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Food and Water Security as Determinants of the Mitigation of Health Risks Due to Exposure to Arsenic in Water

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Abstract

Exposure to arsenic is a global public health problem, and the effects on health are several from cancer to metabolic diseases such as diabetes and hypertension. The metabolism and excretion depends on having a good nutritional status and the latter of an adequate diet. It is known that the consumption of certain trace elements and nutrients intervene in the metabolism, in the excretion and in the protection of the adverse effects that the metalloid has on the organism. The amount of proteins consumed, the type of amino acids such as cysteine, methionine; vitamins such as C, thiamin, vitamin B₁₂, folic acid, minerals such as calcium and other nutrients such as fiber have been studied and associated with a lower concentration of As in blood and urine, as well as minor dermatological lesions as well as other organs and systems. A study by Monroy-Torres et al. (2018, *in press*), in adolescents exposed to As in water, found greater excretion of As with a 4-week vitamin supplementation, increasing iron levels, after the intervention. Reason for which this chapter, shows a review of the main evidence of health impact indicators that can lead to mitigate the effects of exposure to As across to promote food security, access to cleaner drinking water and good nutrition.

Keywords: food security, water security, nutrients, vitamins, nutritional status

1. Introduction

1.1. Food and water security: an era of sustainable development

With the demographic growth, the lack of a culture of water care and the overexploitation of aquifers, the problems of higher levels of arsenic in water for human consumption have

increased, and if there is no solution, the problem will be exacerbated and with its impacts on health. Before continuing with the main approach of this chapter, I will integrate an issue that should be mentioned: lack of food security in the people. The food security is the cornerstone for mitigating the effects that arsenic on people's health and to consider the era of sustainable development.

The Sustainable Development Goals (SDGs) (2015–2030) have been established, leaving behind the millennium development goals, derived from ever more prevailing needs and facing the challenges of the health complexities faced by the population. These are derived from investigations that generate solutions to the great problems of humanity, such as achieving the right to health. Health is a human right, but for this to be achieved, governments must establish the conditions of access to basic services and one of them is access to water and food, among others. The SDGs, which began in 2015, were promoted at the United Nations Conference on Sustainable Development, held in Rio de Janeiro in 2012, with the purpose of creating a set of global objectives related to global environmental, economical, political, and social challenges [1].

The SDG are the pillars for the countries promote in their agenda, actions, and strategies to end poverty, to act for the benefit of the environment and the planet, and ensure that all people enjoy peace and prosperity. The 17 SDGs begin with the objective "Eradicating poverty is the pillar and basis of the 2030 Agenda," which is, therefore, the goal number 1 [2]. All the SDGs are interrelated and are conducive to the complexity that is experienced, such as having solutions for the fight against poverty. More than 800 million people still live in poverty, with only 1.25 dollars a day; they have food shortages, as well as water and public services. This increase will generate the need to obtain an income through a work to obtain food, water, health services, and housing [1]. Goal #6 corresponds to "Clean water and sanitation" [3], where more than 40% of the population does not have access to potable water, and it is estimated that by 2050, one in four people will not have access to water, which impacts in infectious and diarrheal diseases; and finally, goal #3 "health and well-being" [4] would be integrated, where the figures for diseases derived from the lack of drinking water, food safety, and vaccination, require further research. The line of research that leads the name "*Environmental Nutrition and Food Security*," whose origin and foundation can be reviewed [5].

The line integrates a model with the interdisciplinary approach and integrating topics that have been fragmented over time, to understand the conditions of environmental impacts such as food safety and water safety in people. Food security is achieved when people always have constant access to adequate food, without creating health risks, and being constant and permanent. It is studied from the pillars of stability, availability, access, and biological incorporation [6]. In this case, studying food safety without considering water safety, would be walking and moving blindly or as if this complexity could be analyzed and understood from a single methodological paradigm or study design type.

