

This is how 17 Mexican states present problems due to natural water contamination by fluoride. This contamination is of geological origin, the result of the natural interaction that groundwater has with some volcanic rocks that are widely disseminated in the Sierra Madre Occidental, and which constitute some of the main aquifers that supply water to the population. In the states of Baja California Norte, Durango, Aguascalientes, Zacatecas and Guanajuato, groundwater contamination is located in most of the state while in Sonora, Chihuahua, Coahuila, Nuevo León, Sinaloa, San Luis Potosí, Jalisco, Michoacán , Querétaro, State of Mexico, Hidalgo and Puebla, the presence of contaminants is observed only in some localities (Conagua, 2018; Rosales, 2013).

Aquifers with naturally occurring fluoride concentrations greater than 1.5 mg/l are found mainly in Chihuahua, Durango, Coahuila, Aguascalientes, Zacatecas, Guanajuato, San Luis Potosí, Jalisco, Querétaro, Puebla and Guerrero (Figure 1).

Figure 1. Location of aquifers in Mexico with high natural concentrations of fluorides. Source: IMTA (2011).

Fluoride compounds are found in most soil types, with total concentrations of between 20 and 1000 µg/g (microgram/gram) in areas without natural phosphate or fluoride deposits and up to several thousand µg/g in mineral soils with fluoride deposits (Del Razo *et al*., 2021). Gaseous fluoride particles suspended in the air tend to accumulate in the surface layer of the soil, but they can move throughout the rhizosphere, even in calcareous soils. The retention of fluorides in the soil depends fundamentally on the clay and organic carbon content, as well as the pH of the soil (Carrillo, Cardona, & Edmunds, 2002; Alcalá, 2007).

Soil fluorides are fundamentally associated with their colloidal or clay fraction; in all types of soil, soluble fluorides are biologically important for plants and animals (IGME, 2020). Fluorides are ubiquitous in the environment; therefore, it is common for water sources to contain them, at least in small quantities. The amount of fluorides naturally present in non-fluoridated drinking water (i.e., drinking water to which fluorides have not been deliberately added to prevent tooth decay) is highly variable, depending on the particular geological environment in which the water comes from (Aguilera, Domínguez, Acevedo, & Rojas, 2006). Levels can reach up to about 2.0 mg/l; however, in areas of the world where endemic fluorosis of the skeleton and/or teeth is well documented, fluoride concentrations in the drinking water supply network range from 3.0 to more than 20.0 mg/l (SEOP, 2019). Dental fluorosis is a condition that appears because of ingesting too much fluoride during the period of tooth development, generally from birth until the age of 6 to 8 years. Too high levels of fluoride interfere with the proper functioning of the cells that form the enamel (odontoblasts), disturbing them and preventing the enamel from maturing normally. The grading of fluorosis ranges from mild to acute, depending on how much one has been exposed to fluorides during the period of tooth development. Therefore, dental fluorosis is an anomaly of the oral cavity, especially of the teeth, caused by excessive and prolonged ingestion of fluoride (Lara, Cruz, & Li, 2017).

The percolation phenomenon consists of the passage of water through the soil and rock formations that contain minerals such as fluorite, cryolite and fluorapatite. In this process, fluoride compounds dissolve, entering natural underground water sources, being a part of the biogeochemical cycle of the chemical elements present in nature (Martínez, 2013).

The constant consumption of water with a composition that is not suitable for health is the possible origin of various diseases of the skin, teeth, bones and internal organs such as the liver. Therefore, the presence of many compounds and chemical elements dissolved in water should not exceed the levels allowed for adequate and safe human consumption (SIWI, 2005).

Likewise, fluoride is essential for the bone structure of both higher animals and humans. In very low concentrations or absence it can cause deformations in bones and joints. Likewise, in concentrations greater than 1.0 mg/l it can be harmful for health in general (Bavera, 2006).

Fluoride is an important element for human health and is obtained in the form of compounds such as fluorides mainly through the consumption of groundwater. However, when water with more than 0.7 mg/l of fluorides is continuously consumed, which is the maximum recommended by the World Health Organization (OMS, 2018), then the health of the population is being put at risk (USDHHSF, 2015).

