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NEW MAP OF ARGENTINE POPULATION EXPOSED TO ARSENIC IN DRINKING WATER

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Abstract:	This study aims to evaluate the population exposed to arsenic in Argentina, proposing a key risk indicator. By employing specific criteria selection, systematic search of the published evidence on arsenic content in drinking water samples at provincial level was carried out. Considering the limit recommended by the WHO -10µg/L - representativeness of evidence was calculated, as well as the percentage of exposed population to high levels of arsenic. For this research, sixty-one useful publications were found and included in the analysis. They provide relevant data for 50% of the provinces, which represents 70% of the national population. The use of an index, "percentage of population exposed" to high arsenic, is proposed as a summary variable, to homogenize the information in the country. and in this way give it comparative value. Information has been systematized and variables identified that may be useful for analysis in eco-epidemiological studies, detailing the current situation of publications of arsenic in drinking water in Argentina.
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NEW MAP OF ARGENTINE POPULATION EXPOSED TO ARSENIC IN DRINKING WATER

ARSENIC POPULATION MAP AND ARGENTNE

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ABSTRACT

This study aims to evaluate the population exposed to arsenic in Argentina, proposing a key risk indicator. By employing specific criteria selection, systematic search of the published evidence on arsenic content in drinking water samples at provincial level was carried out. Considering the limit recommended by the WHO -10μg/L - representativeness of evidence was calculated, as well as the percentage of exposed population to high levels of arsenic.

For this research, sixty-one useful publications were found and included in the analysis. They provide relevant data for 50% of the provinces, which represents 70% of the national population.

The use of an index, “percentage of population exposed” to high arsenic, is proposed as a summary variable, to homogenize the information in the country. and in this way give it comparative value. Information has been systematized and variables identified that may be useful for analysis in eco-epidemiological studies, detailing the current situation of publications of arsenic in drinking water in Argentina.

Keywords: Argentina - Arsenic - Map - Water -

HIGHLIGHTS

- Half of the provinces provide representative information on populations exposed to high levels of arsenic.

- The percentage of exposed populations is highly variable, from 0 to almost 100%.
- The use of the PEP index, “percentage of exposed population” to elevated arsenic levels, is proposed as a summary variable.
- A map showing different regional situations is drawn –half of the Argentine provinces–two thirds of the total population.

GRAPHICAL ABSTRACT

INTRODUCTION

Arsenic (As) is a ubiquitous element, widely distributed throughout the environment. It can be found in the air, water and land, and is one of the ten chemicals considered by the Word Health Organization as major public health concern (WHO, 2022). The largest amounts of As in the environment come from natural sources (weathering, biological activity, volcanic emissions). However, anthropogenic activities –industrial processes like mining, metal smelting, pesticides usage, wood preservatives, etc. – also play their part (Litter, 2018). Surface and underground water natural resources are affected by the geochemical cycle of arsenic due to many reasons: interactions of the aquatic environment with rocks, sediments and soils; emissions from volcanic and geothermal sources; erosion and leaching of geological formations; and mining waste that produce high concentrations of this element in the environment (RSA, 2018).

Humans can be exposed to arsenic in different ways: by consuming contaminated food or water; using them in meal preparation, crops irrigation or industrial processing, and it can also be inhaled. Prolonged exposure to inorganic arsenic – through any of these ways – can cause acute and chronic poisoning, from skin lesions to neoplasm.

Arsenicism is an endemic disease. This is especially true in Argentina, where the population exposed to high levels of arsenic (> 50 μg/L) has been calculated in about 4 million; moreover, its accepted level places the country among the most affected ones within Latin America (Litter et al., 2019). Chronic Endemic Regional Hydroarsenicism (HACRE, acronym in spanish) characterized due to skin lesions and systemic cancerous and non-cancerous alterations resulting from exposure to low levels for prolonged periods., which has been known in Argentina since 1913, ranks second after the USA in the world's most affected countries (Ministerio de Salud, Argentina, 2006). The situation has worsened considering the long-term and chronic impact on human health. A recent piece of research carried out in the Central Region of Argentina has compared arsenic genotoxicity in two groups of population, one exposed to high levels and one not exposed at all (Quiroga, 2023). Exposure has an impact on chronic diseases, from congenital malformations to neurodegenerative diseases, and cancer. Arsenic was classified by the WHO's International Agency for Research on Cancer (IARC) as carcinogenic to humans (Rousseau et al, 2005).

Perinatal exposure deserves special attention, both intrauterine and during the first years of life. As regards certain cancers, a study carried out in Chile exploring early life exposure and adulthood risks showed a clear association of these two variables. It was thus possible to differentiate the risks of intrauterine and early childhood exposures in periods of high and low exposure (Smith et al., 2006). The literature review confirms this situation as the longest risk period (Young et al., 2018; Martinez et al., 2021).

In its Guidelines for Drinking-water Quality, the WHO established a limit value for arsenic in water. It aims to serve as a world basis for regulatory and standardization tasks in this regard. The recommended limit in drinking water is 10 µg/L (WHO, 2017). The Argentine Food Code [CAA by its Spanish acronym] establishes a higher safety limit, 50 µg/L (MSA-ANMAT, 2005). However, levels well above this limit have already been reached in the country, even exceeding 200 µg/L (Nicolli et al., 1989). Much of the scientific evidence has shown that between the limits of the WHO and the CAA, there is a significant risk to human health.

Despite what has been stated so far, the real proportion of the population exposed to high arsenic level in the country is still unknown. The information available on arsenic content in drinking water is scattered and not updated. Therefore, the objective of this analysis is to carry out a systematic review to collect the published information and evaluate its connection with the exposed population.

METHODOLOGY

Bibliographic Review

The following open-access databases were analyzed to carry out a systematic search of the available evidence: PUBMED, Google Scholar, Latin American and Caribbean Health Sciences Literature (LILACS) and the National System of Digital Repositories [SNRD by its Spanish acronym] (Argentina). The terms "*arsenic AND water consumption AND Argentina*"; "*arsenic AND water AND Argentina" were* used, and the Spanish ones, "*arsénico Y agua de consumo Y provincia Y argentina*".

The selection criteria to include the articles were the following: 1) if the number of evaluated population was available; 2) if it expressed the number of water samples assessed; 3) if it expressed the As value in absolute terms; and 4) if the analyzed water was for human consumption. All these conditions were considered for each province.

Variables Construction

After selecting valid bibliography, the following items were classified and calculated by provinces:

(1) percentage of total population per province. It was calculated following the National Institute of Statistics and Census (INDEC, 2010) taking into account the total population assessed. This allowed to know the ***"representativeness"*** of the samples for each province, which means the percentage of the total population of the province represented in the referenced specific studies. A limit of 30% was established to define this variable as high or low, decided on the basis that -approximately- one in three inhabitants were considered within the population under study.

(2) considering the number of samples above the WHO value (10 μg/L), the percentage of samples with high levels of arsenic was calculated and this was applied to the total population evaluated., obtaining thus its **exposure index**.

(3) the exposure index was applied to the total provincial population, which allowed to obtain the so-called **Percentage of Exposed Population** (PEP) per province.

Through these calculations, two variables were obtained for each province: a) "representativeness" of the samples obtained over the total population; and, b) the population "exposure" variable, or PEP. If the sample captured is representative, the exposure percentage can be projected to the rest of the population and interpreted as a provincial index.

REPRESENTATIVENESS	x	**POPULATION EXPOSURE INDEX**	=	**% EXPOSED POPULATION**
(>30%)		(% of samples >10 ug/L)		PEP

RESULTS

<u>Bibliographic Review</u>

As can be seen in the systematic literature review (Figure 1), 569 publications were found. After applying the duplicates or non-relevant by title or summary filter, 315 publications remained suitable to be analyzed according to the selection criteria detailed in the Methodology. Then, another 254 articles were excluded in this process, resulting in 61 final publications useful for this research. Relevant information was found for 50% of the Argentine provinces, which represents 70% of the total population nationwide; this is twelve provinces and represents approximately thirty-two million inhabitants.

<u>Representativeness and percentages of exposed population</u>

When analyzing provincial representativeness, the population under study presented a considerable heterogeneity: ranging from 0.35% (the lowest, in Chubut province) to 99% (the highest, in Santa Fe province). An arbitrary limit of 30% was established, which made it possible to obtain two groups: high and low representativeness.