The issue of water safety, would carry the following indicators for the 17 sustainable development objectives (**Table 1**) [1], based on the hypothesis that if a person has a good nutritional status derived from food security, environmental stressors (water contaminated with lead, arsenic, for example), respiratory exposures, viruses or bacteria in food would have less

SDGs	Example of the central theme "Arsenic in drinking water in the population"
No poverty	Access to public services and water sanitation as well as healthy, local and fresh foods.
Cero Hunger	Access to drinking water permanently for food preparation.
Good health and well-being	Access to drinking water for the prevention of foodborne diseases, infectious diseases and diarrheal diseases.
Quality education	Teaching techniques for the purification of water, the culture of water, as well as occupational risks, to achieve a prevention education.
Gender equality	Opportunity for all, considering that women provide water and food in most homes in the world.
Clean water and sanitation	Compliance with the law, through the monitoring and supervision of water quality in homes
Affordable and clean energy	Harvest of rainwater, use of solar energy to heat water.
Decent work and economic growth	Occupational health and risk reduction in work areas. Decent Salary.
Industry, innovation and infrastructure	Sustainable production programs, water treatment plants, rainwater harvesting in companies
Reduced inequalities	Opportunities for all, with quality education, gender inclusion and access to public services.
Sustainable cities and communities	Construction of recreational spaces, social security. Design and promotion of green spaces
Responsible consumption and production	Green industry, use of additives and ingredients that do not cause harm to the consumer.
Climate action	Sustainable feeding, care of water and environment.
Life below water	Care and protection of marine life.
Life of land	Protection of ecosystems and protected areas
Peace, justice and strong institutions	Actions to reduce violence.
Partnerships for the goals	Institutional links and synergies in actions that lead to address social problems in common, with less cost, inputs and time.
<i>With permission: Monroy-Torres R.</i>	

Table 1. A proposal for an agenda in research based on the 17 SDGs with the research line of "Environmental Nutrition Food Safety" and the topic water.

impact or manifestations (less risk of developing or manifest an outcome) than populations or people with a poor nutritional status (obesity, low weight, etc.) [7].

Given this introduction and justification, I share the studies we have done with my research team since 2005 in the State of Guanajuato, Mexico. The difficulties to achieve impact even with the scientific evidence, as well as the proposals and strategies that we have had to raise for this constant search to solve problems with the investigations carried out. While there are many pollutants as conditioning factors to which people are currently exposed, the actions

and approach of arsenic from the approach of environmental nutrition and food security, and water can be triggers for a new and different way of decrease the damage to the health with the different pollutants:

“Time to give focus to public health and with it the promotion of food security as a strategy to mitigate the effects and risks to health”

1.2. Arsenic: food and water security

Arsenic is a metalloid that can be found naturally in the Earth, mainly in the Earth's crust, and can leak into the groundwater reserves. In many countries of the world, groundwater represents the main source of drinking water; therefore, exposure to arsenic from drinking water is considered a public health problem [8, 9]; not only the direct consumption of water contaminated with arsenic is a factor of exposure but also indirect consumption through food, when water is used in the preparation of food, in the irrigation of fields, and for consumption of animal, is an exposure factor [10].

The World Health Organization (WHO) and the guidelines of the Environmental Protection Agency (EPA) of the United States, established an allowed limit of 0.01 mg/L for arsenic in drinking water [11]. The Ministry of Health of Mexico establishes an allowable limit of 0.05 mg/L of arsenic in drinking water [11, 12], with current modifications at 0.025 mg/L, which are still above international standards.

1.3. Metabolism

To study and know the toxicity of the metalloid, must be made of the speciation of it, but also of the physiological conditions of the exposed population (age, body surface, nutritional status, etc.), which will be addressed in this chapter. Arsenic compounds are classified into three groups: (1) The inorganic arsenic compounds; (2) Organic compounds, and (3) Gaseous compounds; they are usually in their trivalent and pentavalent state. The most common trivalent inorganic arsenic compounds are arsenic trioxide, arsenic trichloride, and sodium arsenic; the most common pentavalent inorganic arsenic compounds are arsenic pentoxide, arsenic acid, and arsenate; and the organic arsenic compounds are monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA) [13, 14]. The level of toxicity of arsenic depends on its valence and its organic or inorganic form. Organic arsenic is considered less toxic than inorganic as it is easier to excrete. The inorganic arsenic is the most toxic form of As, in its trivalent form it can combine chemically with the sulfhydryl groups, which are organic compounds that contain a sulfur atom as a functional group attached to a hydrogen (-SH), these functional groups form inter- and intramolecular bridges in proteins and their structure and biological function depend on them.