The natural concentration of fluorides depends on geological, chemical and physical characteristics of the aquifer, the porosity and acidity of the earth and stone material, temperature, the action of other chemical elements and the depth of the extraction wells (Huízar, Varela, & Espinoza, 2016).

The main source for the supply of drinking water in most of the administrative regions of the state of Jalisco (Mexico) are underground aquifers, which in many cases are of hydrothermal origin, and are characterized by the presence of chemical compounds potentially harmful to the environment human and animal consumption.

In Mexico, the Official Mexican Standard NOM-127-SSA1-2021 (Secretaría de Salud, 2021), which refers to the permissible limits of the quality of water for human use and consumption, in its section on chemical sanitary specifications, establishes as the maximum permissible limit for fluorides the value of 1.50 mg/l for all locations, this reference must be adjusted to 1.0 mg/l, according to the gradual compliance Table 1, which refers both to the population density of the various localities in the national territory, and to the year in which these populations must observe the new limit for the fluoride content in water for human consumption.

Table 1. NOM-127-SSA1-2021; phased compliance for fluorides.

Location	**Year**	**Allowable limit**	**Units**
Greater than 500000 inhabitants	One year after the entry into force of this Standard	1.0	mg/l
Between 50000 and 499999 inhabitants	Three years after the entry into force of this Standard	1.0	mg/l
Less than 500000 inhabitants	Six years after the entry into force of this Standard	1.0	mg/l

Source: DOF (2022).

It is important to mention that NOM-127-SSA1-2021 came into force on April 26, 2023, according to the Official Journal of the Federation (DOF, 2023).

On the other hand, both the Department of Health and Human Services and the United States Environmental Protection Agency (USDHHSF/USEPA) recommend a maximum concentration of fluorides in drinking water of 0.7 mg/l (USDHHSF, 2015; USEPA, 2016), seeking to balance the benefits of preventing dental caries and setting the limit of unwanted effects on health. While the Agency for Toxic Substances and Disease Registry (ATSDR, 2020) has calculated the minimum reference fluoride consumption of 0.05 mg/kg/day for chronic oral exposure. The recommended doses in the United States and Canada are 4.0 mg/day for men, 3.0 mg/day for women, and between 2.0 and 3.0 mg/day for children and adolescents (Alarcon *et al*., 2013).

The main objective of the present study is to determine the concentration of fluorides in groundwater in the South-Highland region of the state of Jalisco (Altos-Sur). The aim is to establish the trend in the presence of fluorides presented by the deep wells that supply drinking water to the municipalities of the Tepatitlan aquifer, comparing the results in the evaluations carried out in 2021 and 2022.

Likewise, the results obtained will be contrasted with the official regulations in Mexico for relation to the preservation of the health of the population that uses these supply sources for drinking and consumption water.

Materials and methods

The study area essentially includes the Tepatitlan aquifer (Identification key: 1414, according to the National Water Commission (Conagua for its acronym in Spanish), Conagua (2018), which is located in the northeastern portion of the state of Jalisco in western Mexico (Figure 2), covering an area of 1940 km², approximately 2.47 % of the state territory (Conagua, 2002).

Figure 2. Location of the state of Jalisco in the Mexican Republic.
Source: Travel By Mexico (2023).

Comprising nine municipalities located in the South-Highlands administrative region; Tepatitlan, Arandas, Acatic, San Miguel el Alto, Canadas de Obregon, Mexticacan Valle de Guadalupe and Yahualica and one municipality in the Central administrative region (Centro); Cuquio (Figure 3), the Population density of this area can be seen in Table 2.

Figure 3. Location of the administrative regions of the state of Jalisco. Source: Mapa Interactivo (2023).

Table 2. Population density in the study area (2020).

Municipality	Population	Delegations
Tepatitlan	150190	Pegueros, Capilla de Guadalupe, San Jose de Gracia, Mezcala, Capilla de Milpillas, Tecomatlan
Arandas	80609	El tule, Los Dolores, Santiaguito de Velazquez, Manuel Martinez Valadez.
Acatic	23175	El Refugio, Tierras Coloradas, Las Motas, Santa Rita, Tequilillas
Cuquio	17820	Las Cruces, San Juan del Monte, Teponahuasco, Juchitlan
Mexticacan	53076	San Jose de Ojuelos, San Felipe, Chimaliquin de Arriba, Canada de Islas, El Santuario
Valle de Guadalupe	6628	La Llave, Puerta de Macías, Alto de San Joaquín, El Bajío, La Providencia
Canadas de Obregon	4388	El Rosario, Temacapulin, Los Yugos, El Zapotillo, Santa Rosalía
San Miguel el Alto	31965	Santa Maria del Valle, Mirandillas, San José de los Reynoso, Belen
Yahualica de Gonzalez Gallo	22394	Manalisco, Huisquilco, Rio Colorado, El Baluarte, Apozol de Gutiérrez, Tecoluta
San Ignacio Cerro Gordo	18341	Los Dolores, La Trinidad, San Vicente, Cerro Gordo