In relation to the Percentage of Exposed Population (PEP), the highest exposure (Table 1) was found in La Pampa (87.98%), followed by Catamarca (78.90%) and Buenos Aires provinces (68.55%). In relation to the provinces with low representativeness (Table 2), the PEP is significantly low, between 0 and 10%. However, due to the fact that the sampling is small, the data identified is not precise. The distribution of the provinces according to the PEP is presented in a graphic (Figure 2). Of a total population of approximately 32 million inhabitants, 55% (around 17 million) is exposed to arsenic levels greater than 10 μg/L in drinking water.

DISCUSSION

It has been documented worldwide that millions of people are affected by being exposed to drinking water with high levels of arsenic. Among the largest and most populated areas involved, in Asia, for example, the populations most at risk are: the Gulf of Bengal, in Bangladesh (Rahman et al., 2001); Northeast India (Bhattacharyya et al., 2003); Inner Mongolia in China (Guo et al., 2001); and Taiwan and Vietnam (Smedley et al., 2003). In North and Central America, the west of the United States (BEST, 2001) and Mexico (Rodriguez et al., 2004); and in South America, Argentina, Chile, Bolivia and Peru (Bundschuh el al, 2012).

Argentina has empirically known for more than a century that its drinking water contains high levels of As because there are endemic diseases associated to this element. However, the country does not possess unified and precise information to identify its true sanitary risk. There have been two attempts to draft a "map" of this situation but they have shown varied limitations, especially because they referred to isolated values that did not specify the population involved (Ministerio de Salud Argentina, 2006) or else showed a general distribution of the population in graphics but did not specify As consumption (Litter et al., 2019). Preliminary information –using a limit value of 50 µg/L – mentions a total exposed population of 4 million inhabitants. This piece of research, however, employing the WHO limit (10 µg/L) finds an approximate total of 17 million, more than four times the previous one.

The accumulation of evidence on chronic toxicological effects of arsenic ingestion through drinking water has led to a progressive reduction in the threshold limit of arsenic concentrations in water intended for human consumption (Smedley et al., 2002). In Argentina and Chile, this threshold is 50 ug/L (MSA-ANMAT, 2005; Diario Oficial de la República de Chile, 1984). This level is intended to be reduced to 10 µg/L, as set by the European Union (European Union, 1998), recommended by the World Health Organization (WHO, 2004), and proposed since January 2006 by the United States Environmental Agency as a "Maximum Contaminant Level Goal" (MCLG) (USEPA, 2005). According to these standards, the economic implications of ensuring that water has an acceptable arsenic concentration has opened an important debate on the level to be set, both in large areas of developed and developing countries (Smith & Smith, 2004). The existing literature confirms that the levels of arsenic in drinking water recommended by the WHO in relation to chronic non-communicable diseases are those that have been shown to be associated with this lower threshold (Rehman et al., 2018; Ferragut Cardoso & Udoh, 2020; Jaafarzadeh et al., 2022).

Although arsenic contamination has been exhaustively and long studied as acute poisoning (Campbell & Alvarez, 1989), pathologies related to deferred impacts over time, such as cancer, were little addressed in the country as specific associated issues. However, recent analyses have demonstrated their link in Argentina (Duarte et al., 2022). It is, therefore, necessary to update the information on arsenic in drinking water in the country. In other countries such as the USA, approximation models on As levels in drinking water have been built at national level, which have made possible to define high and low risk areas (Ayotte et al., 2017). Likewise, Bangladesh has carried out a review of related publications that made possible to determine an (approximate) total exposed population (Karim, 2000). Other countries, including higher-risk countries, only have partial information available.

This work contributes in highlighting both the existing and missing information. It raises awareness to the situation of a large proportion of Argentina's population in the face of arsenical water consumption. The wide variability of information observed in this work is mainly due to the particular or regional epidemiological alert, which leads local researchers to delve into the subject. It can be therefore deduced that, in provinces with fewer perceived risks of exposure to arsenic, publications are fewer than in those that have historically been associated with this environmental toxicant. Although "exposed population" is a key -and original- concept in this analysis, an extensive use of this term was not found. Most of the analyzed articles that had to be discarded detail the analytical determinations of water samples and collection sites. However, they do not describe the population under analysis, which is fundamental to assess the true sanitary impact of arsenic contamination in drinking water. Conversely, the number of samples is not a correct parameter to determine the scope of the analysis, nor the level reached by the assessment above the cutoff applied. Undoubtedly, when a region presents epidemiological alarms related to chronic non-communicable diseases related to arsenical contamination in drinking water, it is necessary to evaluate the precise levels of this element in representative samples of the population.

The methodology employed in this analysis presents some bias: 1) possible duplications of the exposed populations in each province, given that some studies overlap in these territories without mentioning the specific places of collection; 2) there is a bias inherent to the publications, which is related to sampling, especially in well water, with the distribution of populations in relation to sources of consumption unknown; 3) the concept of exposed population is not included in publications related to arsenic, with the PEP variable, proposed in this work, being an indirect calculation.;

4) the temporality of the water evaluations is dissimilar; in any case, arsenic has been described as a stable toxicant in the environment -with little variability- given the fundamentally natural contamination, except that interventions have been carried out to remove this element, a scarce, partial or non-existent issue in Argentina throughout of the years.

CONCLUSIONS

This review adds value to the already published evidence, systematizing information and identifying variables that may be useful for ecoepidemiological studies to analyze both humans and fauna. An index is proposed, the "percentage of exposed population" (PEP) to high arsenic levels as a summary variable, to homogenize the information in the country, giving it thus a comparative value. It has also been validated in a previous work, related to cancer mortality at provinces' departmental level in the central region of Argentina (Duarte et al, 2022).

Territorial interventions in health management, especially in sensitive issues such as population's consumption of arsenical water, require orderly, organized and coordinated information to guide actions to provide tools and introduce public policies that benefit inhabitants' life.

Finally, the present work allows to identify -indirectly- the areas of high exposure, as a guide to deepen future research that allows to give certainty to these findings.

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Figure 1. Systematic Review Flowchart

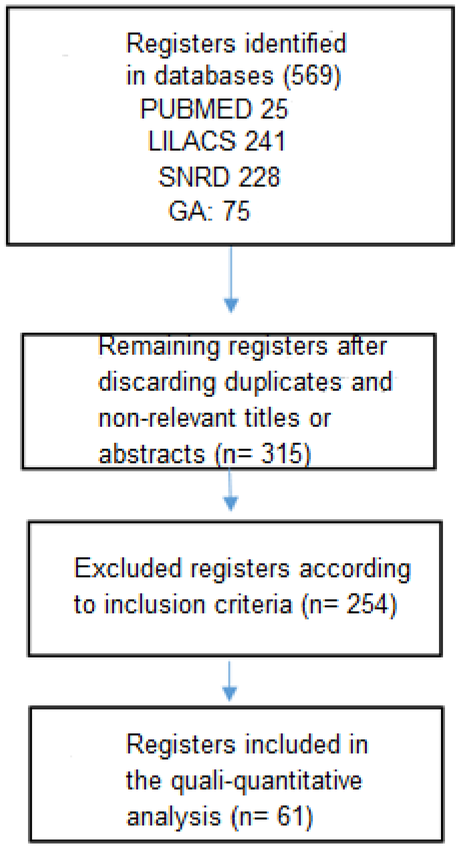


Table 1. High representativeness and exposition levels to arsenic by province

PROVINCES	Percentage of population under study (%)	Percentage of Population exposed (PEP) to high levels of As	Bibliograpy
	REPRESENTATIVENESS	EXPOSITION	
SANTA FE	99	60.08	ENRES (2019)
LA PAMPA	95.75	87.98 %	Pariani et al., (2014); Vercellino. (2020); O'Reilly et al. (2020)
NEUQUÉN	88.98	0	Center for Environmental Engineering (CIMA), ITBA (2020); Velazquez (2019)
CATAMARCA	86.64	78.9	Rugierri et al. (2009); Saracho et al. (2016); Saracho et al. (2019); Graziano et al. (2013); CIMA (2020); Vilches et al. (2005).
BUENOS AIRES	77.6	68.55	Navoni et al. (2012); RSA CONICET (2018); Galindo et al. (2005).
CORRIENTES	57.17	11.4	CIMA (2020)
CHACO	75.43	53.51	Roshdestwensky et al. (2016); Martínez et al. (2014); Trinelli et al. (2018); Concha et al. (1998); Osicka et al. (2002); CIMA (2020); Buchhamer et al. (2012); Blanes et al. (2011)
CÓRDOBA	70.6	29.09	Villalba et al. (2000); Blarasin et al. (2015); Penedo and Zigaran (1998)
ENTRE RÍOS	61.64	28.02	UNER (2019); CIMA (2020)
TIERRA DEL FUEGO	44	0	CIMA (2020)
JUJUY	34.2	22.27	López Steinmetz et al (2018); CIMA (2020); Murray et al. (2019); Ruggeri et al. (2009)