1.4. Absorption

Arsenic can be incorporated into the body by ingestion, inhalation or through the skin, more than 90% of the ingested arsenic is absorbed in the gastrointestinal tract. Organic arsenic is easier to excrete and is usually found mainly in meat, seafood, and some cereals. The ability of trivalent arsenic (AsIII) to join groups -SH, confers that toxic capacity while pentavalent arsenic (AsV) interferes with phosphorylation reactions, due to its similarity chemical with

phosphate [13]. In food, the organic form is the most frequent and is most susceptible to elimination, except for some types of fish, crustaceans, and algae, in most foods (fruits, vegetables, cereals, meats, etc.) that have arsenic concentration lower than 0.25 mg/kg [13]. After ingestion, arsenic is absorbed in the gastrointestinal tract, then passes into the portal circulation and reaches the liver.

The metabolism of arsenic depends on various reduction and methylation reactions in which enzymes and compounds such as s-adenosylmethionine (SAM), arsenic methyltransferase (AS3MT), glutathione (GSH), and oxidized glutathione (GSSG) participate. Initially, GSH participates in the reduction of AsV to AsIII, which is pH dependent and is influenced by the presence of other substances that can be reduced or oxidized; subsequently, the AS3MT participates in the transfer of a methyl group of the SAM enzyme to the trivalent inorganic arsenic to generate MMA(V) Ácido monometilarsónico (monomethylarsonic acid), this compound is reduced to MMA(III) Ácido metilarsenioso (monomethylarsonous acid) by the action of a specific reductase and in this reaction participate the AS3MT, the GSH, and the GSSH, between other compounds; MMAIII enters a methylation reaction to generate DMA(V) Ácido dimetilarsínico (dimethylarsonic acid), and finally, DMAV can be reduced to DMA(III) Ácido dimetilarsenioso (dimethylarsonous acid). These reactions are carried out regardless of the route of absorption [13, 15].

1.5. Excretion

The excretion of As is variable among people; it will depend on the time and dose of exposure to As, as well as the efficiency of the methylation reactions [8]. It is known that the ability to meet arsenic is saturated when the ingestion exceeds 0.5 mg/d [16]. The main metabolites found in urine after acute or chronic exposure to arsenic are inorganic arsenic, MMA and DMA [8, 17], residual As can also be found in keratinized tissues (skin, hair, and nails), where the presence of arsenic in these tissues has a significant association with chronic exposure to metalloid [15]. Although in general, the presence of arsenic in urine is considered an indicator of acute exposure, it has been found that in prolonged exposures arsenic levels in urine are maintained and increase [8].

That is why the presence of arsenic in urine is considered a reliable marker of chronic exposure to As. It is known that the usual consumption of arsenic varies between 5 and 25 µg/d, and the excretion of arsenic in urine is usually less than 25 µg in 24-hour urine. It has been reported that after a consumption of seafood products, the concentration of arsenic in urine can increase to 300 µg in 24 hours, however, this concentration will decrease after 1 day to <25 µg in 24-hour urine [18]. An excretion rate greater than 1000 µg in 24-hour urine is a sign of significant exposure to As [19, 20].

1.6. Effects of acute and chronic exposure: signs and symptoms

Chronic exposure to inorganic arsenic causes, mainly, skin lesions, cancer of the bladder, kidney, lungs, and liver. Keratosis and changes in skin pigmentation are recognized signs of chronic exposure to arsenic, while melanosis is a sign associated with acute exposure [8, 21]. Cumulative doses in adults of 0.10 mg/kg/d are related to signs of chronic intoxication and usually appear after 2–8 weeks of exposure. It also causes alterations in intestinal

epithelial tissue, decreased production of red and white blood cells, central nervous system involvement, liver damage, and kidney damage [17, 22–24]. The acute lethal dose of arsenic in humans has been estimated at 0.6 mg/kg/day [25].