Source: INEGI (2021).

Using information from the drinking water operating organizations in the participating municipalities, as well as several field trips and geographical information, the main deep wells in operation for the supply of drinking water in the study area were located, including on this occasion

118 wells, with average dynamic extraction levels of 180 meters deep, which operate regularly from 4 to 24 hours a day, with flow rates ranging from 3 to 40 liters per second (lps).

Sampling and monitoring campaigns were carried out in the extraction wells in the study area in the years 2021 and 2022, during the months of July to November; the water samples were collected as described by Mexican regulations (NOM-230-SSA1-2002) (DOF, 2005).

The analysis of the fluoride concentration was carried out in the Water Analysis Laboratory of the Centro Universitario de los Altos (University of Guadalajara), observing both the current official regulations (NMX-AA-077-SCFI-2001) (SCFI, 2001) and the methodology analysis included in standard methods for examinations of water and wastewater (APHA, 2017).

Fluoride concentrations were determined using the "SPANDS" colorimetric method (Hach, 2018), which has high sensitivity, with an analytical range between 0 and 2.50 mg/l. This technique uses reagents: Hydrochloric acid, Zirconium oxychloride and Sodium arsenate (Cat. 44449-LM, Hach). The main equipment used for the determination of fluorides in groundwater was the DR 2800 visible spectrophotometer (Hach), which consists of a visible spectrum spectrophotometer, with a wavelength range of 340 to 900 nanometers (Figure 4).

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Figure 4. DR 2800 spectrophotometer (Hach). Source: Hach (2018).

The equipment was calibrated according to the manufacturer's specifications, with the program for fluoride determination, making dilutions with standard deionized water when necessary (1:10, 1:20).

In general, the arithmetic averages of each group of samples (deep wells), of each section (ID) of the study area were determined to generate the following results.

Results

Most of the 118 deep wells used as sources for the supply of drinking water for the corresponding populations that made up the study area belong to the Tepatitlan aquifer, located in the northeastern portion of the state of Jalisco in region VIII Lerma- Santiago-Pacific, covering an approximate surface of 1940 km² (2.47 % of the state territory), according to the Federal Law on Water Rights (2015), this aquifer has limited availability (Conagua, 2018).

Based on the historical data of precipitation, temperature and evaporation from the climatological stations that cover the study area, and with the support of the 1:1 000 000 scale Climate Atlas, it is observed that the study area is characterized by three types of climates: (A) C(w1) w, C(w1) (w) and C(w2) (w), which correspond to a semi-dry sub-humid and temperate sub-humid climate (CEA-Jal, 2018a). The average concentration of fluorides in deep wells during the evaluated years of 2021 and 2022, of the 10 municipalities in the study area, appear in Table 3, observing maximum standard deviations (sd) in 2021 of 0.110 and 0.117 for 2022.

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Table 3. Average concentration of fluorides in mg/l and standard deviation (sd) by location in two evaluations: 2021 and 2022.