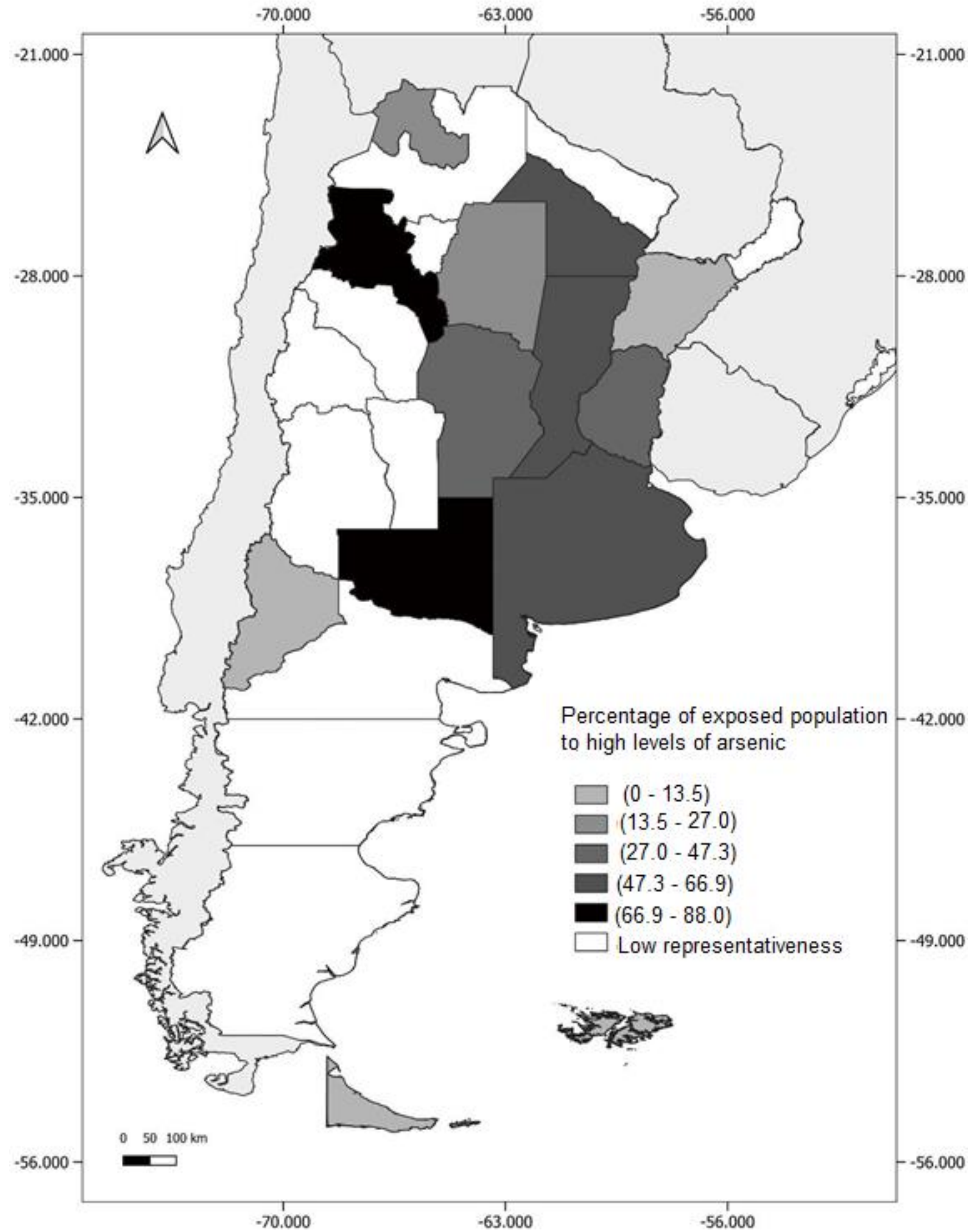
SANTIAGO DEL ESTERO	32.84	26,36	Bhattacharya et al. (2006); Revelli et al. (2016); Vidoni et al. (2010); Bejarano Sifuentes and Nordberg. (2003); Bundschuh et al. (2004); Calatayud et al. (2019); Navoni et al. (2014); CIMA (2020); Litter et al. (2015)

Table 2. Low representativeness and exposition levels to arsenic by province

PROVINCE	Porcentage of Population under study (%)	Percentage of exposed population (PEP) (%)	Bibliograpy
	REPRESENTATIVENESS	EXPOSITION	
SANTA CRUZ	26.79	0	CIMA (2020)
SAN LUIS	20	0	CIMA (2020)
TUCUMÁN	14.11	10.51	Soria de González et al. (2008-2011); Guber et al. (2009); Nicolli et al. (2012); CIMA (2020); Gerstenfeld et al. (2012); Soria et al.
MENDOZA	12.01	9.13	Elia Dazat (2017); CIMA (2020)
SALTA	9.26	5.01	Concha et al. (1998, 2010); Hudson-Edwards et al. (2012); Boujon (2021); CIMA 2020
FORMOSA	8.97	3.99	CIMA (2020)
RÍO NEGRO	8.46	2.77	Grizmado. (2012); Garrido (2017); CIMA (2020)
SAN JUAN	4.95	4.95	CIMA (2020) O'Reilly et al. (2010)
MISIONES	2.51	0.84	CIMA (2020)

LA RIOJA	1.66	0.21	Miguel et al. (2017); Nievas et al. (2013); CIMA
CHUBUT	0.35	0.27	Nievas et al. (2013)
CABA	0	0	CIMA (2020)

Fig. 2. Map of the population exposed to high arsenic levels in provinces with high representativeness. Argentina.



Source: elaborated with own data

NEW MAP OF ARGENTINE POPULATION EXPOSED TO ARSENIC IN DRINKING WATER

ARSENIC POPULATION MAP AND ARGENTNE

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ABSTRACT

This study aims to evaluate the population exposed to arsenic in Argentina, proposing a key risk indicator. By employing specific criteria selection, systematic search of the published evidence on arsenic content in drinking water samples at provincial level was carried out. Considering the limit recommended by the WHO -10μg/L - representativeness of evidence was calculated, as well as the percentage of exposed population to high levels of arsenic.

For this research, sixty-one useful publications were found and included in the analysis. They provide relevant data for 50% of the provinces, which represents 70% of the national population.

The use of an index, “percentage of population exposed” to high arsenic, is proposed as a summary variable, to homogenize the information in the country. and in this way give it comparative value. Information has been systematized and variables identified that may be useful for analysis in eco-epidemiological studies, detailing the current situation of publications of arsenic in drinking water in Argentina.

Keywords: Argentina - Arsenic - Map - Water -

HIGHLIGHTS

- Half of the provinces provide representative information on populations exposed to high levels of arsenic.

- The percentage of exposed populations is highly variable, from 0 to almost 100%.
- The use of the PEP index, “percentage of exposed population” to elevated arsenic levels, is proposed as a summary variable.
- A map showing different regional situations is drawn, half of the Argentine provinces, two thirds of the total population.

GRAPHICAL ABSTRACT

INTRODUCTION

Arsenic (As) is a ubiquitous element, widely distributed throughout the environment. It can be found in the air, water and land, and is one of the ten chemicals considered by the Word Health Organization as major public health concern (WHO, 2022). The largest amounts of As in the environment come from natural sources (weathering, biological activity, volcanic emissions). However, anthropogenic activities –industrial processes like mining, metal smelting, pesticides usage, wood preservatives, etc. – also play their part (Litter, 2018). Surface and underground water natural resources are affected by the geochemical cycle of arsenic due to many reasons: interactions of the aquatic environment with rocks, sediments and soils; emissions from volcanic and geothermal sources; erosion and leaching of geological formations; and mining waste that produce high concentrations of this element in the environment (RSA, 2018).

Humans can be exposed to arsenic in different ways: by consuming contaminated food or water; using them in meal preparation, crops irrigation or industrial processing, and it can also be inhaled. Prolonged exposure to inorganic arsenic – through any of these ways – can cause acute and chronic poisoning, from skin lesions to neoplasm.

It has been documented worldwide that millions of people are affected by being exposed to drinking water with high levels of arsenic. Among the largest and most populated areas involved, in Asia, for example, the populations most at risk are: the Gulf of Bengal, in Bangladesh (Rahman et al., 2001); Northeast India (Bhattacharyya et al., 2003); Inner Mongolia in China (Guo et al., 2001); and Taiwan and Vietnam (Smedley et al., 2003). In North and Central America, the west of the United States (BEST, 2001) and Mexico (Rodriguez et al., 2004); and in South America, Argentina, Chile, Bolivia and Peru (Bundschuh el al, 2012).