Exposure to arsenic generates oxidative stress, and this represents the main mechanism by which arsenic generates multi-organ damage, there are free radical formation directly and also inhibitory effects on antioxidant components [23]. An alteration in the metabolism of GSH secondary to the union of arsenic with -SH groups has been found, as well as the elevation of genes associated with oxidative stress such as heme oxygenase-1 and metallothioneins, after chronic exposure to arsenic [17, 26]. Chronic exposure to arsenic causes an increase in the production of reactive oxygen species (ROS) and an alteration in defense mechanisms against the pro-oxidative effect of ROS, mainly the catalase enzyme (CAT), superoxide dismutase (SOD), and glutathione peroxidase (GSH-Px) [23].

1.7. Role of nutrition: food security

The effect of several nutrients that can reduce arsenic toxicity has been studied. Oral supplementation with cysteine, methionine, vitamin C, and thiamin at a dose of 25 mg/kg in studies in mice that were exposed to arsenic (10 ppm of sodium arsenite in drinking water) was observed a decrease in oxidative stress caused by exposure to arsenic, these nutrients were able to produce specific changes in the levels of lipid peroxidase, antioxidant enzyme activity and reduction in the concentration of arsenic in blood between 3 and 11%, in liver of 26–37%, and in kidneys from 16 to 24% ($p < 0.05$). Methionine and cysteine are the main amino acids that participate in the metabolism of arsenic, and vitamin C is an antioxidant [23, 27].

A case–control study conducted by Mitra et al. [28] in the adult population ($n = 265$) exposed to arsenic in drinking water ($<500 \mu\text{g/L}$) belonging to the city of West Bengal in India, found a higher probability of lesions due to exposure to arsenic associated with low protein intake (odds ratio = 1.94; CI: 95%, 1.05–3.59), calcium (OR = 1.89, 95% CI, 1.04–3.43), fiber (OR = 2.02, 95% CI, 1.15–4.21), and folic acid (OR = 1.67 95% CI, 0.87–3.2). In a study involving an adult population of 18–65 years ($n = 1016$), exposed to arsenic in drinking water in the city of Bangladesh, the consumption of some nutrients was quantified, finding that the ingestion of cysteine (950–2005 mg/d), methionine (1745–3530 mg/d), calcium (407–1500 mg/d), proteins (77–141 g/d), and vitamin B12 (2.3–9.9 $\mu\text{g/d}$) were associated with minors percentages of inorganic arsenic in urine, this speaks of a decrease in the total concentration of inorganic arsenic. Similarly, high ingestion of niacin and choline were associated with a higher rate of AMD to MMA ($p = 0.02$ for both cases), which indicates a higher conversion rate, and therefore, greater excretion of it [29]. A study developed in adult population (38 ± 10 years) ($n = 130$), evaluated the effect of folic acid on blood arsenic levels, the intervention consisted of an oral supplement of 400 $\mu\text{g/day}$ of folic acid for 12 weeks. The authors found a decrease in the concentration of MMA in blood, going from $22.24 \pm 2.86\%$ in the intervention group and $1.24 \pm 3.59\%$ in the control group ($p < 0.0001$). Total arsenic in blood was reduced by 13.62% in the intervention

group, and 2.49% in the control group ($p = 0.0199$), as well as an increase in the rate of DMA excretion ($p = 0.099$), folic acid participates in methylation reactions [30, 31].