ID	Municipality	Location/Description	Number of wells	2021 Average (sd)	2022 Average (sd)
T1	Tepatitlan	Tepatitlan, center	5	0.65(0.037)	0.88(0.049)
T2	Tepatitlan	Tepatitlan, north	10	1.12 (0.076)	1.34(0.083)
T3	Tepatitlan	Tepatitlan, south	6	2.10(0.093)	2.02(0.082)
T4	Tepatitlan	Tepatitlan, east	11	3.20(0.097)	4.55(0.117)
T5	Tepatitlan	Tepatitlan, west	16	3.70 (0.104)	3.97(0.102)
T6	Tepatitlan	Capilla de Guadalupe	3	1.63(0.051)	1.68(0.065)
T7	Tepatitlan	Pegueros	3	0.25(0.034)	0.18(0.047)
T8	Tepatitlan	San Jose de Gracia	3	0.17(0.045)	0.25(0.059)
T9	Tepatitlan	Mezcla	3	1.57(0.062)	1.59(0.074)
T10	Tepatitlan	Capilla de Milpillas	3	0.55(0.053)	0.67(0.045)
A1	Arandas	Arandas, center	4	1.21(0.077)	1.53(0.083)
A2	Arandas	Arandas, north	2	0.42(0.039)	0.78(0.086)
A3	Arandas	Arandas, south	3	0.68(0.033)	1.34(0.073)
A4	Arandas	Arandas, east	4	0.36(0.086)	0.76(0.092)
A5	Arandas	Arandas, west	6	1.09(0.110)	1.02(0.092)
SMA1	San Miguel el Alto	San Miguel el Alto, center	2	2.43(0.059)	3.76(0.083)
SMA2	San Miguel el Alto	San José de los Reynoso	1	0.38	0.56
SMA3	San Miguel el Alto	Sta. María del Valle	2	0.15(0.036)	0.32(0.056)
VG1	Valle de Guadalupe	Valle de Guadalupe, center	2	3.42(0.083)	3.61(0.093)
VG2	Valle de Guadalupe	La Providencia	1	7.43	8.45
VG3	Valle de Guadalupe	Puerta de Macias	1	2.62	1.78

ID	Municipality	Location/Description	Number of wells	2021 Average (sd)	2022 Average (sd)
VG4	Valle de Guadalupe	Pajaritos	1	1.76	2.74
AC1	Acatic	Acatic, center	3	0.33(0.076)	0.56(0.085)
AC2	Acatic	Las amapolas	1	0.21	0.67
Y1	Yahualica	Yahualica, center	3	0.35(0.045)	0.45(0.057)
Y2	Yahualica	Yahualica, north	2	0.53(0.090)	0.49(0.074)
Y3	Yahualica	Yahualica, south	3	0.17(0.064)	0.32(0.092)
Y4	Yahualica	Yahualica, east	2	0.36(0.023)	0.47(0.061)
Y5	Yahualica	Yahualica, west	3	0.51(0.065)	0.45(0.074)
C1	Cuquio	Cuquio, center	2	0.07(0.057)	0.11(0.073)
C2	Cuquio	Martires del 28	1	0.33	0.53
M1	Mexticacán	Mexticacán, center	2	1.72(0.034)	3.61(0.072)
CO1	Canadas de Obregon	Canadas de Obregón, center	1	1.68	2.32
CO2	Canadas de Obregon	Temacapulln, center	1	3.00	3.52
SI1	San Ignacio Cerro Gordo	San Ignacio Cerro Gordo, center	2	0.75(0.033)	1.03(0.052)

In reference to the year 2021, it is possible to observe an increasing trend in the concentration of fluorides in most of the wells analyzed during the year 2022.

Likewise, fluoride concentrations greater than 1.5 mg/l are found mainly in the population of Tepatitlan (T3, T4, T5, T6 and T9), in the center of the city of Arandas (A1), in the center of San Miguel el Alto, in the municipality of Valle de Guadalupe (VG1, VG2, VG3 and VG4), in the center of the population of Mexticacan (M1) and in the municipality of Canadas de Obregon (CO1 and CO2).

The localities with the highest relative values in 2022 were mainly: East Tepatitlan (T4), center of San Miguel el Alto (SM1), municipality of Valle de Guadalupe (VG2 and VG4) and central Mexticacan (M1), so the intake The water in these areas represents a greater risk to the health of the local population, in contrast to the rest of the study area (Figure 5).

