

# Fluoride content in table salt from the Element Project in Mexico City

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Tamayo-Cabeza G, Mantilla-Rodríguez A, Cantoral A, Téllez-Rojo MM, Peterson KE, Hu H, Martínez-Mier EA. Fluoride content in table salt from the Element Project in Mexico City. *Salud Publica Mex.* 2025;67:48-55.

<https://doi.org/10.21149/15734>

Tamayo-Cabeza G, Mantilla-Rodríguez A, Cantoral A, Téllez-Rojo MM, Peterson KE, Hu H, Martínez-Mier EA. Contenido de fluoruro en sal de mesa del Proyecto Element en la Ciudad de México. *Salud Publica Mex.* 2025;67:48-55.

<https://doi.org/10.21149/15734>

## Abstract

**Objective.** This study evaluated fluoride content in table salts from participants' households of the Element project, comparing them with the Mexican standards of fluoride content in table salt (200 to 250 mg/kg). **Materials and methods.** Salt samples were collected from households of mother-offspring pairs participating in Element. Salt samples were analyzed in duplicates using a combination fluoride ion-selective electrode and a pH/ISE meter. **Results.** Among 657 samples from 14 brands, fluoride varied from 0.016 to 477.9 mg/kg with a median (IQR) of 142.5 (136.9). Of salts labeled as fluoridated or containing fluoride (n= 607), we found that 72.8% (n= 442) had fluoride content below the recommended range and 13.8% (n= 84) were above the Mexican norm. Only 81 salt samples (13.3%) fell within recommended limits. **Conclusion.** Future studies with representative sampling are needed to evaluate table salt fluoride content, especially in high-fluoride areas, to inform potential adjustments to the current monitoring program.

Keywords: fluorides; table salt; Mexico; cohort studies; environmental exposure; public health surveillance

## Resumen

**Objetivo.** Este estudio evaluó el contenido de fluoruro en las sales de mesa de los participantes del proyecto Element, comparándolas con la normatividad mexicana sobre contenido de fluoruro en sal (200 a 250 mg/kg). **Material y métodos.** Se recolectaron muestras de sal de los hogares de pares madre-hijo participantes en Element. Las muestras se analizaron por duplicado utilizando un electrodo selectivo de ion-fluoruro y medidor pH/ISE. **Resultados.** Entre 657 muestras de 14 marcas, el fluoruro varió entre 0.016 a 477.9 mg/kg con una mediana (RIQ) de 142.5 (136.9). De las sales etiquetadas como fluoradas (n= 607), 72.8% (n= 442) estuvo por debajo del rango recomendado y 13.8% (n= 84) mayor a la norma mexicana. Sólo 81 muestras de sal (13.3%) se encontraban dentro de los valores recomendados. **Conclusión.** Futuros estudios con un muestreo representativo son necesarios para evaluar el contenido de fluoruro en la sal de mesa, especialmente en zonas con altas concentraciones de fluoruro, a fin de informar posibles ajustes al programa de monitoreo actual.

Palabras clave: fluoruros; sal de mesa; México; estudios de cohortes; exposición a riesgos ambientales; vigilancia en salud pública

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Received on: March 1, 2024 • Accepted on: August 7, 2024 • Published online: November 27, 2024  
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Fluoride was initially added to community water supplies in the 1940s in the United States due to its observed protective effects against dental caries.<sup>1</sup> Based on the success of water fluoridation for caries prevention, and on the previous use of table salt (sodium chloride) as a vehicle for the micronutrient iodine, fluoride was first added to salt in the 1950s in Switzerland.<sup>2</sup> The cariostatic effect of fluoride added to salt was then observed in other European countries,<sup>3-5</sup> with salt fluoridation (200 mg/kg) providing benefits similar to those of water fluoridation.<sup>6</sup> In the Americas, results from a trial set in Colombia showed a 60-65% reduction in caries when fluoridated salt was consumed.<sup>6,7</sup> The Colombian results encouraged other Latin American countries to implement salt fluoridation.