Zablotska et al. [32] studied 11,746 people over 18 years of age and found that consumption of riboflavin, pyridoxine, vitamin A, C, and E, and folic acid significantly modified the effects of arsenic exposure. Participants in the highest percentile of consumption of each nutrient (≥ 1.17 mg/d of riboflavin, ≥ 4.19 mg/d of pyridoxine, ≥ 351.61 μ g/d of folic acid, ≥ 7113.06 mg/d of vitamin C, and ≥ 6.41 mg/d of vitamin E), showed a reduction in the risk of lesions derived from exposure to arsenic in 46–68% ($p < 0.05$). This reflects that the consumption of these key nutrients not only increase the excretion of arsenic, but also the reduction of adverse effects derived from exposure to As. In addition, it has been observed that the concentration of selenium in blood, which is an essential trace element required for the synthesis of several proteins, is inversely related to the risk of pre-malignant lesions in the skin, finding an inversely proportional relationship ($p = 0.03$) between the concentration of selenium in blood and arsenic in urine [8].

In addition to the above, a poor nutritional status, mainly malnutrition, correlates with the development of skin lesions caused by arsenic poisoning. In 2007 Maharjan et al. [33] developed a study in the adult population ($n = 539$) where an increase in the risk of manifesting skin lesions due to the arsenic exposure was found 1.65 times more in subjects with a body mass index (BMI) per below normal (16.5 – 17.1 kg/m²) compared to those with a normal BMI ($p < 0.05$). In addition, it has been described that the decrease in BMI is also a non-specific manifestation of chronic exposure to high concentrations of arsenic (daily arsenic intake of 30 μ g/kg/d). In rural populations, a low BMI is a reflection of a poor nutritional status, which is associated with a low intake of certain nutrients, including antioxidants, and nutrients whose poor ingestion has been related to increased production of MMA, the toxic form of arsenic, and a low production of DMA [30, 31, 34].

1.8. Evidence in Guanajuato, Mexico: food and water security

During 2002–2003, the State Public Health Laboratory of Guanajuato found, in two communities of the state, San Agustín of the municipality of Irapuato and Cútaró in Acámbaro, amounts of arsenic in well water (0.950 and 0.109 mg/L, respectively), greater than the permissible limits established by the WHO, and the Secretary of Health of Mexico. These communities have been studied for several years, adding other populations, where this metalloid has also been found.

Next, in **Table 2**, a chronology of the studies published and in the process of publication is presented. The first studies were based on identifying a relationship between the consumption of water contaminated with arsenic and the presence of arsenic in the hair of children living in two communities, which had a relationship ($n = 55$, $p < 0.0001$) [35]. In addition, a survey of mothers of children of the previous study revealed that 90–94% of them use well water for different culinary preparations such as broths, soups or beans, even with the knowledge that this source of water is contaminated with arsenic, according to the participants, this is done for lack of economic resources to acquire drinking water [10].