Arsenicism is an endemic disease. This is especially true in Argentina, where the population exposed to high levels of arsenic (> 50 μg/L) has been calculated in about 1 million; moreover, its accepted level places the country among the most affected ones within Latin America (Litter et al., 2019). Chronic Endemic Regional Hydroarsenicism (HACRE, acronym in spanish) characterized due to skin lesions and systemic cancerous and non-cancerous alterations resulting from exposure to low levels for prolonged periods., which has been known in Argentina since 1913, (Ministerio de Salud, Argentina, 2006). The situation has worsened considering the long-term and chronic impact on human health, also due to population growth and the length of exposure times without intervention.

A recent piece of research carried out in the Central Region of Argentina has compared arsenic genotoxicity in two groups of population -using studies in groundwater- one exposed to high levels, which showed 60 ug/L as an average of the total samples, and one not exposed at all (Quiroga, 2023). Exposure has an impact on chronic diseases, from congenital malformations to neurodegenerative diseases, and cancer. Arsenic was classified by the WHO's International Agency for Research on Cancer (IARC) as carcinogenic to humans (Rousseau et al, 2005).

Early childhood exposures (including intrauterine) are a period deserves special attention. As regards certain cancers, a study carried out in Chile exploring early life exposure and adulthood risks showed a clear association of these two variables. It was thus possible to differentiate the risks of intrauterine and early childhood exposures in periods of high and low exposure (Smith et al., 2006). The literature review confirms this situation as the longest risk period (Young et al., 2018; Martinez et al., 2021).

In its Guidelines for Drinking-water Quality, the WHO established a limit value for arsenic in water. It aims to serve as a world basis for regulatory and standardization tasks in this regard. The recommended limit in drinking water is 10 μg/L (WHO, 2017). The Argentine Food Code [CAA by its Spanish acronym] establishes a higher safety limit, 50 µg/L (MSA-ANMAT, 2005). However, levels well above this limit have already been reached in the country, even exceeding 200 µg/L (Nicolli et al., 1989). Much of the scientific evidence has shown that between the limits of the WHO and the CAA, there is a significant risk to human health.

Despite what has been stated so far, the real proportion of the population exposed to high arsenic level in the country is still unknown. The information available on arsenic content in drinking water is scattered and not updated. Therefore, the objective of this analysis is to carry out a systematic review to collect the published information and evaluate its connection with the exposed population.

METHODOLOGY

<u>*Bibliographic Review*</u>

The following open-access databases were analyzed to carry out a systematic search of the available evidence: PUBMED, Google Scholar, Latin American and Caribbean Health Sciences Literature (LILACS) and the National System of Digital Repositories [SNRD by its Spanish acronym] (Argentina). The terms "*arsenic AND water consumption AND Argentina*"; "*arsenic AND water AND Argentina" were* used, and the Spanish ones, "*arsénico Y agua de consumo Y provincia Y argentina*".

The selection criteria to include the articles were the following: 1) if the number of evaluated population was available; 2) if it expressed the number of water samples assessed; 3) if it expressed the As value in absolute terms; and 4) if the analyzed water was for human consumption. All these conditions were considered for each province.

Variables Construction

After selecting valid bibliography, the following items were classified and calculated by provinces:

(1) percentage of total population per province. It was calculated following the National Institute of Statistics and Census (INDEC, 2010) taking into account the total population assessed. This allowed to know the ***"representativeness"*** of the samples for each province, which means the percentage of the total population of the province represented in the referenced specific studies. A limit of 30% was established, since it is representative of a population exposure analysis, considering that the captured samples are covering above a third of the provincial inhabitants.

(2) considering the number of samples above the WHO value (10 µg/L), the percentage of samples with high levels of arsenic was calculated and this was applied to the total population evaluated., obtaining thus its **exposure index**.

(3) the exposure index was applied to the total provincial population, which allowed to obtain the so-called **Percentage of Exposed Population** (PEP) per province.

Through these calculations, two variables were obtained for each province: a) "representativeness" of the samples obtained over the total population; and, b) the population "exposure" variable, or PEP. If the sample captured is representative, the exposure percentage can be projected to the rest of the population and interpreted as a provincial index.

REPRESENTATIVENESS	x	**POPULATION EXPOSURE INDEX**	=	**% EXPOSED POPULATION**
(>30%)		(% of samples >10 ug/L)		PEP

RESULTS

Bibliographic Review

As can be seen in the systematic literature review (Figure 1), 569 publications were found. After applying the duplicates or non-relevant by title or summary filter, 315 publications remained suitable to be analyzed according to the selection criteria detailed in the Methodology. Then, another 254 articles were excluded -following exclusion criteria- in this process, resulting in 61 final publications useful for this research. Relevant information was found for 50% of the Argentine provinces, which represents 70% of the total population nationwide; this is twelve provinces and represents approximately thirty-two million inhabitants.

Representativeness and percentages of exposed population

When analyzing provincial representativeness, the population under study presented a considerable heterogeneity: ranging from 0.35% (the lowest, in Chubut province) to 99% (the highest, in Santa Fe province). An arbitrary limit of 30% was established, which made it possible to obtain two groups: high and low representativeness.

In relation to the Percentage of Exposed Population (PEP), the highest exposure (Table 1) was found in La Pampa (87.98%), followed by Catamarca (78.90%) and Buenos Aires provinces (68.55%). In relation to the provinces with low representativeness (Table 2), the PEP is significantly low, between 0 and 10%. However, due to the fact that the sampling is small, the data identified is not precise. The distribution of the provinces according to the PEP is presented in a graphic (Figure 2). Of a total population of approximately 32 million inhabitants, 55% (around 17 million) is exposed to arsenic levels greater than 10 µg/L in drinking water.

DISCUSSION

This work contributes in highlighting both the existing and missing information about the situation of a large proportion of Argentina's population in the face of arsenical water consumption. The map presented here allows to identify, in the first instance, the provinces that have useful data and those that do not. And, secondly, the differences in their levels of exposure.

The wide variability of information observed in this work is mainly due to the particular or regional epidemiological alert, which leads local researchers to delve into the subject. It can be therefore deduced that, in provinces with fewer perceived risks of exposure to arsenic, publications are fewer than in those that have historically been associated with this environmental toxicant.

Although "exposed population" is a key -and original- concept in this analysis, an extensive use of this term was not found. Most of the analyzed articles that had to be discarded detail the analytical determinations of water samples and collection sites. However, they do not describe the population under analysis, which is fundamental to assess the true sanitary impact of arsenic contamination in drinking water. Conversely, the number of samples is not a correct parameter to determine the scope of the analysis, nor the level reached by the assessment above the cutoff applied. Undoubtedly, when a region presents epidemiological alarms related to chronic non-communicable diseases related to arsenical contamination in drinking water, it is necessary to evaluate the precise levels of this element in representative samples of the population.

Argentina has empirically known for more than a century that its drinking water contains high levels of As because there are endemic diseases associated to this element. However, the country does not possess unified and precise information to identify its true sanitary risk. There have been two attempts to draft a "map" of this situation but they have shown varied limitations, especially because they referred to isolated values that did not specify the population involved (Ministerio de Salud

Argentina, 2006) or else showed a general distribution of the population in graphics but did not specify As consumption (Litter et al., 2019). Preliminary information –using a limit value of 50 µg/L – mentions a total exposed population of 1 million inhabitants (Ministerio de Salud Argentina, 2006). The present analysis, however, employing the WHO limit (10 µg/L) finds an approximate total of 17 million, much more than the previous one.

The accumulation of evidence on chronic toxicological effects of arsenic ingestion through drinking water has led to a progressive reduction in the threshold limit of arsenic concentrations in water intended for human consumption (Smedley et al., 2002). In Argentina and Chile, this threshold is 50 ug/L (MSA-ANMAT, 2005; Diario Oficial de la República de Chile, 1984). This level is intended to be reduced to 10 µg/L, as set by the European Union (European Union, 1998), recommended by the World Health Organization (WHO, 2004), and proposed since January 2006 by the United States Environmental Agency as a "Maximum Contaminant Level Goal" (MCLG) (USEPA, 2005). According to these standards, the economic implications of ensuring that water has an acceptable arsenic concentration has opened an important debate on the level to be set, both in large areas of developed and developing countries (Smith & Smith, 2004). The existing literature confirms that the levels of arsenic in drinking water recommended by the WHO in relation to chronic non-communicable diseases are those that have been shown to be associated with this lower threshold (Rehman et al., 2018; Ferragut Cardoso & Udoh, 2020; Jaafarzadeh et al., 2022).