In Mexico, salt fluoridation has been implemented in some areas since 1981 and in most states since 1995.<sup>8,9</sup> It has been suggested as one of the contributing factors in the reduction of dental caries in Mexico City.<sup>10,11</sup> To regulate fluoride content in salt and its distribution throughout the country, the Mexican standards (Official Mexican Norm NOM-040-SSA1-1993) establishes that fluoridated salt distributed in the country should contain 200 to 250 mg/kg, except in populations where drinking water has a concentration above 0.7 mg/L (in some northwestern states).<sup>12</sup>

Although a monitoring program for salt fluoridation has been implemented in Mexico by the Federal Commission for Protection Against Health Risks (Cofepris, by its acronym in Spanish),<sup>13</sup> previous studies have reported that the true content of fluoride in table salt in Mexico City, where no water fluoridation program exists, has been found to be inconsistent with the NOM's recommended content and also to differ from the content indicated on the package labels.<sup>14,15</sup> In addition, previous studies have reported a broad variation in the fluoride content of table salt in Mexico City, which raises the need for better monitoring its concentration and distribution.<sup>15,16</sup> A meta-analysis of nine studies,<sup>17</sup> including one from Mexico,<sup>11</sup> found significant reductions in Decayed, Missing, and Filled Teeth (DMFT) scores with salt fluoridation: -0.98 for 6-8-year-olds, -2.13 for 9-12-year-olds, and -4.22 for 13-15-year-olds, suggesting higher dental caries risk with lower exposure to fluoridated salt as intervention. An adequate concentration of fluoride in salt would balance the proven protective effects against dental caries while limiting the risk of toxicity in the population.

In addition to the widely known dental and skeletal defects caused by excessive intake of fluoride, previous studies have investigated the effects of fluoride on cognition and have found that higher prenatal fluoride exposure was associated with more Attention

Deficit Hyperactivity Disorder-like symptoms in the offspring,<sup>18</sup> lower scores on tests of cognitive function in the offspring,<sup>19</sup> and a two-point decrement in children's Full-Scale IQ scores.<sup>20</sup> Also, sex-specific associations on cognitive scores have been associated with dietary fluoride intake in pregnancy.<sup>21</sup> While evidence indicates adverse effects of fluoride at higher concentrations, such as an IQ decrease above 1 mg/L in water, there is a growing body of research suggesting optimal concentrations for minimizing harm and maximizing benefit.<sup>22</sup> This evidence supports the need to evaluate fluoride exposure in the population, especially in communities where systemic fluoridation is implemented, such is the case of most states in Mexico. The aim of the present study was to determine the fluoride content in various Mexican salts collected from the participant's households of the Early Life Exposures in Mexico to Environmental Toxicants (Element) cohorts, located in Mexico City, and to compare the fluoride content to the NOM's recommended range of fluoride content in table salt.

## Materials and methods

### Selection of samples

Salt samples were collected from households of mother-offspring pairs participating in cohorts one to three of Element. The Element project is a series of sequentially enrolled epidemiological birth cohorts based in Mexico City. The project began in 1994 as an effort to understand the effects on health and neurodevelopmental derived from exposure to environmental toxins. Description of the number of participants recruited in each cohort by each study period can be found elsewhere.<sup>23</sup> Participants were originally recruited from three maternity hospitals affiliated with the *Instituto Mexicano del Seguro Social* (IMSS). These hospitals serve a broad segment of the population, including middle-class families.

### Inclusion criteria and selection process

The mother-offspring pairs were selected based on their participation in the Element project, with eligibility criteria including residency in Mexico City, having a child within the age range of the ongoing evaluations and consent to participate in additional environmental sample collection. The households participating in this study encompassed a range of socioeconomic backgrounds, predominantly middle-class. In this study, salt samples were collected from the households of 545 mother-offspring pairs participating in the Element project, representing a subset (27%) of the 1988 participants originally recruited across the three cohorts.

## Collection of samples

A sample (approximately 10.0 g with minimum sample of 5.0 g) of salt was collected from the top of the table salt package or container and transferred to a 15 mL Corning™ CentriStar™ polypropylene tube (Fisher, catalog # 05-538-59B) using a funnel and spoon (one funnel and spoon per collection avoiding cross-contamination). In some cases (n= 115), the same household provided an additional sample of different origin (land or sea) or grain size (coarse or refined) as identified in the label. Salt samples were stored at room temperature. Salt samples collection period begun in January 2015 and was completed in January 2016.