References	Main evidence
<p>Effect of four-week multivitamin supplementation on nutritional status and urinary excretion of arsenic in adolescents</p> <p>Rebeca Monroy-Torres, Espinoza Pérez JA, Ramirez Gomez X, Carrizalez Yañez L, Linares-Segovia B, Mejía Saavedra JJ</p> <p>Aceptado 2018, en la revista de Nutrición Hospitalaria</p>	<p>Our objective was to measure the effect of multivitamin supplementation on the nutritional status and urinary excretion of arsenic in adolescents exposed to this metal through drinking water. With an intervention study was carried out on 45 adolescents, exposed to arsenic in drinking water, who were given a daily multivitamin supplement for 4 weeks. The nutritional status, and the levels of arsenic in urine and drinking water were evaluated weekly. The main results were Basal nutritional intake was low for protein, fiber, folic acid, vitamin B2, B6, B12, E, C, selenium and iron, increasing its consumption through the supplement during the intervention and with an increase of approximately 1 g/dL of hemoglobin in all participants. At the end of the intervention the participants presented increase of fat-free mass and decrease in the percentage of body fat. The urinary excretion of arsenic, was greater [35.91 µg/gCr (95% CI = 23.2–74.8 µg/gCr)] in the first week of intervention (p < 0.05) compared to baseline levels of urinary arsenic [43.2 µg/gCr (95% CI = 30.8–117.6 µg/gCr)] and an average of As in water of 96.2 ± 7.5 µg/L. Four-week multivitamin supplementation in the adolescent population studied improved nutritional status and increased metalloid excretion significantly in the first and second post-intervention weeks.</p>
<p>Experiences around the lack of access to water in homes in the State of Guanajuato, Mexico</p> <p>Rebeca Monroy Torres, Jaime Naves Sánchez, Hugo Melgar-Quirñonez</p> <p>(Enviado a publicación a la revista Española de Nutrición Comunitaria)</p>	<p>We analyze the experience in households in the State of Guanajuato, Mexico that suffer from limitations regarding access to water in quality and quantity. A survey of 17 items was applied to 352 households (female heads of household) to measure experiences regarding access to water, in addition to food security, schooling and sociodemographic aspects. Where 33.4% of households reported concern about not having access to water and 74.8% did not have access. 70.8% had to buy water to drink and 5.7% got sick and related it to water consumption. 65.6% of households showed food insecurity. The correlation was significant for the level of education of female heads of household, households with children under 1 and 12 years old with the use of tap water, preparing powdered milk for children, and for food at home and water. These experiences of households around access to water contribute to the discussion and development of scales that insecurity to water, considering food security.</p>
<p>Monroy-Torres y Espinoza-Pérez [39]</p>	<p>The objective of the present work was to identify the presence of risk factors of exposure to arsenic contamination in water, in population living in areas where high levels of this metalloid have been detected. For the identification of the risk factors that could intensify the metalloid exposure, an analytical and transversal study was carried out. For the measurement of food security, a scale validated for Latin America and the Caribbean was applied to 30 heads of family responsible for food, in addition to 30 items, with a three-month time limitation that measured the main risk factors of exposition, which were integrated from the derived risk factors selected from previous studies in the communities exposed to the metalloid and from the scientific literature collected so far. The main risk factors were: food insecurity in 70% of households, 63% worried about not having access to water, lack of access and availability of drinking water and 4% did not have access to water during the last 3 months, since 40% used well, pipe or tap water without previous treatment to prepare food, and 83.3% used to prepare beverages; Other risk factors to consider were the education level of the head of the family and access to public services. The identification of the main risk factors will allow the design of a validation scale, for screening and preventing possible arsenic poisoning in communities exposure to arsenic in water in addition to measuring food security.</p>
<p>Monroy-Torres R et al. [38]</p>	<p>The objective of the study was to evaluate feeding and nutrition practices in communities of the state of Guanajuato exposed to arsenic and to identify some indicators of nutritional risk that contribute to the health effects of the metal. With a transversal design, a survey was applied to 30 family heads, who were selected from a previous study, culinary practices, food consumption, sociodemographic characteristics were evaluated. Culinary and food practices were detected as risk indicators in a population exposed to arsenic. Therefore, these practices should be considered as indicators in the evaluation of the health effects of exposure to the metalloid and other pollutants.</p>

