Arsenic levels in immigrant children from countries at risk of consuming arsenic polluted water compared to children from Barcelona

S. Piñol 1
Email sergiyllw@hotmail.com

A. Sala 1
Email annacleta333@hotmail.com

C. Guzman 2
Email 39105cgm@comb.es

S. Marcos 2
Email susanamarcosal@yahoo.es

X. Joya 1
Email jjoya@imim.es

C. Puig 1
Email carmepuig@yahoo.es

M. Velasco 1
Email martavrb@gmail.com

D. Velez 3
Email deni@iata.csic.es

O. Vall 1,4
Email OVall@hospitaldelmar.cat

O. Garcia-Algar 1,4,5,*
Email 90458@hospitaldelmar.cat
Abstract

Arsenic is a highly toxic element that pollutes groundwater, being a major environmental problem worldwide, especially in the Bengal Basin. About 40% of patients in our outpatient clinics come from those countries, and there is no published data about their arsenic exposure. This study compares arsenic exposure between immigrant and native children. A total of 114 children (57 natives, 57 immigrants), aged 2 months to 16 years, were recruited and sociodemographic and environmental exposure data were recorded. Total arsenic in urine, hair, and nails and arsenic-specified compounds in urine were determined. We did not find significant differences in total and inorganic arsenic levels in urine and hair, but in organic arsenic monomethylarsenic acid (MMA) and dimethylarsinous acid (DMA) in urine and in total arsenic in nails. However, these values were not in the toxic range. There were significant differences between longer than 5 years exposure and less than 5 years exposure (consumption of water from tube wells), with respect to inorganic and organic MMA arsenic in urine and total arsenic in nails. There was partial correlation between the duration of exposure and inorganic arsenic levels in urine. Immigrant children have higher arsenic levels than native children, but they are not toxic. At present,
there is no need for specific arsenic screening or follow-up in immigrant children recently arrived in Spain from exposure high-risk countries.

Keywords

Arsenic
Children
Immigrants
Nails
Hair
Urinary arsenic level

Highlights: • Arsenic is a highly toxic element that pollutes groundwater, being a major environmental problem worldwide, especially in the Bengal Basin • Immigrant children have higher arsenic levels than native children, but they are not toxic. • At present, there is no need for specific arsenic screening or follow-up in immigrant children recently arrived in Spain

Background

Arsenic (As) is an ubiquitous trace element that is widely disseminated in the environment. It is highly toxic and causes groundwater pollution and has become a major problem worldwide (Rahman et al. 2001; WHO 2011). The toxicity of As depends on the chemical forms in which it is present in the environment and in the organism. Inorganic As III species is present in soil and water and is the most toxic, so they are considered part of Group I of human carcinogens by the International Agency for Research on Cancer (IARC) (Díaz et al. 2004; US EPA 2006; US EPA 2014, 2015). Organic forms of As are present in fish, seafood, and seaweeds and cause different forms of toxicity. The most common organic forms are monomethylarsenic acid (MMA), dimethylarsinous acid (DMA), and trimethylarsine oxide (TMAO). There is evidence in the literature that MMA is more toxic than DMA and is an important determinant of arsenic-induced toxicity (Suner et al. 2002). Other minor sources are the trimethylated compounds, arsenobetaine, and arsenocoline that can be found in fish and seafood but are not considered toxic since they are rapidly excreted in the urine (Suner et al. 2002). And finally, arsine, a high volatile gas, which is formed when arsenic-containing materials like metals
and ores react with freshly formed hydrogen in water or acids (Suner et al. 2002).

There is considerable evidence of its implication in increased risk of bladder, lung, skin, and prostate cancers, as well as higher mortality rates (Smith et al. 1998; Ahsan et al. 2006; Chen et al. 2007; Argos et al., 2010; Chen et al. 2011). It also causes other health effects, including vascular diseases, probably diabetes mellitus and hypertension, peripheral neuropathy, and poor intellectual function (Rahman et al. 1999; Kwok et al. 2007; Heck et al. 2008). Children are the most threatened group, especially regarding neurological damage, since the brain undergoes changes during childhood that can have a lasting impact on behavior and cognitive processing (Calderon et al. 2001; Wasserman et al. 2007; Von Ehrenstein et al. 2007; Parvez et al. 2011).

