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Biomonitoring of arsenic in woodworkers exposed to CCA and evaluation of other non-occupational sources in Uruguay

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ABSTRACT
In Uruguay wood-impregnation plants use chromated copper arsenate (CCA) as preservative applying good manufacture practices (GMP). This study aims a retrospective evaluation of toxicologically relevant species levels in CCA exposed woodworker's urine (As-U) and an assessment of the effects of work risk factors and non-occupational sources in As-U of workers from a selected plant. From 2014 to 2016, As-U in 212 urine samples (As-U) of 73 woodworkers from six CCA impregnation plants were determined. In one of these plants, 35 workers were interviewed to obtain individual data of work tasks, lifestyles, diet, habits, etc. that may contribute to their overall exposure to Arsenic. Responses were statistically evaluated. Out of the 212 urine samples from 73 woodworkers, 96% showed lower levels of As-U than those established by health regulations (<35μgL^{-1}). According to their work tasks 34% of 35 surveyed workers showed high exposure risk to As and 29% moderate exposure risk. Although they have lower levels of As-U owing to their personal protective equipment, As-U significantly correlate to work risk factors. Consumption of bottled water could also contribute to As-U levels as a non-occupational source. These results confirm that efforts of Uruguayan authorities to promote GMP were successful and justify the importance and frequency of As-U systematic biomonitoring for occupational risk assessment. A significant accomplishment of this work is that non-occupational sources of As-like bottled water consumption should also be considered in future studies.

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Background

Arsenic (As) is a natural component of the earth's crust and is widely distributed [1,2]. Industrially, As is used as an alloying agent as well as in manufacture processes of glass, pigments, textiles, paper, metal adhesives, pesticides, and wood preservatives [2]. Therefore, non-occupationally exposed population may be exposed to As present in air, soil, drinking water, and food [3].

Arsenic compounds can be categorized as inorganic or organic species. Inorganic As (iAs) include arsenate (AsO_4^{3-}) and arsenite (AsO_2^{-}) where oxidation states are As(V) and As(III), respectively. Organic species include methylated arsenic compounds such as monomethylarsonic acid (MMA), dimethylarsinic acid (DMA), arsenosugars, arsenolipids, and tri-methylated arsonium compounds such as arsenobetaine [4]. Inorganic arsenic species have demonstrated toxicity in humans but trivalent iAs species are more toxic than pentavalent ones [5]. Fish, shellfish, kelp, and some other seafood can contain organic species of As, mostly arsenobetaine with very low toxicity [6].

Arsenic exposure through the consumption of drinking water from wells is one of the greatest threats to human health, because in groundwater, As is naturally found as soluble iAs and it has been responsible for the development of severe adverse effects on populations in many regions around the world, including several countries in Latin America [1].

Other commonly reported contributors to iAs intake include vegetables, fruits, and beverages [7,8]. In cereals, such as rice, iAs and di-methylated species are present as a "natural" component. Another contribution that must be taken into account is the As exposure in smokers since tobacco contains iAs [7,9].

Since ancient times inorganic arsenic has been recognized as a human poison, and a single large oral dose can result in death [3]. On the other hand, long-term exposure to low iAs levels can lead to chronic arsenic poisoning [2] and skin lesions and skin cancer are the most characteristic effects. Exposed population is prone to develop also bladder, kidney, and lung cancer [10].

When iAs enters the organism through dermal absorption, inhalation, or ingestion it undergoes

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methylation reactions and the methylated species MMA and DMA are formed, both less toxic than iAs species [11].

Urine is the main route for iAs and is excreted as a mixture of 10–30% of unchanged iAs, 10–20% of MMA and 60–80% of DMA [6,11]. Arsenobetaine, with very low toxicity, is rapidly absorbed and excreted in urine and up to now there is no evidence that it is metabolized by humans [7,12].

Among the industrial uses of As compounds and occupational exposure risks, the chromated copper arsenate (CCA) must be mentioned. It is used as wood preservative (60% aqueous solution) to prevent fungal decay and infestations by wood-boring insects [3]. CCA composition, expressed as oxides is: 28.5% Cr_2O_3, 11.1% CuO and 20.4% As_2O_5. This product is registered as a pesticide with a restricted use, and is available for commercialization as an aqueous solution [13].

In the European Union countries [14], USA [15] and Canada [16], the use of CCA-treated wood in residential applications has been banned since 2004 because of its toxicity, although CCA-treated wood is still used in agricultural or industrial applications due to the low cost. Wood treated with CCA is known as "pressure-treated wood" [13]. There are different alternatives to the use of CCA, although they are generally more expensive, such as quaternary alkaline copper (ACQ), borates and copper azole (CA), among others. Currently, ACQ is widely used as wood preservative for residential applications [17].