References	Main evidence
Monroy-Torres y cols [37]	To identify the state of food security and access to water in Mexican households, using a validated scale applied in 352 households in rural and urban communities, as well as a pilot scale to assess access to water. Where a 73% of households were classified as food secure (level 1), 15% as being mildly food insecure (level 2), 7% were considered food insecure at a moderate level (level 3) and only 4% were households with severe food insecurity (level 4). At all food security levels interviewees were worried about not having enough access to water, and in the last 3 months 50% of households experiences water scarcity. Most of the households used tap water to prepare the milk for the children, as well as for personal hygiene. 25% of the interviews reported that water availability has declined in their households, while the cost of water has increased. Food security cannot be conceived without taking into account the water situation. The majority of the households report lack of access to enough water, which usually does not meet the conditions of safety for human consumption and food preparation.
Monroy-Torres R et al. [36]	The objective of this study was to describe the perception of the beneficiaries of the Oportunidades program, about food and nutrition security in Atarjea, Guanajuato. A descriptive and qualitative approach study was carried out in 10 families, with a population under 10 years old, in two Atarjea localities. A nutritional and validated food safety survey was applied. Families and doctors do not perceive that the program is fair. New and constant evaluations are suggested to the program by external personnel and by the same beneficiaries of the program. On a proportional basis, families presented food insecurity with moderate hunger and mild food insecurity.
Monroy Torres R et al. [10]	The chronic exposition to arsenic has been linked to various health problems, and some studies have been winged as a source of exposition, in addition to water and food. In some communities in the state of Guanajuato levels were detected outside the rule of arsenic in drinking water. OBJECTIVE: To describe the accessibility to safe water for consumption and preparation food in a community exposed to groundwater with arsenic. MATERIAL Y METHODS: Survey conducted across in 55 housewives from 27 to 55 years of age. The questions were about the use of well water in the preparation in food such as broths, soups, beans, water, fruit; ingestion milk background; main crops in the community, raising cat le and source of drinking water for them. RESULTS: The 90% of housewives used well water for drinking and preparing their food. With regard to the consumption of the well of milk, 24 (44%) consumed milk brand and 31 (44%) consumed cow's milk. The well water was used for livestock and to irrigate crops. CONCLUSIONS: It is emerging that seeks strategies for the population for to have access to water safe, and that health risks are predictable with these sources of exposition to arsenic, like cancer, diabetes and hypertension.
Monroy-Torres R et al. [35]	This cross-sectional study measures the arsenic level in school children exposed to contaminated well water in a rural area in México. Arsenic was measured in hair by hydride generation atomic absorption spectrophotometry. Overall, 110 children were included (average 10 years-old). Among 55 exposed children, mean arsenic level on hair was 1.3 mg/kg (range < 0.006–5.9). All unexposed children had undetectable arsenic levels. The high level of arsenic in water was associated to the level in hair. However, exposed children drank less well water at school or at home than unexposed children, suggesting that the use of contaminated water to cook beans, broths or soups may be the source of arsenic exposure.

Table 2. Compilation of main evidence of the conditioning factors in environmental nutrition and food security of 2009–2018, in Guanajuato, México.

Another study, derived from being able to identify other factors of exposure to As, even though 11% drank tap water and 24.4% both tap water and tap water, even though the population was alerted about concentrations of the metalloid, most reported that in their homes tap water was used to prepare food under cooking as well as in the preparation of flavor water or fruit.

The use of direct water from the tap was treated with drops of chlorine or silver nitrate, which reflects that the population has knowledge about the microbiological form of disinfection, but not for the removal of metals or other toxic substances. The trust that people perceived that they used tap water for food, because they use to boiling the water became drinkable and safe. But it is known to boil water from food or with food, only eliminate microbiological and non toxicological risks, such as eliminating arsenic in water [10, 35].

The first evidence in two communities of the state of Guanajuato (Cútaró and San Agustín) of the presence of arsenic in water and food consumption, biological incorporation to metal, together with environmental factors such as feeding and nutrition practices, socioeconomic, deficiency in public services and lack of access to an innocuous source of water, reflect a risk to the health of the inhabitants of these communities. On the other hand, the evidence shows that the greater the deterioration of the nutritional status, the greater the harmful effects in the organism derived from exposure to arsenic. In addition, several studies show that the consumption of several nutrients, in isolation, improves the detoxification of the metal and reduces the damage to the organism [36–39].

The poor nutritional status in these populations, either due to the excess or nutritional deficiency, the history that supplementation with some nutrients improves the nutritional status, and therefore, the metabolism of the metal in the body, besides that there is no evidence of treatment with A multivitamin supplementation scheme in school population exposed to arsenic are factors that justify the analysis of a multivitamin supplementation plus a dietary regime, on the urinary excretion of arsenic in the school population of the communities of San Agustín and Cútaró as well as others that there are high levels of the metal [40].