It has been demonstrated that As interferes in cellular respiration, which explains its powerful toxicity. Moreover, As interferes in many other cellular processes which end up producing oxygen reactive species (ORS) which interfere with DNA-reparation and produce oxidative damage. These mechanisms are related to the carcinogenic and genotoxic potential of As.
According to World Health Organization (WHO) data, 1 in 100 people who drink highly concentrated As drinking water (>50 μg/L) for a long time will probably die from arsenic-related cancer (WHO 2011). In children, a chronic exposure to As has been related to digestive, respiratory, cardiovascular, and neuropsychologic adverse effects, as well as intellectual deterioration. They retain a higher quantity of As in their tissues because the methylation of arsenic compounds is not as efficient as in adults. Thus, children are more sensitive to this element. Water and food are the main sources of As (Suner et al. 2002). In As endemic areas, where the levels in water are high, the majority of epidemiological studies consider only water as the main source of exposure. Intoxication is especially relevant in countries like Bangladesh, where 21.4 % of all deaths and 23.5 % of deaths related to chronic diseases can be attributed to an As exposure higher than 10 μg/L (the current WHO recommended limit) in drinking water (Rahman et al. 2001; Roychowdhury et al. 2002; Sohel, 2009; Williams et al. 2006; WHO 2011). In the 1970s, a wells’ construction program took place at the Bengala’s Basin in order to avoid the infectious diseases due to the use of backwaters. Unfortunately, the majority of these wells were built between 20 and 100 m depth, where the highest concentrations of As can be found, as reported by several studies. This contaminated water is still used for drinking and irrigation for rice fields, reaching toxic levels and affecting negatively the quality of a basic food in this area (Roychowdhury et al. 2002; Williams et al. 2006).

Arsenic can also pass through the placental barrier. For this reason, the intrauterine exposure to As in fetus whose mothers consume drinking water with more than 50 μg/L of As can lead to non-evolutive pregnancies, premature births, spontaneous abortions, and an increased neonatal and infantile mortality due to the transplacental carcinogenic potential (Concha et al. 1998; Calderon et al. 2001; Kwok et al. 2007; Von Ehrenstein et al. 2007).

http://eproofing.springer.com/journals/printpage.php?token=gfeVecz33O09KX5VzP_pmrME7PnxyZpw-8Iig9RceEvSB6sUXyVCvw
As is mainly excreted in the urine, and it can be accumulated in many body tissues, especially in keratin-rich ones like hair, skin, and nails (Das et al. 1995; Adair et al. 2006) after chronic exposure, which make those tissues useful in the evaluation of As exposure. This highlights the importance of minimizing polluted water intake among women of reproductive age. On the contrary, the excretion of As in breast milk is very low, remaining under the accepted maximum daily dietary intake level: 15 μg/kg. According to more recent publications, this level should be reduced as much as possible (Concha et al. 1998; Sternowsky et al. 2002).

This study has a sound public health significance in immigrant-receiving cities like Barcelona. Despite the high number of Asian immigrants in Catalonia (71,027 legal residents in 2006), there is no published data about As poisoning in immigrant children coming from at-risk countries. The main objective of this study was to determine the prevalence of As exposure in immigrant children who arrive to Barcelona from high risk of exposure countries and to compare their As levels to Spanish children. What makes the study unique is the use of multiple long-term and short-term biomarkers of exposure to compare between native and immigrant groups of children. The recognition of children with high levels of As would justify the screening and clinical follow-up of positive cases in order to prevent and detect its toxic long-term effects.