Ethical approval for the Element project, including the collection of salt samples from participants' households, was obtained from the research committees from *Instituto Nacional de Salud Pública* (INSP), and by the institutional review board of Indiana University and University of Michigan.

## Table salt characteristics

Labels of table salt samples were reviewed and characteristics such as brand, whether they were labeled as fluoridated or containing fluoride in their list of ingredients, type of fluoride compound listed as used for fluoridation, source (land or sea origin) and grain's size (refined or coarse) were recorded in a Microsoft Office Excel spreadsheet.

## Analysis of fluoride content

Samples were analyzed for fluoride content at the Oral Health Research Institute of Indiana University School of Dentistry. This laboratory developed standards for the determination of fluoride content in various biological and non-biological samples,<sup>24</sup> including table salt.<sup>25</sup> The study adhered to the standards of Good Laboratory Practice for Nonclinical Laboratory Studies as specified in the Code of Federal Regulations Title 21, Part 58 by the U.S. Food and Drug Administration (FDA).

Salt samples were weighed to 2.00 g and dissolved in 20.0 mL deionized water by duplicates; 1 mL of each sample was then mixed with 1.0 mL TISAB II (Orion, #940909 Fisher Scientific) and analyzed using a combination fluoride ion-selective electrode (Orion, #96-909-00 Fisher Scientific Co. USA) and a Thermo Scientific Orion pH/ISE meter (Cat. # 21-15-001, Fisher Scientific Co. USA). Prior to sample analyses, a standard fluoride curve was prepared and used for determination of the fluoride content of each salt sample.

## Data analysis

Descriptive statistics such as frequencies, median, interquartile range (IQR), minimum and maximum were calculated. Shapiro-Wilk test was used to test for normality of the fluoride content in table salt data. Wilcoxon rank sum test with continuity correction was used to compare fluoride content by source, categorized based on the label information (e.g., 'sal marina' for sea salt). This categorization was based solely on label indications. Wilcoxon rank sum test with continuity correction was also used to compare fluoride content by grain's size (refined or coarse). Values of  $p < 0.05$  were considered statistically significant. Statistical analysis was performed using R version 4.2.1.<sup>26</sup>