The theme of the study of food and water security, derived from the experience of studies in the population of Guanajuato, as intervention proposals from the nutritional clinic, derived from the basis of its metabolism (absorption and excretion) where the consumption of nutrients and access to nutrients is through food and these when people have food security [6] and food security achieved an adequate nutritional status and thus a way to mitigate the toxicity problems of the metalloid. Reason for which the designs of the studies integrated the dietary evaluation and the nutritional status until to design a clinical nutritional intervention study in a follow-up population, entitled *“Effect of a multivitamin supplementation of 4 weeks on the nutritional status and urinary excretion of arsenic in adolescents.”* The main objective was to measure the effect of multivitamin supplementation on nutritional status and urinary excretion of arsenic in 45 adolescents exposed to the metalloid through drinking water. The vitamin supplement was given daily, for 4 weeks, and to the adolescents. Nutritional status, arsenic levels in urine and drinking water were measured too. The main findings were a low intake for proteins, fiber, folic acid, vitamin B₂, B₆, B₁₂, E, C, selenium, and iron, increasing their consumption through the supplement during the intervention, and with an increase of approximately 1 g/dL of hemoglobin, increase in fat-free mass, decrease in the percentage of body fat, with a higher urinary excretion of arsenic [35.91 µg/g Cr (95% CI = 23.2–74.8 µg/g Cr)] from the 1st week of intervention, which was statistically significant

in comparison with basal levels of urinary arsenic [$43.2 \mu\text{g/g Cr}$ ($\text{IC}_{95\%} = 30.8\text{--}117.6 \mu\text{g/g Cr}$) ($p < 0.05$) with an average water with As of $96.2 \pm 7.5 \mu\text{g/L}$.

Other data of interest of the study were a higher percentage of body fat in women (women 27.4 vs. 17.2% in men), where it is known that the presence of obesity generates an inflammatory process [41]. A high BMI has been associated with alterations in the metabolism and excretion of As, due to the relationship between sex hormones, as main donor of methyl groups, in addition to SAM, is the choline, its secretion is influenced by the presence of estrogen. Therefore, a higher risk of toxicity in men could be expected, although it is also known that adolescents have better methylation than the adult population [23, 42, 43]. The consumption of vitamin B₆ and folic acid were low, they are essential nutrients for the formation of methionine, which in turn is required in the metabolism of As and in the formation of the SAM cofactor, part of the arsenic methylation process; and on the other hand nutrients such as vitamin C and vitamin E, are recognized antioxidants in reducing oxidative damage caused by arsenic. The nutritional contribution improved with the supplementation, for the case of hemoglobin it increased almost 1 gram during the 4 weeks of treatment [42, 44] as well as polyphenols present in some of the components of the multivitamin (broccoli extract, cranberry, etc.), although they did not have an important effect in the excretion of arsenic, can provide protection to the organism from the oxidative stress that is being produced by exposure to arsenic in these adolescents [44]. In relation to fiber, a deficiency in its consumption is associated with a higher probability of the appearance of dermatological lesions since fiber could decrease the absorption of arsenic in the gastrointestinal tract [30, 44, 45]. Soluble fiber (fructo-oligosaccharides), acts as a prebiotic, and therefore, to a better metabolism of As [44, 45]. Many of the foods consumed traditionally in Mexico are rich in fructo-oligosaccharides, such as beans and other legumes [38]. The consumption of fruits and vegetables has been low among the young population as well as greater food insecurity in Guanajuato households (71.2% of food insecurity), which represents a low consumption of antioxidants that have an important role in As metabolism [46].

This is the first study, which addressed the analysis of the effect of a 4-week vitamin and mineral supplementation, integrating dietary and nutritional variables. Therefore, the interaction of diet and the environment should be studied, as well as the integration of problems such as overweight, obesity, and anemia mainly.

2. Conclusion

Adequate nutrition in childhood and adolescence as well as in all stages of life, should not only be promoted to prevent chronic degenerative diseases, which entails an inflammatory problem, it is important to equip people with the mechanisms that promote the greatest excretion of the metalloid combined with adequate growth and development. There are environmental factors that cannot be avoided, such as exposure to heavy metals through natural sources such as water, but food and water security as determinants of the mitigation of health risks from exposure to arsenic.

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Conflict of interest

None.

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