Although arsenic contamination has been exhaustively and long studied as acute poisoning (Campbell & Alvarez, 1989), pathologies related to deferred impacts over time, such as cancer, were little addressed in the country as specific associated issues. However, recent analyses have demonstrated their link in Argentina (Duarte et al., 2022). It is, therefore, necessary to update the information on arsenic in drinking water in this country. In other countries such as the USA, approximation models on As levels in drinking water have been built at national level, which have made possible to define high and low risk areas (Ayotte et al., 2017). Likewise, Bangladesh has carried out a review of related publications that made possible to determine an (approximate) total exposed population (Karim, 2000). Other countries, including higher-risk countries, only have partial information available.

The methodology employed in this analysis presents some bias: 1) possible duplications of the exposed populations in few provinces, given that some studies overlap in their territories without mentioning the specific places of collection; 2) there is a bias inherent to the publications, which is related to sampling, especially in well water, with the distribution of populations in relation to sources of consumption unknown; 3) the concept of exposed population is not included in publications related to arsenic with the PEP variable, proposed in this work, being an indirect calculation.; 4) the temporality of the water evaluations is dissimilar; in any case, arsenic has been described as a stable toxicant in the environment -with little variability- given the fundamentally natural contamination, unless interventions have been carried out to eliminate this element; a scarce, partial or non-existent issue in Argentina.

CONCLUSIONS

This review adds value to the already published evidence, systematizing information and identifying variables that may be useful for ecoepidemiological studies to analyze both humans and fauna. An index is proposed, the "percentage of exposed population" (PEP) to high arsenic levels as a summary variable, to homogenize the information in the country, giving it thus a comparative value. It has also been validated in a previous work, related to cancer mortality at provinces' departmental level in the central region of Argentina (Duarte et al, 2022).

Territorial interventions in health management, especially in sensitive issues such as population's consumption of arsenical water, require orderly, organized and coordinated information to guide actions to provide tools and introduce public policies that benefit inhabitants' life.

Finally, this work allows to identify -indirectly- the areas of high exposure, as a guide to deepen future field investigations that permit to give certainty -or not- to these findings.

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Figure 1. Systematic Review Flowchart

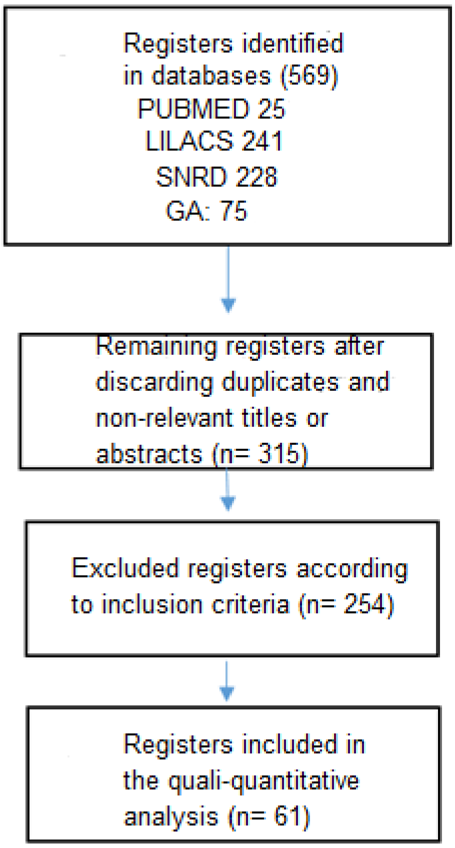


Table 1. High representativeness and exposure levels to arsenic by province

PROVINCES	Percentage of population under study (%)	Percentage of Population exposed (PEP) to high levels of As	Bibliograpy
	REPRESENTATIVENESS	EXPOSITION	
SANTA FE	99	60.08	ENRES (2019)
LA PAMPA	95.75	87.98 %	Pariani et al., (2014); Vercellino. (2020); O'Reilly et al. (2020)
NEUQUÉN	88.98	0	Center for Environmental Engineering (CIMA), ITBA (2020); Velazquez (2019)
CATAMARCA	86.64	78.9	Rugierri et al. (2009); Saracho et al. (2016); Saracho et al. (2019); Graziano et al. (2013); CIMA (2020); Vilches et al. (2005).
BUENOS AIRES	77.6	68.55	Navoni et al. (2012); RSA CONICET (2018); Galindo et al. (2005).
CORRIENTES	57.17	11.4	CIMA (2020)
CHACO	75.43	53.51	Roshdestwensky et al. (2016); Martínez et al. (2014); Trinelli et al. (2018); Concha et al. (1998); Osicka et al. (2002); CIMA (2020); Buchhamer et al. (2012); Blanes et al. (2011)
CÓRDOBA	70.6	29.09	Villalba et al. (2000); Blarasin et al. (2015); Penedo and Zigaran (1998)
ENTRE RÍOS	61.64	28.02	UNER (2019); CIMA (2020)
TIERRA DEL FUEGO	44	0	CIMA (2020)
JUJUY	34.2	22.27	López Steinmetz et al (2018); CIMA (2020); Murray et al. (2019); Ruggeri et al. (2009)

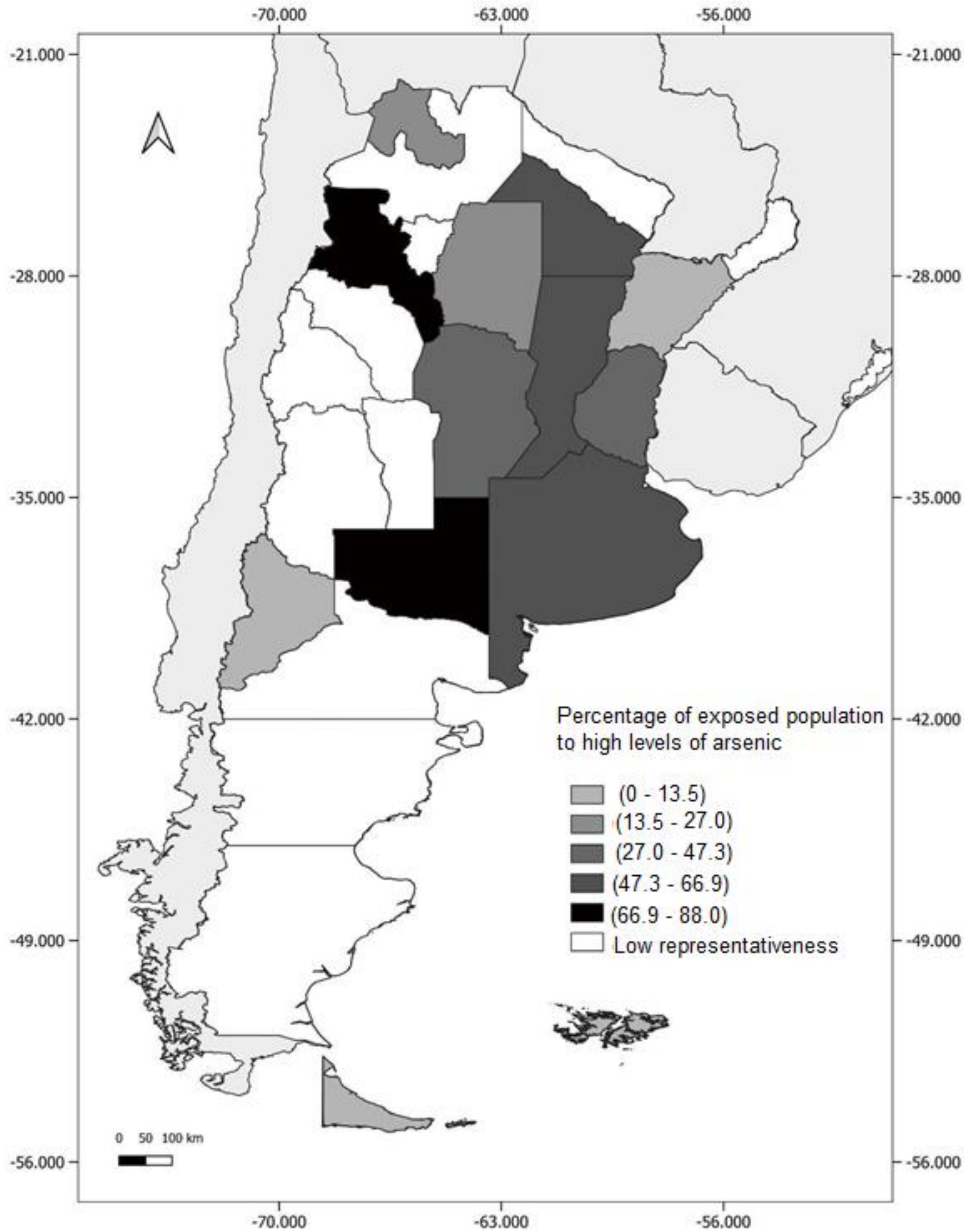
SANTIAGO DEL ESTERO	32.84	26,36	Bhattacharya et al. (2006); Revelli et al. (2016); Vidoni et al. (2010); Bejarano Sifuentes and Nordberg. (2003); Bundschuh et al. (2004); Calatayud et al. (2019); Navoni et al. (2014); CIMA (2020); Litter et al. (2015)