Uruguay is a small country in the southeastern region of South America with a total surface of 176.215 km^2 and 3.45 million inhabitants. The largest productive activities are agriculture and livestock.

In the last decade, government priorities have been the promotion of good quality lumber production, as well as the diversification of wood industries to increase production of higher added value products [18]. Forestry activity in Uruguay has grown steadily over the past 25 years; in these years, the planted surface area has multiplied by 30. In 2015, the planted area reached 25.000 km^2 [19]. Excluding native forests, 73% of the total forested area corresponds to the genus Eucalyptus, while the Pinus genus represents 26% of the total area [20].

As previously mentioned, wood preservation has grown steadily among other forestry-related industries, with 20 wood-impregnation plants installed up to date, producing 100,000 m^3 of treated wood annually [18]. Most of them use CCA as wood preservation agent. Consequently, about 500 tons of CCA are imported annually in Uruguay [21].

Many of Uruguayan impregnation industries have modern plants for the CCA impregnation process. This process is carried out following the good manufacture practices (GMP) described in the "Guidelines on good practices in wood impregnation" published in 2007 [22,23]. These guidelines resulted from a multidisciplinary and interinstitutional approach including Uruguayan and international government organizations and wood impregnation industry delegates. Main operations involved in wood impregnation consist of several stages which are described in the above-mentioned guidelines [22]. In each of these stages, the risk of exposure to As has been characterized, so safety and prevention measures are also established in those guidelines for the different tasks including the use of personal protection equipment [22,23].

In spite of the safety and risk prevention measures to improve health conditions at work, exposure to As in woodworkers may occur through inhalation, dermal exposure, and ingestion during their labor day [23]. Garrod et al. studied potential worker′s dermal and inhalation exposure to CCA in industrial pre-treatment of timber with water-based products under vacuum-pressure and organic based double-vacuum processes; the authors performed a pilot study and the results showed a low uptake by dermal route and inhalation exposure. Poor hands washing before eating or smoking could also contribute to the toxic uptake by ingestion as a secondary route of exposure [24].

Traditionally, the total concentration of As in urine has been commonly used as biomarker for exposure assessment [12]. Recently, occupational biomonitoring and research studies have focused on the sum of inorganic-related species (arsenate + arsenite + DMA + MMA) as a measure of the "toxicologically relevant species" in order to avoid the As contribution from the consumption of certain food, such us seafood, that may contain significant concentrations of organic As [12]. The American Conference of Governmental Industrial Hygienists (ACGIH) provides an occupational biologic effect index (BEI) for urinary inorganic arsenic plus metabolites equal to 35 $\mu g\ L^{-1}$ as a guideline for the evaluation of potential associated risks [25].

So, the "toxicologically relevant species" are quantified in urine (iAs + DMA + MMA), for biomonitoring assessment and risk management of workers' As exposure in order to prevent adverse health effects and diseases [25,26].

Uruguay adopted the recommendations of the ACGIH for the exposed workers: urine samples must be collected twice a year, at the end of workweek for analysis of toxicologically relevant arsenic species in urine (As-U) [25]. In workers exposed to CCA, chromium (Cr) and As biomonitoring in urine is mandatory. When one or both biomarkers are higher than ACGIH limits, a protocol should be followed, for example, the worker could be removed from his/her work activities and the analysis repeated 15 days later [23]. In the meantime, it is necessary to identify possible causes and carry out the appropriate corrective actions. In Uruguay, this biomonitoring surveillance analysis is performed in the Specialized Center of Chemical Toxicology (CEQUIMTOX) in Montevideo, Faculty of Chemistry, Universidad de la República [27]. Since 2014, Cr levels in urine did not show health risks for occupational biomonitoring while As levels in urine have been a matter of concern.

This study was conducted with two main objectives (1) to perform a retrospective study reviewing the data of three years' results of As-U from CCA-woodworkers' biomonitoring in Uruguay, (2) to evaluate the effect of occupational and non-occupational sources of As in urine, not considered in workers surveillance in Uruguay, in a selected exposed population. This was a pilot study designed to provide new tools and knowledge about woodworker's exposure to CCA, and the evaluation of non-occupational sources, to apply it for occupational and environmental health surveillance.

The study was approved by the ethics committee of Faculty of Chemistry that review research proposals on humans and reports periodically to the Ministry of Health [28]. It's members are biochemical and pharmaceutical chemists, physicians, lawyers, among others.