**Materials and methods**

This work was performed in the Primary Health Center of Ciutat Vella’s district (CAP Dressanes), in Barcelona (Spain). It is an urban area with a high percentage (above 40%) of immigrants, many of them from Asia, in particular from Pakistan and Bangladesh. We also assessed native children from the same neighborhood in order to have an age-matched and sex-matched control group.

As a pilot study, all the immigrant parents coming from these countries
who brought their children to the outpatient facility, from April 2008 to May 2009, either to follow the standardized routine health controls or to make a spontaneous visit, were asked to enrol the study. Parental sociodemographics, information on child health, somatometry, and data on environmental exposure, emphasizing those related to water consumption and pollution, were recorded. All the children were physically examined and urine, hair, and nails samples were collected from them, excluding dyed hair and painted nails in order to avoid associated damage.

The urine, hair, and nails samples were tested for As products which are biomarkers for short-term (less than 1 year) exposure, while skin hyperpigmentation and palm plantar hyperkeratosis could suggest long-term (several years) exposure.

For this purpose, we collected a random urine specimen from the continent children and used a collection bag for the rest. The samples were stored in polyethylene containers and transported the same day to the laboratory, where they were kept (at −20 °C) until they were transported on dry ice to the final laboratory. Hair samples (as an entire strand) were cut close to the scalp in the vertex region using stainless steel scissors, collected and stored in polyurethane bags. Nail samples were also cut using stainless steel scissors from hands and feet, collected and stored in polyurethane bags.

Samples were digested adding 5 mL of 50 % nitric acid (HNO3). Afterwards, we added 1 mL (to urine samples) or 2 mL (to hair and nails samples) of an incinerator agent (deionized water with 20 % of magnesium nitrate hexa hydrated (H6NO4Mg) and 2 % of magnesium oxide (MgO)). At least 2 blanks were analyzed for each sample series.

They were evaporated to dryness in a sand bath and then heated to 450° for 12 h on a heating block, in order to obtain a white powder. When the white powder was not present, the samples were re-digested with 5 mL of nitric acid 50 % (HNO3), and the evaporation and heating process was repeated.

To dissolve the powder, 4 mL of 50 % hydrochloric acid (HCl) was added, followed by twice 2 mL of acid, with continuous shaking. These samples were filtered through Whatman grade 1 filters, previously washed with deionized water and with 5 % nitric acid (HNO3) into centrifuge tubes.

After this process, 2 mL of diluent 5 % of potassium iodide (KI) and 5 %
of ascorbic acid (C$_6$H$_8$O$_6$) was added in order to obtain a sample of 10 ml. When necessary, more 50 % hydrochloric acid (HCl) was added for top up to reach the final volume of 10 mL.

These samples were then used to analyze As content by a standardized procedure based on hydride generation atomic absorption spectrometry coupled with flow injection (FI-HG-AAS). We had at our disposal a straight line calibration curve, a pattern to verify it, reference samples (dilutions of intermediate patterns) to confirm the method of quantification and 2 white samples for each series. For both the reference and the white samples, we calculated the concentration of total As.

As was speciated in urine samples: inorganic As, MMA and DMA, were reduced to their corresponding arsines with sodium borohydride after injection of a urine sample in a flow of deionized water which was mixed with this agent. Then, the sample was driven to a U-shaped tube and was immersed in liquid nitrogen, with the cryogenically generated arsines trapped in a chromatography equipment. After 3 min, the liquid nitrogen was displaced by heating the U-tube. The different As species start their volatilization process at different boiling points; they are displaced to a heated multiatomizator, detected with a discharge lamp, and quantitated using chromatographic measurements. By speciating, the percentage of organic or inorganic As can be identified. Different forms of organic As can be obtained, essentially MMA, DMA, and others (mainly arsenobetaine) together with the two inorganic As forms: arsenite and arsenate.

The speciation was not performed in hair and nails samples, due to the small available amount. Nevertheless, the main form of As in both matrices is the inorganic one, due to the affinity of this form of As to the sulphidril groups of the keratin-rich tissues.