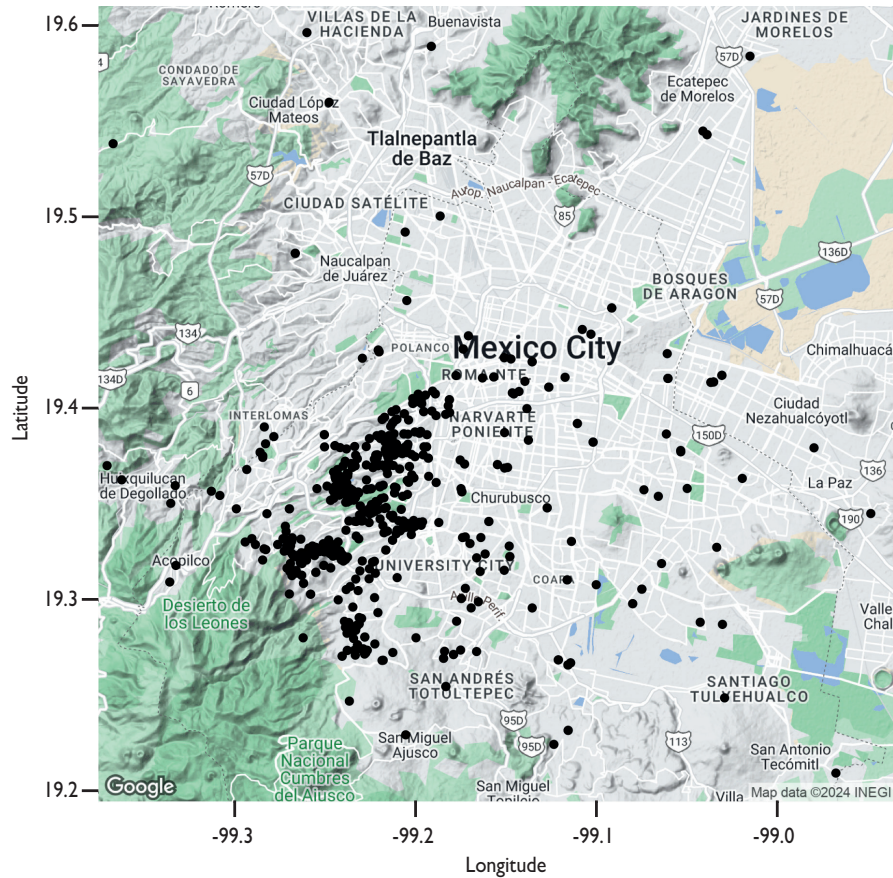
## Results

A total of 657 table salt samples from 14 distinct commercial brands were analyzed for fluoride content. The fluoride content in salt ranged from 0.016 to 477.9 mg/kg and median (IQR) of 142.5 (136.9) mg/kg. Figure 1 shows the locations of households where samples were collected across Mexico City. The households were more frequently located in Alvaro Obregon (n= 336, 61.7%), Magdalena Contreras (n= 62, 11.4%), Tlalpan (n= 56, 10.3%), Miguel Hidalgo (n= 29, 5.3%), Coyoacán (n= 22, 4.0%) and other boroughs of Mexico City (n= 40, 7.3%).

Table I presents the fluoride content in salt samples by each commercial brand. Seventy percent of collected salt samples were "Sal La Fina" with median (IQR) fluoride content of 135.9 (136.0) mg/kg, which is below the range established by the NOM (200 to 250 mg/kg). The second most common brand collected ("Sal Elefante") also had a median (IQR) fluoride content below the norm (188.3 [142.5] mg/kg). It was also observed that 11.1% (n= 51/460) and 25.4% (n= 29/114) of "Sal La Fina" and "Sal Elefante" samples, respectively, were above the recommended fluoride levels (figure 2).

Overall, comparing the fluoride content in table salt samples labeled as fluoridated or containing fluoride in their ingredients (n= 607) to the NOM's recommended range, we found that 72.8% (n= 442) had fluoride content below the recommended range, and 13.8% (n= 84) were above the Mexican guidelines. Only 81 salt samples (13.3%) fell within recommended limits (figure 2).

Salt samples labeled as fluoridated or having fluoride listed in their ingredients showed median (IQR) fluoride content of 144.7 (129.5) mg/kg (table II). Most salt products (92.2%) had potassium fluoride (612 to 765 mg/kg salt) listed as the fluoride compound used for fluoridation. There were 556 (84.6%) products of



Note: the map shows the locations of households, with a higher frequency of samples collected from Álvaro Obregón ( $n = 336, 61.7\%$ ), followed by Magdalena Contreras ( $n = 62, 11.4\%$ ), Tlalpan ( $n = 56, 10.3\%$ ), Miguel Hidalgo ( $n = 29, 5.3\%$ ), Coyoacán ( $n = 22, 4.0\%$ ), and other boroughs ( $n = 40, 7.3\%$ ).

**FIGURE I. GEOGRAPHIC DISTRIBUTION OF HOUSEHOLDS (N= 545) IN MEXICO CITY WHERE TABLE SALT SAMPLES WERE COLLECTED**

land origin with median (IQR) fluoride content of 141.2 (137.4) mg/kg. Regarding the salts' grain size, there were 515 (78.4%) refined salt products with a median (IQR) fluoride content of 135.7 (137.2) mg/kg. Coarse salt samples showed a higher median fluoride content compared to refined salt ( $p < 0.001$ ) (table II).

## Discussion

Fluoride content in table salt collected in Mexico City displayed a broad range of concentrations, from 0.016 to 477.9 mg/kg. We found that 72.8% ( $n = 442$ ) of samples had fluoride content below the recommended range, and 13.8% ( $n = 84$ ) were above the Mexican regulations. Moreover, we observed a lower mean fluoride content in refined salt samples compared to coarse salt samples.