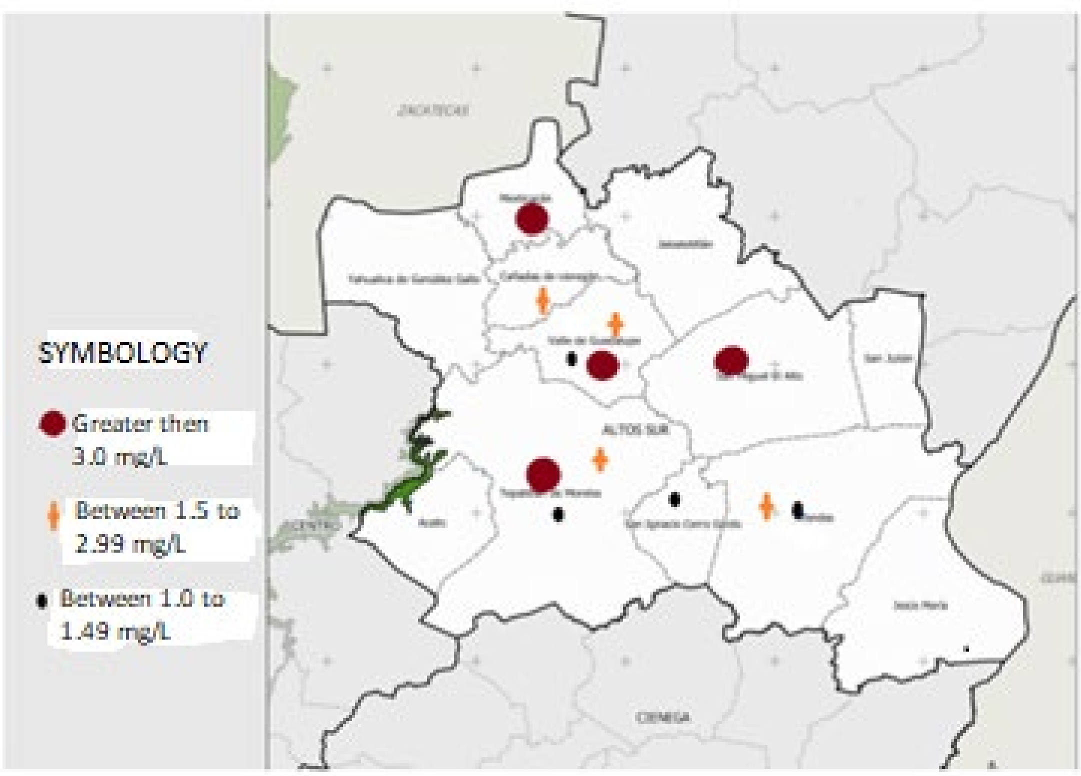

Figure 5. Location of the highest concentrations of fluorides in the study area (2022).

In the 2022 evaluation, 14 of the 35 samples studied (40 %) exceed the maximum permissible limit of 1.5 mg/l for drinking water established by the official standard in force in Mexico and 51 % of the samples analyzed exceed the reference of 1.0 mg/l. Making a comparison between the results obtained in 2021 and those generated in 2022 (Table 4), it can be seen that the majority suffered increases (31 out of 35) with increase percentages ranging from 4.4 to 220 %.

Table 4. Variations between evaluations (2022 and 2021) and percentage increases.

ID	2021	2022	Variations 2022-2021	Increase percentage (%)
T1	0.65	0.88	+0.23	35.4
T2	1.12	1.34	+0.22	7.0
T3	2.10	2.02	-	-
T4	3.20	4.55	+1.35	42.2
T5	3.70	3.97	+0.27	7.3
T6	1.63	1.68	+0.05	4.4
T7	0.25	0.18	-	-
T8	0.17	0.25	+0.08	25.5
T9	1.57	1.59	+0.02	16.1
T10	0.55	0.67	+0.12	21.8
A1	1.21	1.53	+0.32	26.5
A2	0.42	0.78	+0.36	85.7
A3	0.68	1.34	+0.66	97.1

ID	2021	2022	Variations 2022-2021	Increase percentage (%)
A4	0.36	0.76	+0.4	11.4
A5	1.09	1.02	-	-
SMA1	2.43	3.76	+1.33	54.7
SMA2	0.38	0.56	+0.18	47.4
SMA3	0.15	0.32	+0.17	113.3
VG1	3.42	3.61	+0.19	5.5
VG2	7.43	8.45	+1.02	13.7
VG3	2.62	1.78	-	-
VG4	1.76	2.74	+0.98	55.6
AC1	0.33	0.56	+0.23	70.0
AC2	0.21	0.67	+0.46	220
Y1	0.35	0.45	+0.1	28.6
Y2	0.53	0.49	-	-
Y3	0.17	0.32	+0.15	88.2
Y4	0.36	0.47	+0.11	30.5
Y5	0.51	0.45	-	-
C1	0.07	0.11	+.04	57.1
C2	0.33	0.53	+0.2	60.6
M1	1.72	3.61	+1.89	110
CO1	1.68	2.32	+0.64	38.1
CO2	3.00	3.52	+0.52	17.3
SI1	0.75	1.03	+0.28	27.2