To evaluate the relationship between qualitative variables to compare between groups, we used the chi-square or Fisher’s exact test. An analysis of the correlation between quantitative variables, using the Pearson correlation coefficient or Spearman ($r$) was also done.

We performed the analysis of variance (ANOVA) to assess differences between continuous independent variables (total As and inorganic As) and the categorical variable: child’s country of origin. The statistical
significance criterion used was $p < 0.05$, and therefore, the confidence level is 95%. We used the SPSS Statistics software as statistical program, version 12.0 (SPSS Inc., Chicago, IL).

This study adhered to the principles of the Declaration of Helsinki. The laws governing data confidentiality (Law 15/1999 of 13 December on the Protection of Personal Data (Act)) was at all times respected. The study protocol was submitted to the approval of the Clinical Research Ethics Committee of the IMAS (CEIC-IMAS). An information sheet was given to the potential participants, parents, or tutors. All the patients who finally joined the study signed an informed consent form. The intervention was successfully conducted with the involvement of intercultural mediators.

Results

We recruited 114 children between 2 months and 16 years old, from whom we obtained 107 samples of urine, 101 samples of hair, and 108 samples of nails. Out of the 114 children, 57 were born in Spain and 57 were immigrants, 42 of them born in Bangladesh, 12 in Pakistan, and 3 in India (Table 1).

Table 1

General description of the sample studied

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Natives</th>
<th>Immigrants</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>114</td>
<td>57</td>
<td>57</td>
</tr>
<tr>
<td>Bangladesh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sylhet Province (Bangladesh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sylhet city (Bangladesh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, years</td>
<td>6.7 (4.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex M/F</td>
<td>73/48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight, kg</td>
<td>24.5 (14.4)</td>
<td>25.4</td>
<td>23.7</td>
</tr>
<tr>
<td>Height, cm</td>
<td>110.6 (27.6)</td>
<td>113.9</td>
<td>108.4</td>
</tr>
<tr>
<td>Type of lactation received B/A/M</td>
<td>89/23/9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
We found the following data among all the analyzed samples: total As in urine, mean 58.4 ng/mL, median 18.2 ng/mL; inorganic As in urine mean 1.0 ng/mL, median 0.4 ng/mL; organic As in urine MMA mean 0.7 ng/mL, standard deviation (SD) 2.0; DMA mean 9.2 ng/mL, SD 15.9; arsenobetaine mean 36.1 ng/mL, SD 62.9; hair total As mean 226.1 ng/g, SD 930.2; nails total As 232.0 ng/g, SD 501.6 (Table 2).

**Table 2**

Mean, standard deviation and p50 levels of As found in different biological matrices on the origin of the children