We found a broad variation of the fluoride content in table salt samples. A previous report published in the

year 2008 that assessed fluoride concentration in table salt distributed in Mexico City also demonstrated a similar variation from 0 mg/kg to 485 mg/kg.<sup>15</sup> It was suggested that the variability in the fluoride content of table salt could be attributed to a possible lack of information from the salt manufacturers on the regulations recently enacted at that time by the Mexican Health Secretary that mandates a fluoride content in salt between 200 to 250 mg/kg salt, and no distribution in areas with water fluoride concentration above 0.7 mg/L.<sup>12,15</sup> A second possible reason could be that salt manufacturers have not set up appropriate monitoring procedures to evaluate fluoride content in their final products.

The findings from our study show a discrepancy in fluoride content of table salt when compared to the Mexican standards. According to Cofepris, the compliance rate for fluoride content in table salt (200-250 mg/kg) has consistently been reported to be ranging between

**Table I**  
**FLUORIDE CONTENT (MG/KG) IN TABLE SALT**  
**SAMPLES BY COMMERCIAL BRAND.**  
**MEXICO CITY, 2016**

Name	Number of samples (%)	Median (IQR)	Min-Max
Sal La Fina	460 (70.0)	135.9 (136.0)	0.0-436.3
Sal Elefante	114 (17.4)	188.3 (142.5)	0.0-478.0
Unknown	29 (4.4)	35.9 (164.1)	0.2-332.1
Sal Aurrera	13 (2.0)	159.5 (84.1)	0.4-211.4
Sal Sol	12 (1.8)	183.2 (74.5)	0.3-389.3
Sal Cisne	10 (1.5)	129.3 (64.7)	76.2-244.6
Sal Fragata	5 (0.8)	172.6 (98.3)	0.8-187.7
Sal Great Value	4 (0.6)	218.0 (88.2)	154.8-313.5
Sal Novoxal	3 (0.5)	0.6 (0.4)	0.1-0.9
Sal Forte	2 (0.3)	161.7 (1.1)	160.6-162.8
Sal Amores y Sabores	1 (0.2)	1.7 (0.0)	1.7-1.7
Sal Golden Hills	1 (0.2)	48.0 (0.0)	48.0-48.0
Sal Klara	1 (0.2)	135.6 (0.0)	135.6-135.6
Sal Pragná	1 (0.2)	0.2 (0.0)	0.2-0.2
Sal Vernatu	1 (0.2)	2.0 (0.0)	2.0-2.0

IQR: interquartile range

20 and 32% from 2012 to 2017, the period encompassing our study.<sup>13</sup> Our analysis revealed that 72.8% of the samples had fluoride levels below the recommended range, and 13.8% exceeded the upper limit. This finding highlights the need for an enhanced monitoring mandated by policy that could provide guidance and ensure the appropriate concentration of fluoridated salt in Mexico City.

Among samples labeled as fluoridated or containing fluoride in their list of ingredients, it was found that 72.8% (n= 442) had fluoride content below the recommended range (<200 mg/kg). A lower fluoride content in table salt may limit the protective effect of fluoride for dental caries prevention, especially if other sources such as fluoride in water and fluoride-containing oral health products are not available. In Mexico, it was observed a significant reduction in the prevalence of dental caries among 12-year-old students in the State of Mexico after nine years of salt fluoridation.<sup>11</sup> The proportion of caries-free children increased from 10.3% in 1988 to 27.7% in

**Table II**  
**FLUORIDE CONTENT (MG/KG) IN TABLE SALT**  
**SAMPLES BY FLUORIDATION, TYPE OF FLUORIDE**  
**COMPOUND, SOURCE, AND GRAIN SIZE.**  
**MEXICO CITY, 2016**