The areas where the greatest increases in fluoride concentrations occurred between the two determinations were: Acatic, Mexticacan, Arandas, San Miguel el Altos and Yahualica, likewise the municipalities that presented the smallest increases were: Cuquio, Valle de Guadalupe and Tepatitlan (Figure 6).

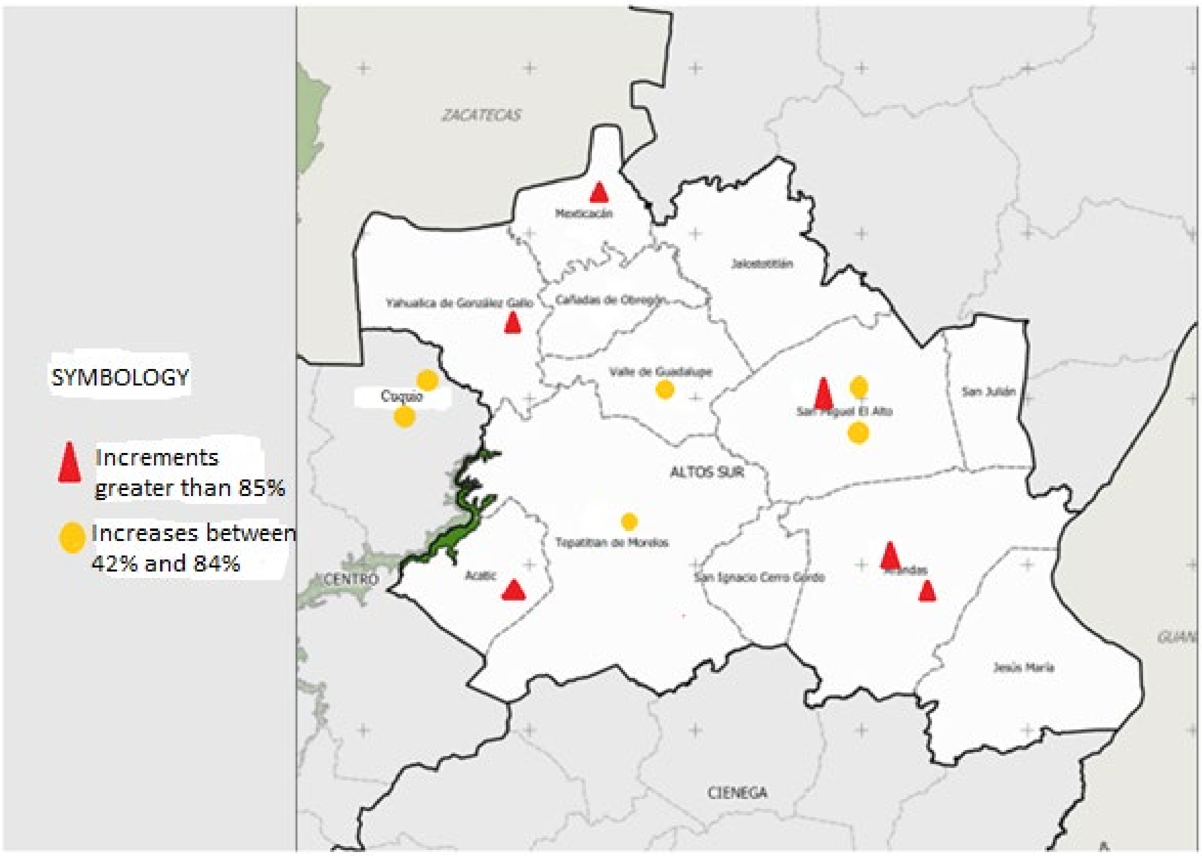

Figure 6. Location of the largest increases in fluoride concentrations in the study area (from 2021 to 2022).

Likewise, most of the municipalities studied presented increases greater than 0.5 mg/l of fluorides in their groundwater (Figure 7).