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Natives</th>
<th>Immigrants</th>
<th>p</th>
<th>Bangladesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine, n</td>
<td>107</td>
<td>50</td>
<td>57</td>
<td>0.484</td>
<td>76.5 (246)25.5</td>
</tr>
<tr>
<td>TAs in urine, ng/mL</td>
<td>58.4 (159.1)</td>
<td>46.9 (63.4)</td>
<td>68.4 (210.2)</td>
<td>0.092</td>
<td>76.5 (185)38.1</td>
</tr>
<tr>
<td>TAs in urine, ng/mL</td>
<td>1.0 (1.6)</td>
<td>0.9 (1.5)</td>
<td>1.1 (1.9)</td>
<td>0.613</td>
<td>0.83 (1.1)</td>
</tr>
<tr>
<td>MMA*, in urine ng/mL</td>
<td>0.7 (2.0) 0.0</td>
<td>0.3 (0.9) 0.0</td>
<td>1.1 (2.9) 0.4*</td>
<td>0.008</td>
<td>1.4(3.5) 0.4*</td>
</tr>
<tr>
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</tr>
<tr>
<td>DMA*, in urine ng/ml</td>
<td>9.2 (15.9) 2.6</td>
<td>7.0 (13) 1.4</td>
<td>12.4 (19) 5.4*</td>
<td>0.006</td>
<td>10.4 (12.9) 5.4*</td>
</tr>
<tr>
<td>Arsenobetaine in urine, ng/mL</td>
<td>36.1 (62.9) 15.8</td>
<td>32.3 (34.9) 22.2</td>
<td>41.4 (88.6) 9.6</td>
<td>0.439</td>
<td>26.1 (34.6) 10.7</td>
</tr>
<tr>
<td>Hair, n</td>
<td>101</td>
<td>53</td>
<td>48</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>AQ35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAs in hair (ng/g)</td>
<td>226.1 (930.2) 43</td>
<td>351.9 (1269.3) 43</td>
<td>87.2 (144.6) 42</td>
<td>0.576</td>
<td>74.6 (105.0) 37</td>
</tr>
<tr>
<td>Nails, n</td>
<td>108</td>
<td>54</td>
<td>54</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>TAs* in nails (ng/g)</td>
<td>232.0 (501.6) 98</td>
<td>147.1 (187.6) 55.5</td>
<td>317 (676.8) 195</td>
<td>0.065</td>
<td>395.3 (783.0) 195*</td>
</tr>
</tbody>
</table>

The differences between native and immigrant children were significant regarding MMA (p = 0.008) and DMA (p = 0.006), not significant regarding total As in urine, hair and marginally significant regarding to total As in nails (p = 0.065). The differences between native and immigrant children from Bangladesh were significant regarding MMA (p = 0.031) and DMA (p = 0.009) and total As in nails (p = 0.006). Parentheses: values of the standard deviation. Italic characters: values of the p50.

As arsenic, TAs total arsenic, IAs inorganic arsenic, MMA monomethylarsonic acid, DMA dimethylarsinic acid

*The differences found between these groups were statistically significant for these variables (confidence interval 95 %, p < 0.05)

There is no international consensus regarding the normal urinary As values, depending on the source (Agency for Toxic Substances and Diseases Registry 2007; NIST 2014). So, the values can vary from 60 to 100 μg/L (μg/L = ng/mL).

AQ36

The established value of biological exposure is 35 μg/L of total As (American Conference of Governmental Industrial Hygienists 2004). Thirty eight out of 107 samples exceeded this limit, and 14 were above the limit indicated by the ATSDR (Agency for Toxic Substances and Diseases Registry 2007). After the specification, we confirmed that none of the samples was above the pathological limit of 35 μg/L of inorganic As. Total As levels in urine were increased because of arsenobetaine. However,
inorganic As levels were not pathologic.

Among the hair samples, 3 out of 101 exceeded the limit of 1000 ng/g (Agency for Toxic Substances and Diseases Registry 2007). These patients were all native, with normal levels in urine and nails.

Regarding the nails samples, 5 out of 108 were above the pathological limit of 1000 ng/g of As (Agency for Toxic Substances and Diseases Registry 2007). Two of them had normal levels in urine (one was native), two had normal levels in urine and hair, and the last one, who had total As levels in urine of 49 ng/mL, was born in Bangladesh. This sample speciation was not possible, so we cannot confirm the toxic levels in urine.

There were no statistically significant differences between native and immigrant children regarding levels of total and inorganic As in urine and total As in hair.

There were statistically significant differences in organic As MMA and DMA between natives and immigrants, MMA mean in natives was 0.3 ng/mL, SD 0.9 and MMA mean in immigrants was 1.1 ng/mL, SD 2.9 (confidence interval 95 %, \( p = 0.008 \)). DMA mean in natives was 7.0 ng/mL, SD 13.0 and DMA mean in immigrants was 12.4 ng/mL, SD 19.1 (confidence interval 95 %, \( p = 0.006 \)). However, organic As has no toxic effects.