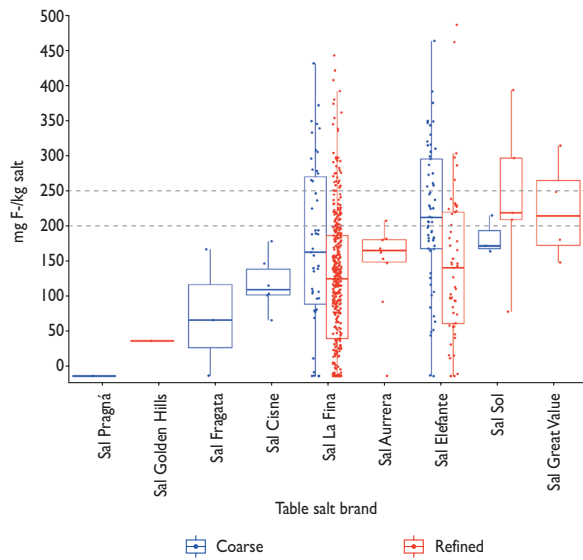
Characteristic	Number (%)	Median (IQR)	Min-Max
Labeled as fluoridated			
Yes	607 (92.4)	144.7 (129.5)	0.0-478.0
No	4 (0.6)	0.8 (0.6)	0.1-1.70
Unknown	46 (7.0)	107.2 (169.1)	0.2-332.1
Fluoride compound			
Potassium fluoride*	606 (92.2)	144.8 (129.2)	0.0-478.0
None	4 (0.6)	0.8 (0.6)	0.1-1.70
Unknown	47 (7.2)	103.5 (167.5)	0.2-332.1
Source			
Land	556 (84.6)	141.2 (137.4) <sup>‡</sup>	0.0-478.0
Sea	101 (15.4)	153.1 (136.5) <sup>‡</sup>	0.1-425.4
Grain size			
Refined	515 (78.4)	135.7 (137.2) <sup>§</sup>	0.0-478.0
Coarse	142 (21.6)	183.6 (170.2) <sup>§</sup>	0.0-456.0

IQR: interquartile range  
 \* 612 to 765 mg/kg salt  
 ‡ p= 0.4952, Wilcoxon rank sum test with continuity correction  
 § p <0.001, Wilcoxon rank sum test with continuity correction

1997, and the mean DMFT index decreased from 4.39 to 2.47, demonstrating a 43.7% reduction. According to the Oral Pathologies Epidemiological Surveillance System of Mexico (Sivepab, by its acronym in Spanish) 2021 data, the proportion of children and adolescents aged 2-19 years who are free of dental caries peaks at around 32.9% at ages 11 and 12, but generally remains below 30% for most other age groups, with a drop to about 19.8% at ages 8 and 9.<sup>27</sup> These findings underscore the importance of adequate fluoride levels to prevent dental caries, particularly in areas where dental caries is highly prevalent.

The NOM establishes that fluoridated salt should not be distributed in areas with fluoride concentration in water above 0.7 mg/L; however, water in Mexico City has been reported to have a wide range of concentrations, both below and above the threshold set by the regulation.

Hernández-Guerrero and colleagues<sup>28</sup> reported a range of fluoride concentration in water supplies of



Note: each boxplot represents a brand ordered based on their median fluoride content. Subsets based on grain size are highlighted as coarse or refined in blue and red color, respectively. The horizontal dashed lines represent the fluoride content levels of 200 mg/kg and 250 mg/kg (according to the NOM), respectively.

**FIGURE 2. BOXPLOT ILLUSTRATING FLUORIDE CONTENT (MG/KG) OF DIFFERENT TABLE SALT BRANDS LABELED AS FLUORIDATED OR HAVING FLUORIDE LISTED IN THEIR INGREDIENTS**

Mexico City from 0.26 m/L to 1.38 m/L. Hernández-Guerrero and colleagues also found that 40.9% of the collected water samples were above the threshold of 0.7 mg/L. Similarly, a study by Martínez-Mier and colleagues<sup>16</sup> carried out in Mexico City found that fluoride content of tap water samples ranged from 0.036 to 0.88 mg/L. A third study by Galicia-Chacón and colleagues<sup>29</sup> also observed a broad variation from 0.44 to 1.28 mg/L in drinking water samples collected from one of Mexico City's delegations. Based on these previous reports, it is essential to conduct a detailed risk assessment of fluoride exposure from drinking water and natural sources, including any potential additional fluoride in the water supply. This assessment should inform any reconsideration of the current guidelines for the distribution of fluoridated salt in Mexico City. These results support the need for further policy development not only for fluoride concentration in drinking water, but also to refine guidelines for the distribution of fluoridated table salt in areas where the population might be overexposed via multiple sources of fluoride including foods, other beverages and dentifrice.<sup>30,31</sup>