To the best of our knowledge this is the first study focused on arsenic occupational exposure risks in Uruguay.

Methods

From 2014 to 2016, 212 urine samples from 73 workers of six CCA impregnation plants were analyzed as routine assessment of health risks. The distribution of the 73 workers and urine samples per plant are shown in Table 1. Plants A and B sent samples periodically to our laboratory while the others only once a year, thus the total number of analyzed samples in this period was 212. In addition, staff turnover is a very frequent practice in most plants.

Toxicologically relevant species of As in urine (As-U) were determined in these samples according to ACGIH Biological Exposure Indices ("BEIs®") [25].

In 2016, Plant (A), located in a forest area in the central zone of the Uruguayan territory, was selected for a pilot study to evaluate the impact of occupational and non-occupational factors that could affect As-U levels. This plant was selected because it had a reasonable number of workers in relation to the number of operations carried out there. However, surveys were conducted, only for those workers with working contracts by that moment ($N = 35$). Surveys were conducted the same day that the urine samples were collected.

Table 1. Distribution of workers in Uruguayan CCA plants during the period 2014–2016.

Plant	Number of workers (*N*)	Samples collected over period 2014–2016	Samples with values higher than ACGIH limit
A	51	Dec.2014/Jun.2015/ Dec.2015/Jun.2016/ Dec.2016	2
B	12	Jun.2015/Dec.2015/ May2016/Oct.2016	7
C	4	Jan.2015	0
D	2	Aug.2015	0
E	2	Aug.2016	0
F	2	Jul.2016	0

Note: Some plants did not send samples to CEQUIMTOX twice a year although Guidelines recommend it.

This project was previously presented to the executive board of Plant A and workers signed a written informed consent document to participate. They were interviewed at the workplace and their answers were recorded in a form.

These workers performed different tasks, some worked directly in the wood impregnation process while others worked in offices far from the place where the impregnation process takes place. The plant should follow the above-mentioned guidelines of Good Manufacture Practice [22,23].

Correlations between As-U levels of each worker and variables obtained from individual data about work tasks, lifestyles, diet, habits, etc., that may contribute to their overall exposure to As were statistically evaluated using the software Stata 12® [29].

Sampling and analysis

Urine samples were collected from each worker after at least 2-h retention, at workplace, at end of a workweek in urine cups according to ACGIH [25]. Specimens were stored in a portable cooler and delivered to the laboratory within 24 h.

Quantification of the sum of toxicologically relevant species of As in urine (As-U) was performed using an alternative method to HPLC-ICP/MS, technique not available in Uruguay. This method was developed in the CEQUIMTOX using Hydride Generation Atomic Absorption Spectrometry (HG-AAS) as previously reported [30].

Briefly, the method consists of a pre-reduction step with L-cysteine of As species to As (III) and subsequent determination using HG-AAS (Atomic Absorption Spectrometer Varian SpectrAA 55B) [30].

Detection limit (LOD, using 3σ criteria) was 1.5 μg L^{-1} and quantification limit (LOQ, using 10σ criteria) was 5.1 μg L^{-1}; precision (RSD %) was 12% and repeatability was in the range from 5.3 to 8.1% (for the highest and lowest concentrations respectively) [30]. Interlaboratory assays obtained from German External Quality Assessment Scheme (G-EQUAS), Institute for Occupational, Environmental and Social Medicine (Erlangen, Germany) are performed twice a year in our laboratory as external quality control, to ensure reliable results. Analytical conditions were validated with standard quality assurance and control (QA/QC) procedures [31].

Interviews

Trained interviewers conducted a questionnaire to each of the 35 participants of the selected plant through face-to-face interviews at the workplace. The questions were divided into the following sections: (a) personal information including, years of work in the company, (b) Work tasks, safety conditions at workplaces and risks' perception, (c) eating habits (including cereals, fish, shellfish, beef, chicken), (d) drinking water at home/at workplace (bottled, tap, well), (e) free time (gardening, agricultural work practices, carpentry, mechanics, etc.), (f) smoking and alcohol consumption

Variables used in the present study were: gender, years of work in the same site, use of personal protective equipment (no, yes); risks of exposure to As at workplace (categorized as non-exposed; low exposed; moderate exposed and highly exposed); risks' perception at work (dust, noise, metals, fuels, none); cereal consumption (rice, corn, others), fish or shellfish (no; yes, weekly frequency; last time (days)), beef (no; yes, weekly frequency); chicken (no; yes, weekly frequency); water at home (bottled, tap, well); water in workplace (bottled, tap, well); gardening (no; yes), carpentry (no; yes); mechanics (no, yes); painting (no; yes); free time exposure (solvents, painting, pesticides, none); heating (fuels, wood, electric), smoking habit (never smoked; ex-smoker; current smoker); alcohol beverages (every day; weekend; occasionally); alcoholic beverages consumed (wine, beer, whisky, others).