We found marginally significant differences in the levels of total As in nails between native children, mean 147.1 ng/g, \( p \text{ 50} = 55.5 \) and SD 187.6 and immigrants, mean 317.0 ng/g, \( p \text{ 50} = 146.5 \) and SD 676.8 (confidence interval 95 %, \( p = 0.065 \)). These levels are far from being toxic (< 1000 ng/g in all cases) (Table 2).

When comparing natives with immigrants from Bangladesh, we found significant differences in total As levels in nails and organic As (MMA and DMA) in urine. MMA mean in natives was 0, 3 ng/mL, SD 0.9, and MMA mean in immigrants born in Bangladesh was 1, 4 ng/mL, SD 3.5 (confidence interval 95 % \( p = 0031 \)). DMA mean in natives was 7, 0 ng/mL, SD 13.0, while DMA mean in immigrants from Bangladesh was 10, 4 ng/ml, SD 12.9 (confidence interval 95 % \( p = 0.009 \)). As mean levels in nails in native children was 147, 1 ng/g, SD 187.6 and 395, 3 ng/g in immigrants born in Bangladesh, SD 783.0 (confidence interval 95 % \( p = \)
0.006) (Table 2).

The average time of possibly polluted water consumption for the 64 immigrant children was 6 years and 3 months; 40 of them used to drink from tube wells in their native villages. Moreover, 5 parents reported that the tube wells around their homes had been painted red by the local authorities to signal this risk.

We found partial correlation, (correlation coefficient 0.614), between the duration of exposure and the inorganic As levels in urine, remaining however under pathological levels.

We found marginally significant difference between the levels of total As in urine of immigrants who drank at-risk water for more than 5 years, mean 92.5 ng/mL, \( p = 18 \), and SD 258.0, and those who drank it for less than 5 years, mean 23.9 ng/mL, \( p = 14 \) and SD 30.6 (confidence interval 95\%, \( p = 0.060 \)) (Table 3).

**Table 3**

Mean and standard deviation levels of As in urine and nails from immigrant children who had been drinking risk polluted water for more or less than 5 years. The differences found were marginally significant for the total As in urine (\( p = 0.060 \)) and significant for the IAs (\( p = 0.002 \)) and MMA (\( p = 0.016 \)) in urine and As in nails (\( p = 0.005 \))

<table>
<thead>
<tr>
<th></th>
<th>Less than 5 years of exposure</th>
<th>More than 5 years of exposure</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAs in urine, ng/mL</td>
<td>23.9 (30.6)</td>
<td>92.5 (257.9)</td>
<td>0.060</td>
</tr>
<tr>
<td>IAs* in urine, ng/mL</td>
<td>0.1 (0.2)</td>
<td>1.5 (2.1)*</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AQ37</td>
</tr>
<tr>
<td>MMA* in urine, ng/mL</td>
<td>0.1 (0.2)</td>
<td>1.5 (3.3)*</td>
<td>0.016</td>
</tr>
<tr>
<td>DMA in urine, ng/mL</td>
<td>3.5 (2.7)</td>
<td>15.7 (21.4)</td>
<td>0.245</td>
</tr>
<tr>
<td>Arsenobetaine, ng/mL</td>
<td>22.3 (27.5)</td>
<td>48.0 (101.6)</td>
<td>0.432</td>
</tr>
<tr>
<td>As in hair, ng/g</td>
<td>100.6 (200.1)</td>
<td>78.4 (94.4)</td>
<td>0.874</td>
</tr>
<tr>
<td>As in nails*, ng/g</td>
<td>335.7 (1022.2)</td>
<td>305.1 (324.5)*</td>
<td>0.005</td>
</tr>
</tbody>
</table>
Parentheses: values of the standard deviation

As arsenic, TAs total arsenic, IAs inorganic arsenic, MMA monomethylarsonic acid

*The differences found between these groups were statistically significant for these variables (confidence interval 95 %, p < 0.05)

These differences were significant regarding the levels of inorganic As and organic MMA As in urine. We found inorganic As mean 1.5 ng/mL, $p_{50} = 0.66$, MMA mean 1.5 ng/mL, $p_{50} = 0.57$ and SD 3.3 among those who had more than 5 years of exposure, and inorganic As mean 0.1 ng/mL, $p_{50} = 0.00$ (confidence interval 95 %, $p = 0.002$), MMA mean 0.1 ng/mL, $p_{50} = 0.00$ and SD 0.2 (confidence interval 95 %, $p = 0.016$) when the exposure was shorter.