Table 2. Low representativeness and exposition levels to arsenic by province

PROVINCE	Percentage of Population under study (%)	Percentage of exposed population (PEP) (%)	Bibliograpy
	REPRESENTATIVENESS	**EXPOSITION**	
SANTA CRUZ	26.79	0	CIMA (2020)
SAN LUIS	20	0	CIMA (2020)
TUCUMÁN	14.11	10.51	Soria de González et al. (2008-2011); Guber et al. (2009); Nicolli et al. (2012); CIMA (2020); Gerstenfeld et al. (2012); Soria et al.
MENDOZA	12.01	9.13	Elia Dazat (2017); CIMA (2020)
SALTA	9.26	5.01	Concha et al. (1998, 2010); Hudson-Edwards et al. (2012); Boujon (2021); CIMA 2020
FORMOSA	8.97	3.99	CIMA (2020)
RÍO NEGRO	8.46	2.77	Grizmado. (2012); Garrido (2017); CIMA (2020)
SAN JUAN	4.95	4.95	CIMA (2020) O'Reilly et al. (2010)
MISIONES	2.51	0.84	CIMA (2020)

LA RIOJA	1.66	0.21	Miguel et al. (2017); Nievas et al. (2013); CIMA
CHUBUT	0.35	0.27	Nievas et al. (2013)
CABA	0	0	CIMA (2020)

Fig. 2. Map of the population exposed to high arsenic levels in provinces with high representativeness. Argentina.



Source: elaborated with own data

NEW MAP OF ARGENTINE POPULATION EXPOSED TO ARSENIC IN DRINKING WATER

ARSENIC POPULATION MAP AND ARGENTNE

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ABSTRACT

This study aims to evaluate the population exposed to arsenic in Argentina, proposing a key risk indicator. By employing specific criteria selection, systematic search of the published evidence on arsenic content in drinking water samples at provincial level was carried out. Considering the limit recommended by the WHO -10μg/L - representativeness of evidence was calculated, as well as the percentage of exposed population to high levels of arsenic.

For this research, sixty-one useful publications were found and included in the analysis. They provide relevant data for 50% of the provinces, which represents 70% of the national population.

The use of an index, "percentage of population exposed" to high arsenic, is proposed as a summary variable, to homogenize the information in the country and, in this way, give it comparative value. Information has been systematized and variables identified that may be useful for analysis in eco-epidemiological studies, detailing the current situation of publications of arsenic in drinking water in Argentina.

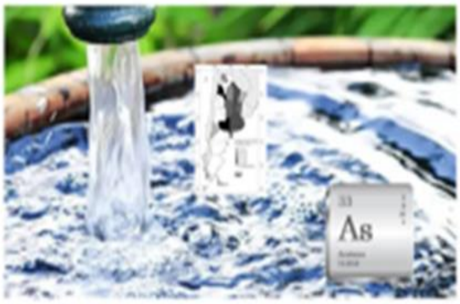
Keywords: Argentina - Arsenic - Map - Water -

HIGHLIGHTS

- Half of the provinces provide representative information on populations exposed to high levels of arsenic.

- The percentage of exposed populations is highly variable, from 0 to almost 100%.
- The use of the PEP index, “percentage of exposed population” to elevated arsenic levels, is proposed as a summary variable.
- A map showing different regional situations is drawn –half of the Argentine provinces–two thirds of the total population.

GRAPHICAL ABSTRACT



INTRODUCTION

Arsenic (As) is a ubiquitous element, widely distributed throughout the environment. It can be found in the air, water and land, and is one of the ten chemicals considered by the Word Health Organization as major public health concern (WHO, 2022). The largest amounts of As in the environment come from natural sources (weathering, biological activity, volcanic emissions). However, anthropogenic activities –industrial processes like mining, metal smelting, pesticides usage, wood preservatives, etc. – also play their part (Litter, 2018). Surface and underground water natural resources are affected by the geochemical cycle of arsenic due to many reasons: interactions of the aquatic environment with rocks, sediments and soils; emissions from volcanic and geothermal sources; erosion and leaching of geological formations; and mining waste that produce high concentrations of this element in the environment (RSA, 2018).

Humans can be exposed to arsenic in different ways: by consuming contaminated food or water; using them in meal preparation, crops irrigation or industrial processing, and it can also be inhaled. Prolonged exposure to inorganic arsenic – through any of these ways – can cause acute and chronic poisoning, from skin lesions to neoplasm (Kapaj S et al, 2006).

Arsenicism is an endemic disease. This is especially true in Argentina, where the population exposed to high levels of arsenic (> 50 μg/L) has been calculated in about 4 million; moreover, its accepted level places the country among the most affected ones within Latin America (Litter et al., 2019). Chronic Endemic Regional Hydroarsenicism (HACRE, acronym in spanish) characterized due to skin lesions and systemic cancerous and non-cancerous alterations resulting from exposure to low levels for prolonged periods, which has been known in Argentina since 1913, ranks second after the USA in the world's most affected countries (Ministerio de

Salud, Argentina, 2006). The situation has worsened considering the long-term and chronic impact on human health. A recent piece of research carried out in the Central Region of Argentina has compared arsenic genotoxicity in two groups of population, one exposed to high levels and one not exposed at all, showing damage oxidative and genotoxic at high levels (Quiroga, 2023). Exposure has an impact on chronic diseases, from congenital malformations to neurodegenerative diseases, and cancer. Arsenic was classified by the WHO's International Agency for Research on Cancer (IARC) as carcinogenic to humans (Rousseau et al, 2005).

Perinatal exposure deserves special attention, both intrauterine and during the first years of life. As regards certain cancers, a study carried out in Chile exploring early life exposure and adulthood risks showed a clear association of these two variables, suggest that exposure to arsenic in drinking water during early childhood or in utero has pronounced pulmonary effects, greatly increasing subsequent mortality in young adults from both malignant and nonmalignant lung disease (Smith et al., 2006). The literature review confirms this situation as the longest risk period (Young et al., 2018; Martinez et al., 2021).

In its Guidelines for Drinking-water Quality, the WHO established a limit value for arsenic in water. It aims to serve as a world basis for regulatory and standardization tasks in this regard. The recommended limit in drinking water is 10 µg/L (WHO, 2017). The Argentine Food Code [CAA by its Spanish acronym] establishes a higher safety limit, 50 µg/L (MSA-ANMAT, 2005). However, levels well above this limit have already been reached in the country, even exceeding 200 µg/L (Nicolli et al., 1989). Much of the scientific evidence has shown that between the limits of the WHO and the CAA, there is a significant risk to human health.

Despite what has been stated so far, the real proportion of the population exposed to high arsenic level in the country is still unknown. The information available on arsenic content in drinking water is scattered and not updated. Therefore, the objective of this analysis is to carry out a systematic review to collect the published information and evaluate its connection with the exposed population.

METHODOLOGY

Bibliographic Review

The following open-access databases were analyzed to carry out a systematic search of the available evidence: PUBMED, Google Scholar, Latin American and Caribbean Health Sciences Literature (LILACS) and the National System of Digital Repositories [SNRD by its Spanish acronym] (Argentina). The terms "*arsenic AND water consumption AND Argentina*"; "*arsenic AND water AND Argentina" were* used, and the Spanish ones, "*arsénico Y agua de consumo Y provincia Y argentina*".

The selection criteria to include the articles were the following: 1) if the number of drinking water samples evaluated population was available; 2) if it expressed the number of water samples assessed; 3) if it expressed the As value in absolute terms; and 4) if the analyzed water was for human consumption. All these conditions were considered for each province, consider the PRISMA guidelines (Page et al, 2021).