Statistical analysis

As previously mentioned, this study comprises two parts. One is a retrospective study performed using the results of 73 woodworkers' arsenic biomonitoring of 212 urine samples analyzed as described above. These samples were from workers from six CCA impregnation plants as shown in Table 1. In this part, we assessed the results of As-U of all samples to search for those cases that exceeds regulations recommended levels (As-U > 35 μgL^{-1}) and evaluate if those "risk levels" decreased after the action taken.

The other part was a pilot study with 35 workers of one of the plants (Plant A). In this study, a statistical analysis by means of a Spearman's rank correlation coefficient test was used for the different variables (numerical and ordinal). ρ and p values (<0.05) were assessed [32]. Spearman's rank correlation coefficient or Spearman's rho, is a nonparametric measure of statistical dependence between two variables. ρ indicates the strength of association between two variables. When ρ is 1 it means a perfect positive correlation and when ρ is −1 means a perfect negative correlation while p-value determines whether the correlation between variables is significant, compared to significance level, usually 0.05.

Results

Retrospective study 2014–2016; workers form 6 plants

Results of As-U biomonitoring are summarized in Table 2 and the distribution is shown in Figure 1.

In the studied period, 96% of the analyzed urine samples showed As-U lower than the limit established by occupational health regulations (As-U < 35μg L^{-1}). Only 9 samples (from 9 workers) had values higher than limits from ACGIH BEIs as it can be observed in Figure 1. For those workers with higher levels, a safety protocol, referred in Guidelines, was followed [22,23]: the workers were removed from their workplace for at least 15 days, then the urine analysis was repeated. All of them showed significant lower As-U after this action as it is shown in Figure 2. The initial high levels decreased to values lower than the limit, thus confirming that the taken actions were adequate for their safety conditions at work.

Pilot study

Responses of the individual interviews conducted to the 35 workers are shown in Table 3.

Interestingly, 29% of interviewed workers had more than 35 years of permanence in the same plant while 40% had less than three years in the job.

As mentioned before, the Guidelines [22,23] describes that these kinds of plants had several stages of the wood impregnation process with different potential As exposure risks to workers. For example, manipulation of drums containing concentrated CCA, manipulation of the product and connections with the pressure cylinder feed circuit, working near the ventilation of the vacuum pump that generates potentially contaminated mists, opening the pressure cylinder, wood discharge from the wagons, and handling recently treated wood, as well as the final cleaning process [22]. A scheme of the main stages of the whole process and associated As exposure risks is shown in Figure 3.

An assessment and classification in four categories of work exposure risks was carried out. This classification was focused on the individual tasks performed by the workers (based on their responses) and considering the map of risks of the CCA wood impregnation process detailed in the Guidelines [22,23]. Distribution the categories is shown in Figure 4.

Table 2. As-U results in the period 2014–2016 for biomonitoring purposes.

	As-U (μg L^{-1})
Mean	11.8 ± 1.4
Median	5.9
Minimum	<5.1
Maximum	82.5 ± 9.9
Total workers	73
Samples with As-U>35 μg L^{-1}	9 (from 9 workers)
Total number of samples	212

