Seasonal and Spatial Variability of PM$_{2.5}$ Concentration, and Associated Metal(lloid) Content in the Toluca Valley, Mexico

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Abstract
This study provides evidence of the seasonal and spatial variation of metal(lloid)s in particulate matter minor to 2.5 microns (PM$_{2.5}$) in the Toluca Valley Metropolitan Area (TVMA), the fifth largest urban center in Mexico. Four sites were sampled between 2013 and 2014, which included urban and industrial areas, in the dry-cold (November-February) and dry-hot (March-May) seasons; PM$_{2.5}$ was collected using high- and medium-volume samplers. Metal(lloid) concentrations in PM$_{2.5}$ were analyzed using inductively coupled plasma–mass spectrometry (ICP–MS). The highest 24-hour PM$_{2.5}$ concentration in the northern area was observed, and the PM$_{2.5}$ concentrations were independent of the season. Five metal(lloid)s with a recovery percentage above 80% were considered to be reported (Co, Cr, Cu, Mn, and Sb). The maximum concentrations of metal(lloid)s were observed during the dry-cold season, and concentrations were up to one hundred or thousand fold with respect to the dry-hot season. The 24-hour PM$_{2.5}$ and metal(lloid) concentrations exceeded national and international guidelines to protect population health.

Keywords PM$_{2.5}$ · Toluca valley · Metals and metalloids · Seasonal and site variation

Introduction
Acute and chronic exposure to atmospheric particles less than 2.5 micrometers (PM$_{2.5}$) is considered an environmental risk to human health. There is a correlation between the daily concentration of PM$_{2.5}$ in urban areas and an increase in morbidity and mortality associated with all causes (Pope et al. 2009; WHO 2021). To address this public health problem, various international environmental agencies have proposed setting limits to PM$_{2.5}$ exposure; however, the World Health Organization (WHO) has stated that “there are not yet safe values regarding PM$_{2.5}$ pollution”. In Mexico, the 24-hour average concentration limit is 45 µg m$^{-3}$ (OMSNOM-025-SSA1-2014), which is high in comparison to the 2021 WHO recommendation of 15 µg m$^{-3}$.

Atmospheric particle matter (PM) is a dynamic and polydisperse material with a complex composition mainly of organic and inorganic compounds. The toxicity mechanism of PM is oxidative stress, which is related to its chemical composition and has been linked to the biological effects of PM (Sørensen et al. 2005; Hennigan et al. 2019). The measurement of PM$_{2.5}$ metal(lloid) content provides an
understanding of the sources of air pollution, which depends on the human local socioeconomic activities and geography of the studied region.

Air pollution studies in Mexico have been carried out mostly in Mexico City, with a focus on the metal(loid) content of PM$_{10}$ and PM$_{2.5}$ samples (Aldape et al. 2005; Vega et al. 2010). The Toluca Valley Metropolitan Area (TVMA) is part of Estado de Mexico, a geographic entity nearly to Mexico City; it is the fifth metropolitan zone by size in Mexico, and it produces 2.3% of the total gross country production, suggesting high industrial and economic activities. TVMA is strongly influenced by great mountain ranges, which is a determinant factor of wind dynamics (Del Campo et al. 2014; Huster and Pierce 2020). The high altitude of the TVMA, between 2,560 and 2,740 m.a.s.l., favors three climate types: temperate-humid, semicold humid and cold. The minimum annual temperature is 0 °C, with a maximum annual temperature of 18 °C. Such geographic and climatological characteristics contribute to physicochemical changes in particles and their chemical speciation, which can contribute to a detrimental effect on public health, as has been suggested by environmental protection agencies and studies (Bravo et al. 2013). It is important to note that there are no historical reports of PM$_{2.5}$ or metal(loid) contents in any atmospheric particulate matter fraction to TVMA.

The aim of this study is to evaluate the seasonal and spatial variation of environmental PM$_{2.5}$ and the trace metal(loid)s content in TVMA, which includes urban and industrial zones that did not have historical reports.