This was also noticed regarding the As levels in nails among immigrants who drank at-risk water for more than 5 years, mean 305.1 ng/g, $p_{50} = 217$ and SD 324.5, and those with shorter exposure, mean 335.7 ng/g, $p_{50} = 41$ and SD 1022.2 (confidence interval 95 %, $p = 0.005$) (Table 3).

We found no statistically significant differences between immigrants who used to drink from tube wells from those who drank harnessed water (Table 4).

**Table 4**

Mean and standard deviation levels of arsenic in urine regarding the source of drinking water. The available results refer to 37 children who drank tubewell water and 17 who drank harnessed water in their country of origin.

<table>
<thead>
<tr>
<th></th>
<th>Harnessed water</th>
<th>Tubewell water</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAs in urine, ng/mL</td>
<td>121.1 (367.8)</td>
<td>45.9 (80.7)</td>
</tr>
<tr>
<td>IAs in urine, ng/mL</td>
<td>1.9 (3.3)</td>
<td>0.8 (1.0)</td>
</tr>
<tr>
<td>MMA in urine, ng/mL</td>
<td>0.5 (1)</td>
<td>1.3 (3.3)</td>
</tr>
<tr>
<td>DMA in urine, ng/mL</td>
<td>16.9 (31.7)</td>
<td>10.7 (12.5)</td>
</tr>
<tr>
<td>Arsenobetaine in urine, ng/ml</td>
<td>36.3 (40.3)</td>
<td>43.1 (101)</td>
</tr>
<tr>
<td>As in hair, ng/g</td>
<td>72.1 (56.6)</td>
<td>74.0 (102)</td>
</tr>
<tr>
<td>As in nails, ng/g</td>
<td>445 (1144.5)</td>
<td>287.7 (350)</td>
</tr>
</tbody>
</table>

Parentheses: values of the standard deviation
Discussion

The three biological matrices we used, and even the As species found in urine, have different attributes and therefore indicate different conclusions regarding the patient’s exposure to As: Urine reflects recent exposure to As, and organic or inorganic species of As have also a particular meaning. Organic As has a half-life of 20 h, and it is completely excreted in 2 days while inorganic As half-life is shorter (about 10 h) but needs 4 to 5 days to be completely excreted. Normal As levels in urine vary from 5 to 40 μg per day (reference, 1.5 L urine per day). We decided not to adjust the As levels in urine to creatinine values, as it has been proved to be influenced by many factors (i.e., age, sex, race/ethnicity, diet, exercise) and it could therefore complicate the study, as other researchers previously reported (Hwang et al. 1997; Barr et al. 2005; Gamble and Liu 2005; Steinmaus et al., 2009). Nevertheless, this should not affect the interpretation and statistical significance of the study as seen in other cases (Hopenhayn-Rich, Biggs, Smith, et al. 1996a; Hopenhayn-Rich, Biggs, Kalman, et al., 1996b).

Conversely, hair and nails grow slowly and thereby show chronic exposure (2 to 5 and 12 to 18 months after ingestion respectively), not reflecting an acute intoxication (Adair et al. 2006). As levels are usually under 1 μg in hair and between 0.430 and 1.080 μg/g in nails.

Previous studies show that well-nourished families tolerate higher levels of As (Das et al. 1995). Vitamin C and methionine have proved to reduce As toxicity, whereas carbohydrates, proteins, fat, and a lack of vitamine A can increase it.
The accumulation of heavy metals in hair and nails is also presumably influenced by the environment, age, sex, or nutritional state.