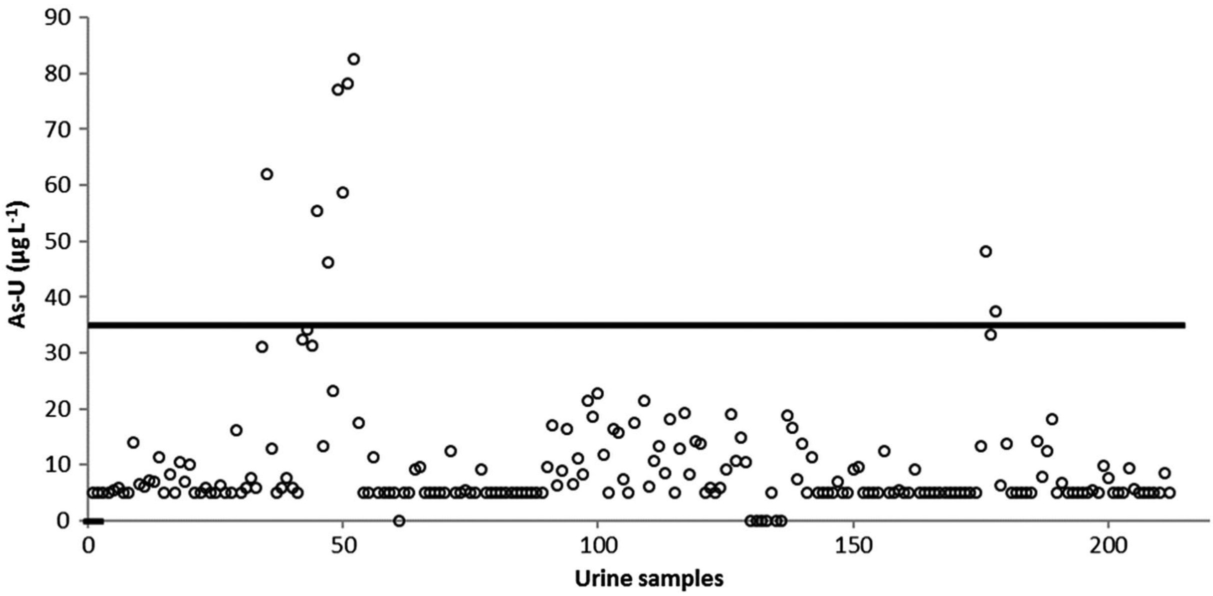

Figure 1. As-U found during the studied period. Black line indicates the reference value (35 µg L^{-1}).

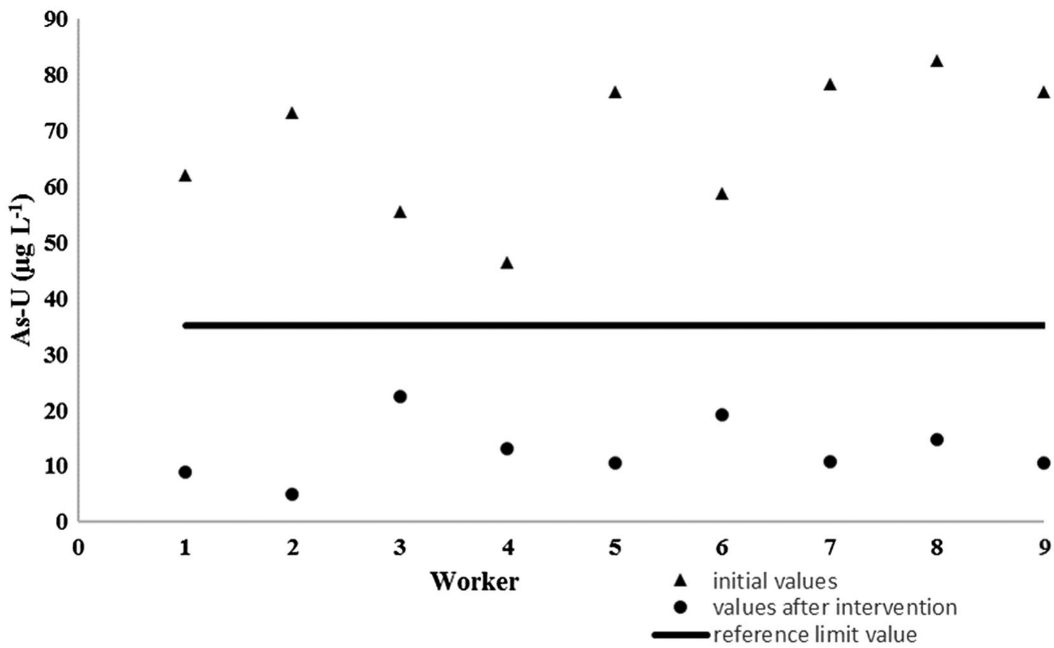

Figure 2. Results of As-U before and after worker removal from the workplace. Black line indicates the reference value (35 µg L^{-1}).

According to their work tasks, 34% of surveyed workers showed high exposure risk to As and 29% moderate risk.

Table 4 shows the As-U results according to different exposure categories. For all the categories, As-U levels were below the ACGIH limits, but higher levels were found in workers that perform tasks where they may be more exposed to As.

The lowest As-U levels were found in the group of workers whose offices were far and separated from the place where the impregnation process takes place. Although this group could be considered as a control group, they were very few ($N = 5$).

Other options in the survey asked about the workers' risk perception at workplace, most of them responded that they were exposed to dust (77%), chemicals (71%), and noise (57%).