Methods and Materials

Sampling Location

PM$_{2.5}$ samples were collected at four sites of TVMA (Fig. 1), located in Nueva Oxtotitlán (OX) as an urban area near Toluca de Lerdo downtown (19° 17’ 0.40” – 99° 41’ 0.56”), San Cristóbal Huichotitlán (SC) as an urban/rural area with agricultural activity (19° 19’ 38.0” – 99° 38’ 3.44”), Airport (AP), which includes runways and hangars surrounded by industrial areas (19° 20’ 4.41” – 99° 34’ 26. 3”), and San Mateo Atenco (SM) as an urban area near the Lerma-Toluca industrial corridor with high activity of commercial and shoe manufacturing (19° 16’ 49.5 ’’ – 99° 32’ 30”). At the OX site, PM$_{2.5}$ was collected on a glass fiber filter (G653, 8 × 10 cm, Whatman, UK) using a high-volume air sampler (model TE-2.5I, Tisch Environmental equipment, US) at a flow rate of 28 L min$^{-1}$. At the other three sites, 47 mm PTFE filters with PMP supporting rings (R2PJ047, Pall Corp, US) were used for sampling PM$_{2.5}$ using medium volume samplers (Echo TCR Tecora, Italy) with a flow rate of 16.7 L min$^{-1}$. Sampling was carried out simultaneously at the four sites, corresponding to four stations of Red Automática de Monitoreo Atmosférico of the Toluca Valley (RAMAT). The samplers have different flows, but the concentrations were calculated based on the flows, which corrected the differences between the samplers. Samples were collected in 24-hour periods with a six-day frequency spanning from November 28, 2013, to May 17, 2014. This included the dry-cold season from November to February and the dry-hot season from March to May. The sampling equipment was calibrated at the sampling sites according to NOM-035-SEMARNAT-1993.

Extraction and Elemental Chemical Analysis

Ambient air filters were weighed before and after sampling to determine the mass of particles collected, and gravimetric analysis was performed at the Red Automática de Monitoreo Atmosférico of Mexico City according to NOM-035-SEMARNAT-1993 and US-EPA, 2008. During this procedure, quality controls were implemented in the gravimetric laboratory that included the laboratory blank filter, field sampling blank filter and collected filters.

Filter digestion was carried out using an acid method in a hot plate, adding an acid solution of HNO$_3$:HCl (5.5%:16.75%) in a 1:5 ratio area:volume, and heating at 44 ± 1 °C for 30 min, always preventing the drying of samples and allowing cooling to room temperature. The extracts were transferred to a volumetric flask (25 mL), and the volume was adjusted with acid solution for the analysis.
of elements by ICP–MS (Model ELAN 6100, Perkin Elmer, USA). Analytical curves were prepared using Perkin Elmer multielement calibration standards in concentrations ranging between 0.01 and 100 ng mL⁻¹ (US-EPA, 2008).

All the filters used for quality control were extracted and analyzed together with the sampling filters to determine background concentration and provide accuracy and precision in metal(loid) detection. The quality control parameters were limit of detection (LOD), limit of quantitation (LOQ), and percent recovery (% R). The LOD was calculated as the element concentration average in the blank filter extracts, per three times the standard deviation of each element (CENAM & EURACHEM, 2005). The LOQ was calculated as the average of each element concentration in blank filter extract per ten times the standard of each element. The efficiency of the method was assessed as the % R of NIST 2783, a standard reference material, which was subjected to the same extraction process as the environmental samples. Quality controls by Perkin Elmer ELAN® ICP–MS equipment were performed with argon plasma gas, the daily performance check for analyzing masses: low beryllium 9.0122, medium magnesium 23.985, and high indium 114.904, as well as with the evaluation of the detection system.

Data processing was performed using Microsoft Excel (Microsoft 365, ver. 2112, US). Temperature and relative humidity are described from the mean, minimum and maximum values; the wind roses were established to each station by season using the WRPLOT View; wind rose Plots for Meteorological Data version 8.0.2(C) 1998–2018 Lakers Environmental Software; gravimetric and chemical PM₂.₅ data are presented with the median and range values. The enrichment for each metal(loid) was considered as the concentration found in the dry-cold season divided by the concentration in the dry-hot season of the same element to determine how many times the concentration changed in the same season.

### Results and Discussion

The weather parameters can dictate the presence of contaminants in the air and their concentration. In the TVMA, the relative humidity (RH) at the four sampling sites was similar in both seasons (Table 1). The mean temperature was similar among the sampling sites and seasons, with a difference of approximately 4 °C among the sites by season. Average temperatures during the dry-cold season varied from 10.41 to 11.49 °C. During the dry-hot season, the mean temperatures varied from 13.89 to 14.9 °C (Table 1). It was observed that the predominant wind direction and vector direction in both seasons were similar in SM (southeast), AP (east), and OX (southwest), with the exception of SC, with vector directions in the southeast and northeast during the cold and hot seasons, respectively (Supplementary Fig. 1).