Variables Construction

After selecting valid bibliography, the following items were classified and calculated by provinces:

(1) percentage of total population per province. It was calculated following the National Institute of Statistics and Census (INDEC, 2010) taking into account the total population assessed, expressed by the quotient between the total population evaluated (sum of the total bibliography) over the total provincial population. This allowed to know the ***"representativeness"*** of the samples for each province, which means the percentage of the total population of the province represented in the referenced specific studies. A limit of 30% was established to define this variable as

high or low, decided on the basis that -approximately- one in three inhabitants were considered within the population under study.

(2) considering the number of samples above the WHO value (10 µg/L), the percentage of samples with high levels of arsenic was calculated and this was applied to the total population evaluated, obtaining thus its **exposure index**.

(3) the exposure index was applied to the total provincial population, which allowed to obtain the so-called **Percentage of Exposed Population** (PEP) per province.

Through these calculations, two variables were obtained for each province: a) "representativeness" of the samples obtained over the total population; and, b) the population "exposure" variable, or PEP. If the sample captured is representative, the exposure percentage can be projected to the rest of the population and interpreted as a provincial index.

REPRESENTATIVENESS	x	**POPULATION EXPOSURE INDEX**	=	**% EXPOSED POPULATION**
(>30%)		(% of samples >10 ug/L)		PEP

RESULTS

Bibliographic Review

As can be seen in the systematic literature review (Figure 1), 569 publications were found. After applying the duplicates or non-relevant by title or summary filter, 315 publications remained suitable to be analyzed according to the selection criteria detailed in the Methodology. Then, another 254 articles were excluded in this process, resulting in 61 final publications useful for this research. Relevant information was found for 50% of the Argentine provinces, which represents 70% of the total population nationwide; this is twelve provinces and represents approximately thirty-two million inhabitants.

Representativeness and percentages of exposed population

When analyzing provincial representativeness, the population under study presented a considerable heterogeneity: ranging from 0.35% (the lowest, in Chubut province) to 99% (the highest, in Santa Fe province). An arbitrary limit of 30% was established, which made it possible to obtain two groups: high and low representativeness.

In relation to the Percentage of Exposed Population (PEP), the highest exposure (Table 1) was found in La Pampa (87.98%), followed by Catamarca (78.90%) and Buenos Aires provinces (68.55%). In relation to the provinces with low representativeness (Table 2), the PEP is significantly low, between 0 and 10%. However, due to the fact that the sampling is small, the data identified is not precise. The distribution of the provinces according to the PEP is presented in a graphic (Figure 2). Of a total population of approximately 32 million inhabitants, 55% (around 17 million) is exposed to arsenic levels greater than 10 µg/L in drinking water.

DISCUSSION

It has been documented worldwide that millions of people are affected by being exposed to drinking water with high levels of arsenic. Among the largest and most populated areas involved, in Asia, for example, the populations most at risk are: the Gulf of Bengal, in Bangladesh (Rahman et al., 2001); Northeast India (Bhattacharyya et al., 2003); Inner Mongolia in China (Guo et al., 2001); and Taiwan and Vietnam (Smedley et al., 2003). In North and Central America, the west of the United States (BEST, 2001) and Mexico (Rodriguez et al., 2004); and in South America, Argentina, Chile, Bolivia and Peru (Bundschuh el al, 2012).

Argentina has empirically known for more than a century that its drinking water contains high levels of As because there are endemic diseases associated to this element. However, the country does not possess unified and precise information to identify its true sanitary risk. There have been two attempts to draft a "map" of this situation but they have shown varied limitations, especially because they referred to isolated values that did not specify the population involved (Ministerio de Salud

Argentina, 2006) or else showed a general distribution of the population in graphics but did not specify As consumption (Litter et al., 2019). Both preliminary reports, using a limit value of 50 µg/L, mention a total exposed population of 1 to 4 million inhabitants. This piece of research, however, employing the WHO limit (10 µg/L) finds an approximate 17 million, more than four times, the last previous one (2006).

The accumulation of evidence on chronic toxicological effects of arsenic ingestion through drinking water has led to a progressive reduction in the threshold limit of arsenic concentrations in water intended for human consumption (Smedley et al., 2002). In Argentina and Chile, this threshold is 50 ug/L (MSA-ANMAT, 2005; Diario Oficial de la República de Chile, 1984). This level is intended to be reduced to 10 µg/L, as set by the European Union (European Union, 1998), recommended by the World Health Organization (WHO, 2004), and proposed since January 2006 by the United States Environmental Agency as a "Maximum Contaminant Level Goal" (MCLG) (USEPA, 2005). According to these standards, the economic implications of ensuring that water has an acceptable arsenic concentration has opened an important debate on the level to be set, both in large areas of developed and developing countries (Smith & Smith, 2004). The existing literature confirms that the levels of arsenic in drinking water recommended by the WHO in relation to chronic non-communicable diseases are those that have been shown to be associated with this lower threshold (Rehman et al., 2018; Ferragut Cardoso & Udoh, 2020; Jaafarzadeh et al., 2022).

Although arsenic contamination has been exhaustively and long studied as acute poisoning (Campbell & Alvarez, 1989), pathologies related to deferred impacts over time, such as cancer, were little addressed in the country as specific associated issues. However, recent analyses have demonstrated their link in Argentina (Duarte et al., 2022). It is, therefore, necessary to update the information on arsenic in drinking water in the country. In other countries such as the USA, approximation models on As levels in drinking water have been built at national level, which have made possible to define high and low risk areas (Ayotte et al., 2017). Likewise, Bangladesh has carried out a review of related publications that made possible to determine an (approximate) total exposed population (Karim, 2000). Other countries, including higher-risk countries, only have partial information available.

This work contributes in highlighting both the existing and missing information. It raises awareness to the situation of a large proportion of Argentina's population in the face of arsenical water consumption. The wide variability of information observed in this work is mainly due to the particular or regional epidemiological alert, which leads local researchers to delve into the subject. It can be therefore deduced that, in provinces with fewer perceived risks of exposure to arsenic, publications are fewer than in those that have historically been associated with this environmental toxicant. Although "exposed population" is a key -and original- concept in this analysis, an extensive use of this term was not found. Most of the analyzed articles that had to be discarded detail the analytical determinations of water samples and collection sites. However, they do not describe the population under analysis, which is fundamental to assess the true sanitary impact of arsenic contamination in drinking water. Conversely, the number of samples is not a correct parameter to determine the scope of the analysis, nor the level reached by the assessment above the cutoff applied. Undoubtedly, when a region presents epidemiological alarms related to chronic non-communicable diseases related to arsenical contamination in drinking water, it is necessary to evaluate the precise levels of this element in representative samples of the population.

The methodology employed in this analysis presents some bias: 1) possible duplications of the exposed populations in each province, given that some studies overlap in these territories without mentioning the specific places of collection; 2) there is a bias inherent to the publications, which is related to sampling, especially in well water, with the distribution of populations in relation to sources of consumption unknown; 3) the concept of exposed population is not included in publications related to arsenic, with the PEP variable, proposed in this work, being an indirect calculation.; 4) the temporality of the water evaluations is dissimilar; in any case, arsenic has been described as a stable toxicant in the environment -with little variability- given the fundamentally natural contamination, except that interventions have been carried out to remove this element, a scarce, partial or non-existent issue in Argentina throughout of the years.

CONCLUSIONS

This review adds value to the already published evidence, systematizing information and identifying variables that may be useful for ecoepidemiological studies to analyze both humans and fauna. An index is proposed, the "percentage of exposed population" (PEP) to high arsenic levels as a summary variable, to homogenize the information in the country, giving it thus a comparative value. It has also been validated in a previous work, related to cancer mortality at provinces' departmental level in the central region of Argentina (Duarte et al, 2022).

Territorial interventions in health management, especially in sensitive issues such as population's consumption of arsenical water, require orderly, organized and coordinated information to guide actions to provide tools and introduce public policies that benefit inhabitants' life.

Finally, the present work allows to identify -indirectly- the areas of high exposure, as a guide to deepen future research that allows to give certainty to these findings.