Some questions where included in the survey to obtain information about non-occupational sources of As with the aim to study their possible contribution to As-U. Consulted about their diet, most of them answered that they consume rice (91%), fish (83%), beef (97%), and all of them consume chicken.

In Uruguay, tap drinking water is provided by a state company but it is also consumed as bottled water from different sources and trademarks; 66% of workers declared

Table 3. Woodworkers of plant A: interviews results.

	Variable	Response
General	Number of workers	35
	Sex- Male	30
	Age (mean)	41
Work	Years of work (mean)	13.5 (max 47)
Workplace exposure to As	Non- exposed	4
	Low exposure	9
	Moderate exposure	10
	High exposure	12
Use of personal protective equipment	yes	30
Perception of risk exposure at workplace	Dust	27
	noise	20
	chemicals	25
	paintwork	7
	fuel	11
	none	2
Diet		
Cereal	rice	32
	corn	1
	others	2
Fish	yes	29
	once a month	4
	once every two weeks	5
	once a week	15
	more than once a week	6
Shellfish	yes	4
Beef	yes	34
	once-twice a week	8
	three to five times a week	16
	five to everyday	6
Chicken	yes	35
	once-twice a week	14
	three to five times a week	17
	five to everyday	6
Drinking water	bottled	23
	tap	15
	well	2
Water for cooking	bottled	0
	tap	33
	well	2
Free time		
Hobby	gardening	13
	carpentry	12
	mechanics	7
	paintings	14
Perception of exposure	solvents	10
	pesticides	7
	welding metals	4
Home		
Heating sources	wood	23
	electric	24
	fuels	4
Smoke habits	current smoker	10
	ex-smoker	9
Alcohol consumption	yes	28
	everyday	1
	weekends	15
	occasionally	14
Type	wine	12
	beer	19
	whisky	5
	others	2

drinking bottled water but most of them use tap water for cooking (94%). In their free time, only a few of them stated that they were exposed to solvents (29%), pesticides (20%), and welding materials (11%). Their houses had mainly electrical and wood heating. One third (29%) were current smokers and 80% drunk alcoholic beverages, especially beer in their free time, with different frequencies.

Associations and statistical correlations of As-U with occupational and non-occupational variables previously described (such as dietary questions: meat, seafood, rice; water; exposure; habits; leisure), are shown in Table 5 where Spearman's correlation coefficient and p value between the As-U and the studied variables can be observed.

According to these results, As-U significantly correlated with occupational exposure risk (ρ = 0.5323; p = 0.0010). Although As-U values are within the regulations, the greater exposure during working hours, the higher levels of As in the urine of workers were found.

As-U also correlated with the workers' perception of being exposed to noise (ρ = 0.4852; p = 0.0056); this result will be discussed later.

Regarding non-occupational variables such as free time activities, diet, drinking water, smoking, and alcohol habits among others, only statistical correlation with consumption of bottled water was found (ρ = 0.4031; p = 0.0164).

Discussion

This was the first retrospective study of As biomonitoring situation of CCA-woodworkers performed in Uruguay. It showed low occupational exposure risks to As since the As-U results were below the recommended limits in 64 workers out of 73 through three years. Only for nine samples (corresponding to nine workers), As-U were higher than 35 μg L^{-1} and after a minimum period of 15 days of workplace removal they re-established safety As-U values, thus demonstrating that the action was adequate. This study reveals the importance of the correct use of the personal protective equipment and the relevance of having national guidelines for these practices [22,23]. Recommendations established in these guidelines can be applied to woodworkers in other countries with CCA-plants, as the guidelines are available on line (in Spanish) [22,23].

As expected, in the selected studied population (pilot study) As-U significantly correlated with occupational exposure risks although As-U levels were below the recommended limits in all urine samples from all workers. Those safe "low levels of As-U" are a consequence of GMP application in the industrial processes, the systematic medical surveillance and the safety and prevention measures at workplace. Particularly all workers who were categorized with As exposed tasks (N = 30), stated the correct use of personal protective equipment during their labor day.