The average wind speed (AWS) for the cold season followed the gradient AP (1.48 m s⁻¹) > OX (1.15 m s⁻¹) > SC (0.93 m s⁻¹) > SM (0.89 m s⁻¹). In the hot season, the highest AWS was observed in SC (1.69 m s⁻¹), followed by OX (1.42 m s⁻¹) > AP (1.12 m s⁻¹), and the lowest AWS was observed in SM (1.06 m s⁻¹). Calm winds were more frequent in the cold-dry season than in the hot-dry season. In the cold season, the calm winds followed the gradient SM (34.26%); SC (30.79%); OX (11.11%) and AP (8.1%), however, in the hot season the higher calm winds frequency is observed in the SM site (26.96%), AP being the second site with calm winds (21.47%) and the lowest frequency of calm winds were 5.45% and 0.32% corresponding to OX and SC, respectively.

In TVMA, an increment of 4 °C was observed in the average daily temperature between the cold and hot seasons; the average daily RH was approximately 10% higher in the dry-cold season than in the dry-hot season. For AWS, differences were approximately 0.5 m s⁻¹; these discrete changes could be associated with the high altitude of TVMA (2660 m.a.s.l.).

The influence of air flow, direction, and calm winds was observed in our study. The AWS was quite different among sites between seasons. However, it seems that the direction
of air flow in OX displaces the atmospheric particles to other sites. In the rest of the sites, the influence of east winds flows from AP and SM sites to the SC site, where AP and SM can be considered industrial zones and SC the receptor site, a suburban zone with the highest PM$_{2.5}$ concentration. Additionally, we observed higher PM$_{2.5}$ concentrations in the dry-cold season than in the dry-hot season at almost all sites. This can be explained by the frequency of calm winds during the cold season, concomitant with the major frequency of thermal inversion according to the high altitude of the east, and with a vector wind in the dry-cold season from the east, and with a vector wind in the dry-cold season from

### Table 2 24-hour PM$_{2.5}$ air gravimetric concentrations in the Toluca Valley Metropolitan Area (TVMA)

| Sites                  | Dry-Cold | N   | Dry-Hot | N   |
|------------------------|----------|-----|---------|-----|
| Nueva Oxtotitlán (OX)  | 15.64 (9.46–51.25) | 18 (1) | 10.88 (7.56–27.72) | 13 (0) |
| San Mateo Atenco (SM)  | 41.16 (12.60–57.93) | 5 (1)  | 37.28 (20.61–59.44) | 13 (4) |
| Airport (AP)           | 41.30 (1.33–57.97)  | 14 (6) | 43.08 (24.10–86.36) | 12 (5) |
| San Cristobal (SC)     | 54.58 (26.10–79.88) | 14 (10) | 72.85 (23.48–102.84) | 11 (8) |

Data are shown as median following range of values in parenthesis. N indicates the number of samples, followed by the number of samples exceeding Mexican government guidelines, 45 µg m$^{-3}$, NOM-025-SSA-2014 in parenthesis.

### Table 3 Quality Control Parameters in the determination of elements present in PM$_{2.5}$, at the TVMA, Mexico, 2013–2014

| Element | LOD (µg m$^{-3}$) | LOQ (µg m$^{-3}$) | NIST 2783 air particulate standard filter |
|---------|-------------------|------------------|------------------------------------------|
|         |                   |                  | Certified (ng/filter) | Measured (ng/filter) | Recovery (%) |
| Cr      | $1.1 \times 10^{-3}$ | $2.0 \times 10^{-3}$ | 135 ± 25 | 127 | 94 |
| Cu      | $1.1 \times 10^{-3}$ | $2.6 \times 10^{-3}$ | 404 | 368 | 91 |
| Co      | $7.9 \times 10^{-8}$ | $1.1 \times 10^{-7}$ | 7.7 | 6.4 | 83 |
| Mn      | $4.9 \times 10^{-6}$ | $6.7 \times 10^{-6}$ | 320 ± 12 | 267 | 83 |
| Sb      | $1.7 \times 10^{-7}$ | $3.2 \times 10^{-7}$ | 71.8 | 59.6 | 83 |

Limit of detection, LOD; Limit of quantification, LOQ.