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Figure 1. Systematic Review Flowchart

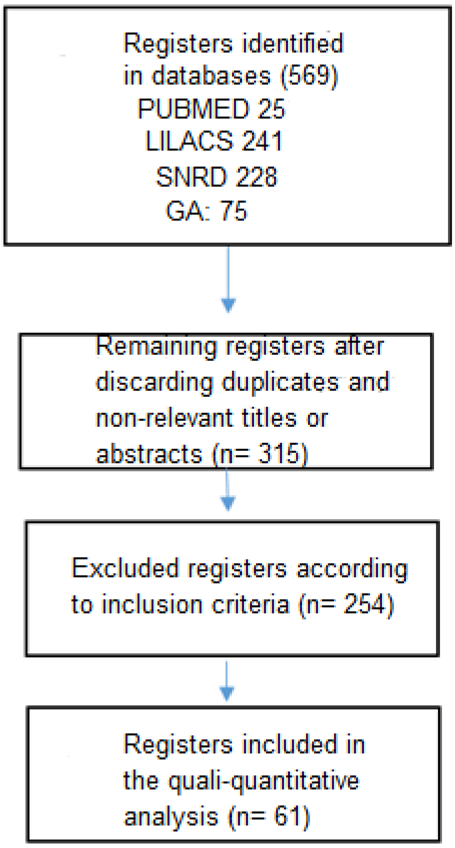


Table 1. High representativeness and exposition levels to arsenic by province

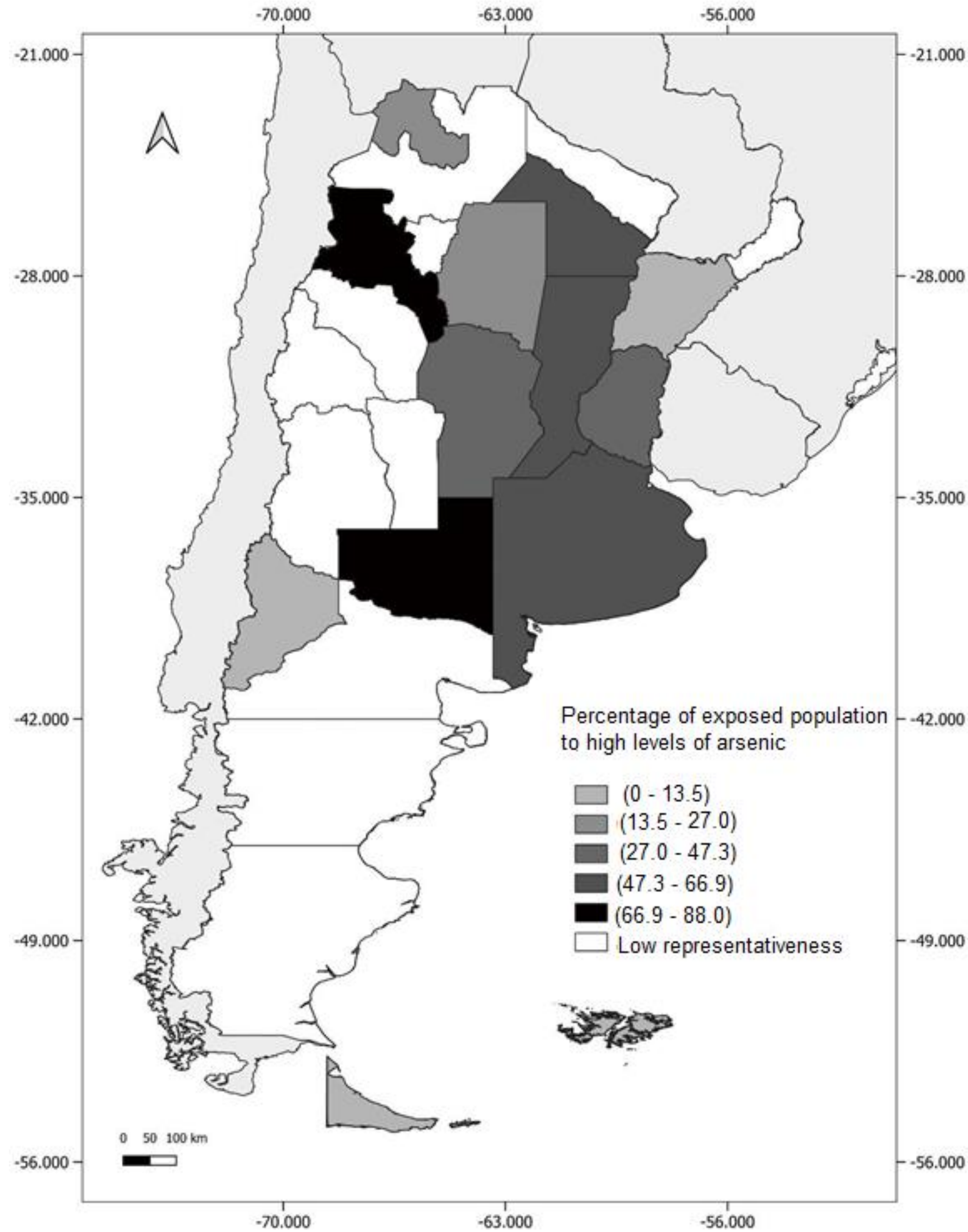
PROVINCES	EVALUATED POPULATION	TOTAL PROVINCIAL POPULATION	Percentage of population under study (%)	Percentage of Population exposed (PPE) to high levels of As (%)	Bibliograpy
			REPRESENTATIVENESS	EXPOSITION	
SANTA FE	3.509.459	3.544.908	99	60.08	ENRES (2019)
LA PAMPA	350.099	361.859	95.75	87.98	Pariani et al., (2014); Vercellino. (2020); O'Reilly et al. (2020)
NEUQUÉN	632.482	710.814	88.98	0	Centro de Ingenieria en Medio Ambiente (CIMA), ITBA (2020); Velazquez (2019)
CATAMARCA	372.173	429.562	86.64	78.9	Rugierri et al. (2009); Saracho et al. (2016); Saracho et al. (2019); Graziano et al. (2013); CIMA (2020); Vilches et al. (2005).
BUENOS AIRES	13.598.621	17.523.996	77.6	68.55	Navoni et al. (2012); RSA CONICET (2018); Galindo et al. (2005).
CORRIENTES	693.298	1.212.696	57.17	11.4	CIMA (2020)
CHACO	852.062	1.129.606	75.43	53.51	Roshdestwensky et al. (2016); Martínez et al. (2014); Trinelli et al. (2018); Concha et al. (1998); Osicka et al. (2002); CIMA (2020); Buchhamer et al. (2012); Blanes et al. (2011)
CÓRDOBA	2.711.679	3.840.905	70.6	29.09	Villalba et al. (2000); Blarasin et al. (2015); Penedo and Zigaran (1998)
ENTRE RÍOS	878.726	1.425.578	61.64	28.02	UNER (2019); CIMA (2020)
TIERRA DEL FUEGO	81.722	185.732	44	0	CIMA (2020)
JUJUY	277.571	811.611	34.2	22.27	López Steinmetz et al (2018); CIMA (2020); Murray et al. (2019); Ruggeri et al. (2009)
SANTIAGO DEL ESTERO	348.402	1.060.906	32.84	26,36	Bhattacharya et al. (2006); Revelli et al. (2016); Vidoni et al. (2010); Bejarano Sifuentes

					and Nordberg. (2003); Bundschuh et al. (2004); Calatayud et al. (2019); Navoni et al. (2014); CIMA (2020); Litter et al. (2015)

Table 2. Low representativeness and exposition levels to arsenic by province

PROVINCES	EVALUATED POPIULATION	TOTAL PROVINCIAL POPULATION	Percentage of population understudy (%)	Percentage of Population exposed (PPE) to high levels of As (%)	Bibliograpy
			REPRESENTATIVENESS	EXPOSITION	
SANTA CRUZ	90.343	337.226	26.79	0	CIMA (2020)
SAN LUIS	108.414	542.069	20	0	CIMA (2020)
TUCUMÁN	244.360	1.731.820	14.11	10.51	Soria de González et al. (2008-2011); Guber et al. (2009); Nicolli et al. (2012); CIMA (2020); Gerstenfeld et al. (2012); Soria et al.(2009)
MENDOZA	245.429	2.043.540	12.01	9.13	Elia Dazat (2017); CIMA (2020)
SALTA	133.469	1.441.351	9.26	5.01	Concha et al. (1998); Hudson-Edwards et al. (2012); Boujon (2021); CIMA 2020
FORMOSA	54.485	607.419	8.97	3.99	CIMA (2020)
RÍO NEGRO	63.515	750.768	8.46	2.77	Grizmado. (2012); Garrido (2017); CIMA (2020)
SAN JUAN	40.731	822.853	4.95	4.95	CIMA (2020) O'Reilly et al. (2010)
MISIONES	32.095	1.278.873	2.51	0.84	CIMA (2020)
LA RIOJA	6.372	383.865	1.66	0.21	Miguel et al. (2017); Nievas et al. (2013); CIMA (2020)
CHUBUT	2.074	592.621	0.35	0.27	Nievas et al. (2013)
CABA	0	3.121.707	0	0	----------

Fig. 2. Map of the population exposed to high arsenic levels in provinces with high representativeness. Argentina.



Source: elaborated with own data

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