Our results are consistent with Cocker et al. [33], where workers of CCA impregnation plants in United Kingdom, had concentrations of inorganic arsenic in urine significantly higher than those from non-occupationally exposed people but all were below biological monitoring guidance values (ACGIH). However, the number of occupationally exposed and non-occupational exposed workers studied, was higher than in our study. In our case, only five of the total workers could

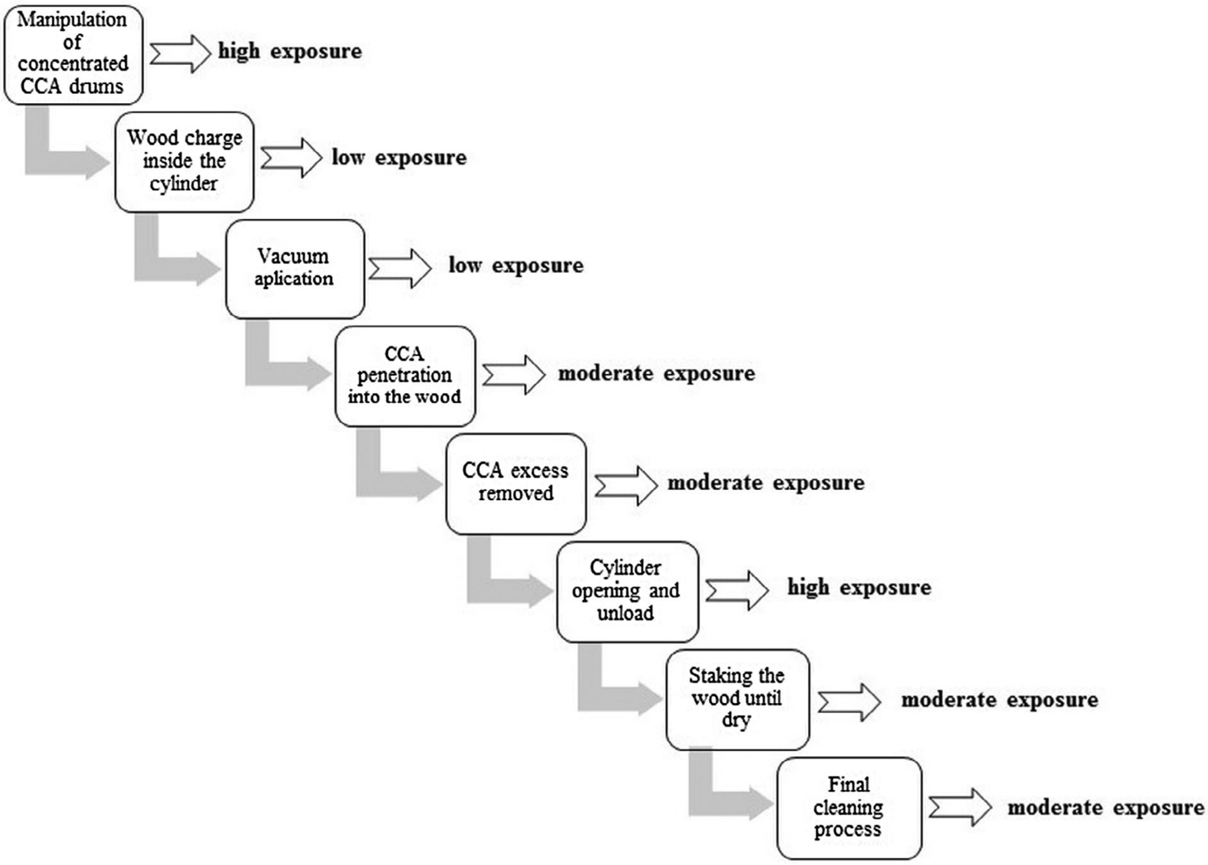

Figure 3. Stages of the wood impregnation process with CCA and potential exposure risks to workers.

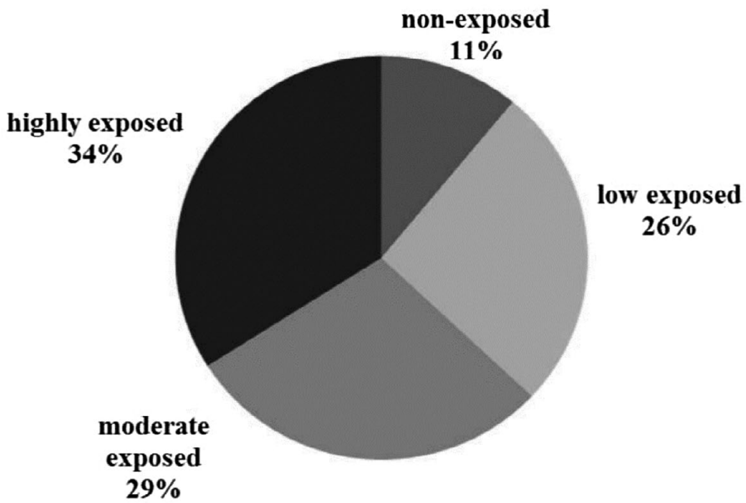

Figure 4. Distribution of categories of workplace exposure.