The metal(loid) analysis by ICP–MS showed a recovery range of 95–80% for Co, Cr, Cu, Mn and Sb, whereas recovery for Zn and Pb was between <80 and >60%; for Mg, Ba, Al, and Ti, the recovery range was below 60% (Table 3).

In the present study, we decided to report only metal(loid) species with a recovery range of 90 to 80%. The highest concentrations of metal(loid) species were observed in the dry-cold season at all stations. Additionally, concentrations during the dry-cold season compared to the dry-hot season were more than one hundred times higher in SM, AP, and SC, with the exception of OX, where the concentrations were less than four times higher (Table 4).

The highest metal(loid) concentrations were found at the SM site, which did not have the highest PM$_{2.5}$ concentrations. SM is located in the southeast of TVMA, bordered by the Lerma-Tenango del Valle and Toluca México highways, neighboring the Lerma-Toluca industrial park, with the main economic activity being shoes and clothing manufacturing. The AP and SC sites share a similar trend in metal(loid) concentrations. Both sites are located north of the Toluca valley, with different economic activities; in addition to airplane transit on the AP site, there is an industrial settlement, land dedicated to agriculture, and the San Antonio roadway. However, SC is considered an urban settlement without natural barriers, the predominant wind coming from the east, and with a vector wind in the dry-cold season from
than in the dry cold season. When calculating the enrichment of the element concentration of the dry-cold season in contrast to the dry-hot season, we observed that at some sites, the increment was a hundred- or thousandfold. However, the PM$_{2.5}$ mass did not change in the same magnitude, suggesting that in the dry-cold season, the frequency of calm winds and probably the thermal inversion at high altitude induce a major permanence of metal(lloid)s associated with the increment in the economic activity of the area.

Comparisons between the PM$_{2.5}$ and metal(lloid) concentrations detected in our study during the dry-hot season in the TVMA and those found in other countries are shown in Supplementary Table 1. The contents of metal(lloid)s in PM$_{2.5}$ in the dry-cold season at the SM, SC, and AP sites were above those reported in all other cities around the world, and the metal(lloid) concentrations observed in the TVMA were on the order of micrograms with respect to the southeast that is influenced by the emissions generated downtown Toluca.

In the TVMA, we observed that in the dry-hot season, the metal(lloid) concentrations had a more important decrease than in the dry cold season. When calculating the enrichment of the element concentration of the dry-cold season in contrast to the dry-hot season, we observed that at some sites, the increment was a hundred- or thousandfold. However, the PM$_{2.5}$ mass did not change in the same magnitude, suggesting that in the dry-cold season, the frequency of calm winds and probably the thermal inversion at high altitude induce a major permanence of metal(lloid)s associated with the increment in the economic activity of the area.

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The station with the lowest PM$_{2.5}$ concentration was the OX site, which is located to the west of Toluca downtown and is characterized by high population density; it is considered a residential area. The main difference from the rest of the sites was the air flow direction that comes from the southwest, opposite to the downtown and industrial areas. Near the area, north of the OX site, there are mountain systems with elevations between 2800–3000 m.a.s.l. that run from west to the east to the limit of downtown Toluca and probably act as a barrier to the pollutants that flow from downtown Toluca to OX. Additionally, the OX site is a place where calm winds are less frequent, suggesting an efficient removal of pollutants.

Table 4 Metal and metalloid concentrations of 24-hour PM$_{2.5}$ collected in Toluca Valley Metropolitan Area (TVMA)

| Cobalt (Co, ng m$^{-3}$)       | Dry-Cold  | DF | Dry-Hot  | DF | Enrichment |
|--------------------------------|-----------|----|----------|----|------------|
| OX                            | 0.031 (0.0065–11.69) | 17/18 | 0.0105 (0.0014–0.057) | 9/13 | 2.95       |
| SM                            | 8.1 (0.808–13.3) | 3/5 | 0.0089 (0.00059–0.022) | 7/13 | 912.87     |
| AP                            | 2.07 (0.017–10.37) | 6/14 | 0.0057 (0.00052–0.015) | 10/12 | 363.27     |
| SC                            | 2.26 (0.0217–3.954) | 7/14 | 0.0174 (0.00298–0.02) | 8/11 | 130.16     |