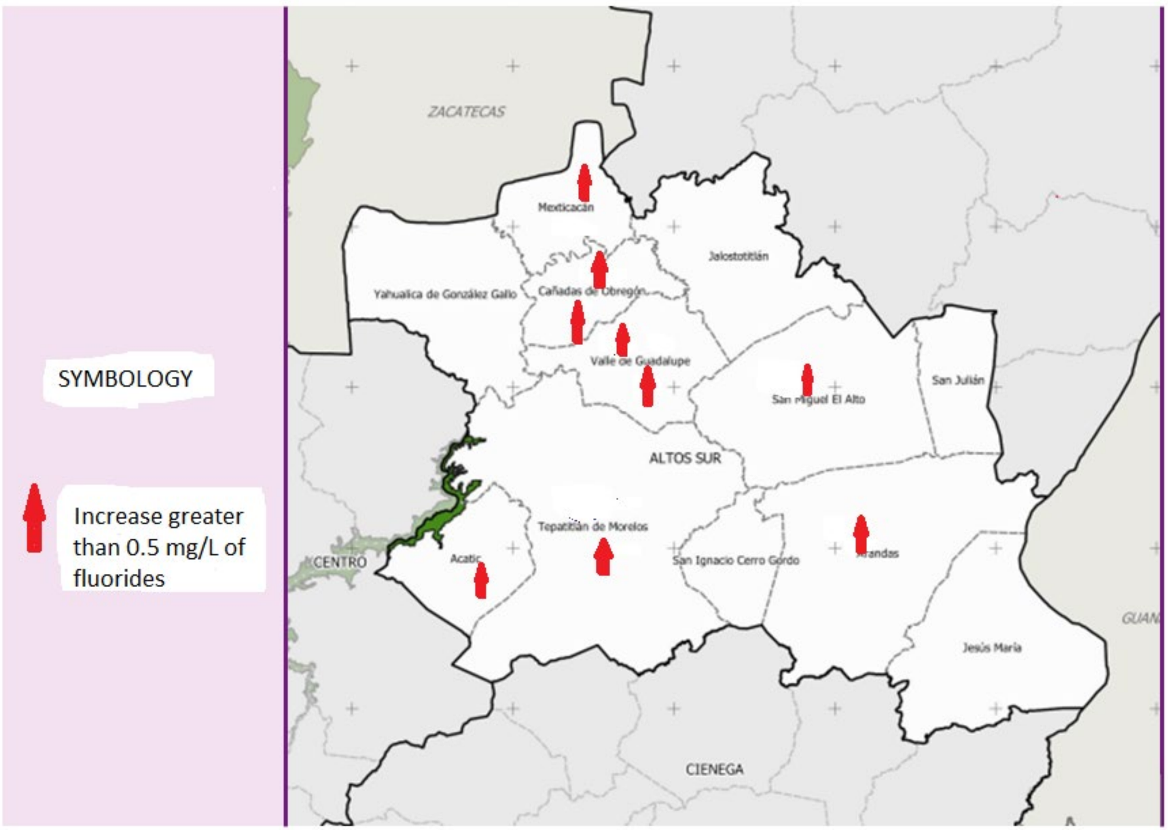

Figure 7. Location of areas with increases greater than 0.5 mg/l of fluorides (from 2021 to 2022).

Discussion

Dental fluorosis is defined as a hypo-mineralization of enamel and dentin related to the ingestion of high concentrations of fluoride in the formation of enamel. It is a public health problem that affects a wide area of Mexico, mainly the central regions and north (Jimenez & Lopez, 2020), likewise, Hurtado and Gardea (2005), state that the risks of dental fluorosis occurring in populations in the northern region of Jalisco are very high, since a large part of the population consumes drinking water (bottled or tap) with concentrations greater than 1.5 mg/l, with the eventual prevalence of skeletal fluorosis in the populations of Teocaltiche, Mexticacan and Temacapulin, since fluorides exceed concentrations of 2.18 mg/l. Likewise, communities in this area that consume drinking water with amounts of fluorides greater than 4.0 mg/l are undoubtedly exposed to severe fluorotic diseases such as skeletal fluorosis, bone fractures, cancer, gastrointestinal disorders, and kidney disorders (Hurtado & Gardea, 2005). The populations with the highest risks are: Encarnacion de Diaz, Lagos de Moreno, Mexticacan, San Juan de los Lagos, Teocaltiche, Tepatitlan and Valle de Guadalupe (Hurtado & Gardea, 2005).