The median fluoride content in fine salt samples was significantly lower than coarse salt samples. This finding is similar to those of Dall'Onder and colleagues<sup>32</sup> where coarse salt samples showed higher fluoride concentrations compared to the refined salt samples collected. Fluoride concentrations in salt particles may be affected by the method of fluoridation, either dry or wet methods which both are implemented in Mexico.<sup>6,33</sup> With the dry method, the fluoride powder tends to separate from the coarser salt particles, which overtime may sink to the bottom of the salt's package resulting in an uneven fluoride concentration in the final product. With the wet method, the separation of salt particles after the application (spraying) of fluoride solution may lead to different concentrations according to the particle's size.<sup>6</sup> Nevertheless, other factors related to the salt processing method, the type of salt produced, how the salt is to be packaged, and the type of salt to be fluoridated may affect the fluoride content<sup>34</sup> and should be taken into consideration by the manufacturers' salt fluoridation systems carried out in Mexico City.

Although the World Health Organization (WHO) recommends salt intake of less than 5 grams (approximately 2 g sodium) per person per day, in Mexico City, data from cohort studies have estimated an average intake of  $3.5 \pm 1.4$  g sodium/day.<sup>35</sup> Consumption of table salt with fluoride content higher than the recommended could be a potential source of overexposure in the population. We found that 13.8% (n=84) of table salt samples were above the Mexican guidelines (fluoride content higher than 250 mg/kg). This finding also supports the need for better monitoring, compliance and risk exposure assessment of fluoride in salt in Mexico City.

Finally, our study had some limitations. First, sampling was not representative or balanced. The non-representative and unbalanced nature of our sample limits the generalizability of our findings, as it may not reflect the fluoride content in table salt across different areas or socio-economic groups in Mexico City. Secondly, neither the dates when the participant bought the salt or opened its package was collected; therefore, we did not control for the age of samples. However, our findings provide evidence of a broad variation of fluoride content in the table salt consumed by a Mexican population. Future studies based on a comprehensive sampling, potentially integrated within the National Health and Nutrition Survey (Ensanut, by its acronym in Spanish) of Mexico framework, are essential to evaluate the fluoride content in table salt, especially considering areas with naturally high fluoride concentrations. These studies could inform policymakers to assess the need of adjustment of current monitoring program for fluoridated salt distributed in the city.

In conclusion, fluoride content in table salt from 14 distinct commercial brands collected in Mexico City displayed a broad variation (range from 0.016 to 477.9 mg/kg). We found that 73% (n= 442) of table salt had fluoride content below the recommended range (<200 mg/kg), and 14% (n= 84) were above the range (>250 mg/kg). Future studies with representative sampling are needed to evaluate table salt fluoride content, especially in high-fluoride areas, to inform potential adjustments to the current monitoring program.

## Funding

This work was supported by the National Institutes of Environmental Health Sciences at the National Institutes of Health (P42ES05947, K23ES000381, P01ES022844, P30DK089503, P30ES00002, R01ES014930, R01ES07821, R24DK097153, R24ES028502, R01ES024732, R01ES021446, P30ES017885, R01ES013744, K01ES014907, K01ES016587, P42ES016454), the US Environmental Protection Agency (RD83543601); *Consejo Nacional de Ciencia y Tecnología* (106565, 261063, 29192-M, 37210-M, 41912-M); and *Consejo de Estudios para la Restauración y Valoración Ambiental (Conserva)*, *Departamento del Distrito Federal*, Mexico. National Science Foundation (NSF) 1744724 and 1430391. The funders did not play any role in the conception or writing of this paper (or any others from the Element Project).

*Declaration of conflict of interests.* The authors declare that they have no conflict of interests.

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