| Chromium (Cr, ng m$^{-3}$)     | Dry-Cold  | DF | Dry-Hot  | DF | Enrichment |
|--------------------------------|-----------|----|----------|----|------------|
| OX                            | 4.58 (2.389–9.64) | 12/18 | 3.113 | 3/13 | 1.47       |
| SM                            | 999.64    | 1/5 | ND       | 0/13 | -          |
| AP                            | 364.46 (360.896–549.53) | 3/14 | ND       | 0/12 | -          |
| SC                            | 328.94    | 2/14 | ND       | 0/11 | -          |

| Copper (Cu, ng m$^{-3}$)       | Dry-Cold  | DF | Dry-Hot  | DF | Enrichment |
|--------------------------------|-----------|----|----------|----|------------|
| OX                            | 23.02 (10.205–318.34) | 4/18 | 12.182 (8.50–15.86) | 1/13 | 1.9        |
| SM                            | 417.32 (313.062–667.94) | 4/5 | 0.2537 (0.0198–0.78) | 12/13 | 1645.1     |
| AP                            | 136.4 (13.043–728.539) | 12/14 | 0.355 (0.257–1.30) | 10/12 | 384.3      |
| SC                            | 119.4 (0.886–339.87) | 8/14 | 0.38 (0.150–1.99) | 9/11 | 314.0      |

| Manganese (Mn, ng m$^{-3}$)    | Dry-Cold  | DF | Dry-Hot  | DF | Enrichment |
|--------------------------------|-----------|----|----------|----|------------|
| OX                            | 3.1 (1.36–6.46) | 17/18 | 1.59 (0.31–5.12) | 12/13 | 1.96       |
| SM                            | 443.1 (426.89–1181.32) | 3/5 | 0.75 (0.18–3.33) | 12/13 | 593.68     |
| AP                            | 82.5 (7.64–728.54) | 13/14 | 0.68 (0.01–3.69) | 12/12 | 121.37     |
| SC                            | 103.6 (1.23–820.32) | 14/14 | 1.32 (0.12–1.62) | 11/11 | 78.41      |

| Antimony (Sb, ng m$^{-3}$)     | Dry-Cold  | DF | Dry-Hot  | DF | Enrichment |
|--------------------------------|-----------|----|----------|----|------------|
| OX                            | 2.3 (0.99–16.74) | 17/18 | 0.92 (0.196–4.05) | 12/13 | 2.5        |
| SM                            | 368.2 (3.93–797.74) | 5/5 | 0.37 (0.01–0.95) | 13/13 | 996.4      |
| AP                            | 82.97 (22.43–215.54) | 14/14 | 0.44 (0.131–1.1) | 12/12 | 189.5      |
| SC                            | 128.98 (0.87–218.54) | 14/14 | 0.62 (0.112–1.5) | 11/11 | 209.3      |

Abbreviations: OX, Nueva Oxtotitlán; SM, San Mateo Atenco; AP, Airport; SC, San Cristobal; DF indicate detection frequency, number of filters in which metal(lloid) was detected over total filters collected. ND indicate Not-Detected.
to other cities. The concentrations observed in the dry-cold season were higher than the limits recommended by regulatory agencies to prevent human health.

Our study presented relevant data over a short sampling time, which is representative of the dry season in our country, in which air pollution contaminants are present at high concentrations. Although the metalloid extraction method varies among the studies that define the chemical form, the sensitivity of different detection systems of analytical methods can influence the data observed (Saldañariga-Noreña et al. 2009; Murillo-Tovar et al. 2015).

The Co content in PM$_{2.5}$ samples from TVMA at the AP, SC and OX sites was observed in the occupational setting concentrations reported (Kim et al. 2006). Co speciation is needed to determine the adverse human health effects. The Cr content in TVMA PM$_{2.5}$ is higher than the annual standard (ATSDR 2012a) and those reported in other countries. According to the Cu concentration from TVMA, it was under the maximum annual concentration and copper concentration for the 24-hour period established by the EPA (1987a), 30 and 100 µg m$^{-3}$, respectively. The PM$_{2.5}$ collected in TVMA has a higher content in Mn than in other reported countries. However, Mn concentrations are below the annual standard limit, but it is higher than the minimal risk level for neurological effects by chronic inhalation (ATSDR 2012b). Sb content in PM$_{2.5}$ in SM, AP, and SC was >1 µg m$^{-3}$, a value referred to as industrial area; however, Sb has not been classified as carcinogenic in humans by the U.S. EPA, but ATSDR (2019) has placed antimony trioxide as a possible human carcinogen. According to the high levels of Sb found in TVMA, further studies are needed to describe the chemical speciation and the potential risk to human health.