Immigrant children from countries at risk of consuming arsenic-contaminated water had a prevalence of exposure to As higher than native children in some of the matrices we analyzed, but As values were far from reaching pathological levels. Furthermore, there were statistically significant differences between inorganic As levels in nails, especially when comparing natives with immigrants from Bangladesh, but they were by far lower than the limit considered to be threatening for human health (Rahman et al. 2001; WHO 2011).

Our study did not find differences in inorganic As levels in urine and in hair between native and immigrant children. One of the reasons that can explain the obtained data is the fact that immigrant children who came to Barcelona may have enough economical resources to avoid drinking water from tube wells in their countries, although the records show that 40 out of 64 used to drink from them. Another fact that could explain these results is that most of our immigrants from Bangladesh, 31 out of 42, came from the division of Sylhet, were the existence of polluted tube wells has been recorded, but it is not as significant as in the neighboring division of Chittagong. Actually in Bangladesh, arsenic-contaminated private wells exist in all areas although their proportion may vary. In a single village, both contaminated and non-contaminated wells are found. Therefore, it may be possible that the subjects who joined the study (and came from Bangladesh) were exposed to well water that was very low on arsenic, and therefore, their arsenic exposure level was as low as the native Barcelona children.

On the other hand, we found significant differences between native and immigrants when comparing the levels of organic As MMA and DMA in urine. This fact is probably related to differences in feeding habits. Theoretically, MMA (more toxic) and DMA could derive from the ingestion of inorganic As, but the low levels of inorganic As found in urine dismissed this hypothesis. It could also come from the ingestion of fish, shellfish, rice, and algae, common products in the Asiatic diet (Suner et al. 2002).
We found statistically significant differences between immigrant children who drank possibly polluted water for more than 5 years and those with shorter exposure, regarding the levels of total, inorganic and organic As MMA in urine, as well as As levels in nails. However, mean levels remained far from being toxic. Nine out of the 114 children in our sample were younger than a year, and only five of them came from at-risk countries. None of them showed matrices with high levels of As. Probably, in the case of mothers exposed to high levels of inorganic As, the transplacental passage was minimal.

Do these data mean that these children are eliminating accumulated As so that their levels are no toxic but higher than those from unexposed children? This is certainly not the case since the rates of inorganic and organic As MMA, DMA, and arsenobetaine found in urine did not match those from people who have drunk As polluted water for a long time. In our patients, the arsenobetaine in urine counts for most of the total As whereas in people who have drunk As polluted water for a long time, DMA and MMA count for the most of As in urine when speciated. Moreover, since the participants in our study were children who arrived in the previous 12 months, a high level of As consumption would have been detected in nails or hair, both matrices that show long-term (months) exposure.

We also have been able to set a normal level of As in urine, hair, and nails for children born and living in Barcelona, well below the pathological levels indicated by the ATSDR (100 ng/mL for total As in urine and 1000 ng/g for As in hair and nails) (Agency for Toxic Substances and Diseases Registry 2007). Our mean levels for native children in urine, nails, and hair samples were 46.9 ng/mL, 147.1 ng/g, and 351.9 ng/g, respectively.

The secondary goal of the study was to evaluate the need to create a program for new immigrants arriving to our primary care centers that could help us to identify asymptomatic children with chronic exposure and avoid the development of important diseases such as cancer. Fortunately, the levels of As in the samples examined where lower than the threatening limits, so we will not consider establishing such a program as of now. However, this possibility should be reconsidered in the future after new prevalence studies similar to the present one will be conducted.
In summary, children arrived from countries at risk of consuming As polluted waters do not have toxic levels of As in urine, hair or nails. However, these children (especially those from Bangladesh) have higher levels than the native ones. The higher levels of organic As found in urine may be due to different dietary habits. This study shows that, at present, there is no need of screening As levels or follow-up immigrant children recently arrived to our primary care centers.

References


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