On the other hand, the increase in the concentration of compounds such as fluorides in extracted groundwater can be an indicator of dynamic depletion (significant decrease in water level) of deep wells used as sources of drinking water supply (CEA-Jal, 2018b). For example, in recent studies carried out in the city of Tepatitlan Jalisco in deep wells for the supply of drinking water, it is reported that; Almost 17 % of the network's wells do not operate mainly due to the reduction in dynamic levels (up to 240 m depth) and more than 25 % of the wells have natural fluoride concentrations greater than 1.5 mg/l. It is assumed that the extraction volumes are greater than the recharge volumes of the aquifer, therefore, where it is possible, deeper waters are extracted, which puts the sustainability of the aquifer at risk (Castañeda, 2020).

It is of utmost importance to maintain continuous monitoring programs of these supply sources, including implementing mechanisms to regulate high concentrations of fluorides, as well as, for example, artificial recharge, through which it is possible to improve the storage conditions of groundwater of the region.

The results and evidence found in these evaluations agree with other studies carried out in the same study area, such as those carried out in the wells for water supply in the towns of Popotes and El Pochote in the municipality of Tepatitlan (Fernández, Venegas, Fuentes, & Trujillo, 2017) where both the high concentration of fluorides was manifested, mainly in the water of the Popotes community, as well as the low level of knowledge on the part of users about the health effects of consuming water with high contents of fluorides (fluorosis).

In another study carried out in primary schools, it was reported that the prevalence of fluorosis in the city of Tepatitlan was 64.1 %, with no significant difference between men and women, in reference to the type of water consumed; jug or filtered, the results did not reflect lower rates of fluorosis, indicating that the purification processes applied are not sufficient to reduce these compounds and other minerals, likewise on that occasion it was concluded that 85 % of children who consume well water, they present some degree of fluorosis (Briones, 2017).

Pérez, Scherman and Hernández (2007) for drinking water with high fluoride content in children from the population of Mexticacan, Jalisco found significant differences in age, residence time, type of water consumption and dental fluorosis ($p < 0.05$), as well as differences between the average fluoride concentration and the thermal and cold water wells ($p < 0.05$), reaffirming that "The high fluoride content in the water puts the dental health of the children's population at risk."

On the other hand, understanding the hydrogeological models of the regions where the presence of fluorides in groundwater is studied is of great importance to find their main origins and dynamics, as well as the intergranular units (stratified) with families of fractures that affect the sequence. of hard rocks and make hydraulic flow possible in the lithostratigraphic chain, generally forming mixed aquifers (intergranular-fissured), whose recharges take place in the reliefs that delimit the corresponding plains (Huízar *et al*., 2014).

Huízar, Carrillo and Juárez (2016) conclude in their approaches to fluorides in a region of the state of Morelos, that the main source of this compound in groundwater is found in the rocks that make up the relief that surrounds the plain and mainly in that located outside the plain (northeast of the Sierra Nevada), confirming that fluorides are released into groundwater by the process of chemical weathering of intermediate igneous and felsic rocks.

Conclusions

The trend towards increasing the concentration of compounds such as fluorides in the extracted groundwater may be an indicator of the eventual extraction of deeper waters, which may be fossil waters, which presupposes alterations in the recharge cycles, where the Annual quantities extracted exceed the volumes of the natural recharge of the aquifer, presenting a potential risk for the adequate sustainability of the aquifer.

The consistent childhood dental fluorosis predominant in the northern region of Jalisco is linked to the ingestion of high concentrations of fluoride, mainly in the formation of enamel, which causes risks to the public health of the population, in this sense urban centers such as those of Tepatitlan, Arandas, Acatic, Mexticacan, San Miguel el Alto and Yahualica, present greater remains for the adequate management of their underground supply sources for drinking and consumption water, therefore it is necessary to implement programs and strategies that guarantee water sustainability in many regions of the country.

Acknowledgments

We recognize the technical support provided by the Investigation Group UDG-561 "Comprehensive Water Management", to the Laboratory for Water Analysis of the Centro Universitario de Los Altos (University of Guadalajara), as well as to the drinking water operating organizations of the participating municipalities.

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