The extremely high concentrations of the five elements determined in the present study are not unusual in highly contaminated regions. An air concentration of 3.7 to 4.6 µg m$^{-3}$ was reported in a Cr plating plant (Goldoni et al. 2006). In the Valley of Leon, Mexico, which is an urban and Cr industrial area, an air concentration below 25 µg m$^{-3}$ was reported. Other authors have reported 250 ng m$^{-3}$ in boilermaker construction workers (Magari et al. 2002). A median Co concentration of 200 ng m$^{-3}$ has been observed in workplaces (Hengstler et al. 2003). Cu and Mn concentrations of 2.43 and 5.13 µg m$^{-3}$, respectively, have also been reported in the environmental working spaces of boilermaker construction workers (Magari et al. 2002). An annual mean Mn concentration of approximately 20–800 ng m$^{-3}$ has been reported in Japanese cities, with a maximum 24-h concentration of 2 to 3 µg m$^{-3}$. In the case of Sb, there have been no reports of high concentrations in urban areas, and the range reported is 1.4 to 55 ng m$^{-3}$ (Islam et al. 2015). However, the limited data on Sb levels in Chinese air are comparable to or higher than the respiratory benchmark dose of 87 µg m$^{-3}$ established by the EPA, with a concentration of 29.5 to 575 µg m$^{-3}$ observed in ash incinerators (He et al. 2012).

The present study reports the content of metalloid(s) in the PM$_{2.5}$ fraction by ICP-MS at four sites from TVMA. The airborne particles in each geographic area will depend on local anthropogenic sources of emissions, season and weather variables such as temperature, altitude, humidity, wind velocity and airflow direction. The higher concentration observed in the dry-cold season is attributed to two factors, the thermal inversion and the calm winds, which are strongly influenced by large mountain ranges, a determinant factor of wind dynamics. Among these mountain ranges are the Sierra Nevada de Toluca to the southeast, the Sierra de las Cruces and Sierra de Ocoyotepec to the east, the Sierra del Monte Alto to the northeast, and the Sierra Matlazinca to the south (Del Campo et al. 2014; Huster and Pierce 2020). In addition to being surrounded by large mountains and volcanoes, the TVMA is located at a high altitude, between 2,560 and 2,740 m.a.s.l. (Del Campo et al. 2014; Huster and Pierce 2020). Given that the emission sources were established based on the emission inventory of the TVMA, the economic activities that contributed to the high metalloid levels are the metalworking industry, textile industry, chemical industry, petrochemical industry, glass and derivatives industry, rubber and plastic industry, electricity generation, mining industry, and construction industry. Additionally, the demand for services and the high economic activity are directly related to the vehicular fleet and the high consumption and emissions of fuels. The levels of PM$_{2.5}$ and trace metalloid(s) found in the TVMA provide data for understanding the behavior of elements present locally and in other regions with similar features. This evidence can help to control and regulate the emissions of constituents of airborne particles that constitute a potential risk to human health. The control, prevention, and minimization of the levels of these contaminants in the geographic area need to be studied as well as their impact on human health.

In conclusion, according to the gravimetric analysis of PM$_{2.5}$, high concentrations of PM$_{2.5}$ were observed in SC (54.58 µg m$^{-3}$), followed by AP (41.3 µg m$^{-3}$) and SM (41.16 µg m$^{-3}$), and the lowest concentration was observed in OX (15.64 µg m$^{-3}$). Higher amounts of metalloid(s) were observed in the cold-dry season at all sampling sites. The adverse effect of the high content of metalloid(s) can enhance oxidative stress and inflammation, initiate or promote adverse health effects, and increase mortality and morbidity of cardiorespiratory and nonrespiratory diseases such as neuronal, renal and metabolic diseases.

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Data Availability The datasets generated during and/or analyzed during the current study are available in the ww.figshare.com repository, https://figshare.com/s/cafecd077bcfdff913e9a5, https://doi.org/10.6084/m9.figshare.19500569.v1.

Declarations

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