Table 4. As-U results obtained for the woodworkers that participated in the pilot study.

		As-U (µg L^{-1})	
Workers (*N*)	Category	Range	Mean
5	Non-exposed	5.1–6.4	5.3
9	Low exposed	5.8–12.2	7.6
9	Moderate exposed	9.0–17.6	13.6
12	Highly exposed	15.7–22.7	18.7
	Total = 35		

be considered as non-occupationally exposed but they work at the same plant.

The positive correlation between perceived noises and As-U may be because the riskiest areas from the point of view of the pollution are, also, places where the processes of impregnation produce more noise.

Likewise, there was a significant correlation between those workers that consumed bottled water and As-U. In Uruguay, As regulations for drinking tap water states a

Table 5. Spearman's correlation coefficients between As-U and variables.

	Spearman's correlation rank (ρ)	*p* value
Age	−0.0966	0.5808
Gender	0.1648	0.3441
Years of work	−0.0388	0.8248
Occupational As exposure (categorized)	0.5323	0.0010*
Dust at workplace	0.1687	0.3325
Noise at workplace	0.4582	0.0056*
Chemicals at workplace	0.2893	0.0970
Paintwork at workplace	0.0071	0.9678
Fuel at workplace	−0.1894	0.2833
Rice	0.2170	0.2176
Corn	−0.1778	0.3144
Cereals frequency	0.1008	0.5705
Fish	−0.0113	0.9487
Fish frequency	−0.1362	0.4731
Shellfish	0.0089	0.9595
Beef frequency	0.1188	0.5034
Chicken frequency	0.0752	0.6678
Drinking - water bottled	0.4031	0.0164*
Drinking – tap water	0.3179	0.0628
Drinking – well water	0.1038	0.5529
Cooking – tap water	−0.1038	−0.1038
Cooking – well water	0.1038	0.5529
Gardening	0.2141	0.2168
Carpentry	0.2478	0.1512
Mechanics	0.1973	0.2709
Paintings at free time	0.2546	0.1400
Solvents at free time	0.0502	0.7746
Pesticide at free time	0.1417	0.4167
Welding metals at free time	0.2628	0.1272
Heating wood	−0.1092	0.5389
Heating electric	0.0297	0.8677
Heating fuels	−0.0733	0.6852
Current smoker	−0.2196	0.2050
Ex- smoker	−0.0940	0.5911
Years smoking	−0.3046	0.0752
Alcoholic beverages	0.1417	0.4167
Alcohol consumption frequency	0.0347	0.8432
Wine	−0.0220	0.9054
Beer	−0.1520	0.4312
Whisky	0.1214	0.5381

*Variables that showed statistical correlation with p value < 0.05.

maximum admitted value of 20 μg L^{-1} with a target value of 10 μg L^{-1} (WHO recommendations) while the regulations for arsenic in bottled water establish that the limit should be the same as the accepted for tap water (20 μg L^{-1}) [34,35]. This correlation should be better assessed by knowing water consumption per day, and analyzing different brands of bottled water. High levels of iAs were found in some Uruguayan aquifers [36] but there is no available information about analytical results of As levels in bottled water up to now. As mentioned, bottled water is regulated by other norms than for drinking water supply and probably As concentrations, mainly in "mineral water" may be higher than those in tap water. Our results on As in groundwater indicate that it is very important to start monitoring iAs in bottle water systematically [35].

No significant correlation was found for the other studied parameters like cereal, fish, chicken, beef consumption, smoking, alcohol beverages, and activities in the free time, so the contribution of iAs from those sources could be ruled out.

Conclusions

Owing to the difficulty of replacing CCA for economic reasons, Uruguayan authorities promote the use of good practices that consider recommendations of international occupational safety organizations to minimize possible negative impacts on the environment and workers' health. In recent years, efforts have been made to improve the use of better technology in this field [23]. Our results confirm that these efforts were successful and that biomonitoring of toxicologically relevant species of As is necessary for occupational risk evaluation and to know when an action is required for the worker safety.

The pilot study was relevant and novel not only for our country but also as an experience to follow up with larger populations and to compare with what is reported in other countries. Our work was not limited to a survey of arsenic levels in workers exposed and non-exposed (those who work in offices) as an occupational risk assessment, but included other possible sources of inorganic arsenic that could affect the arsenic urinary levels in a selected population. Significant correlations showed that despite good working practices, extreme caution should be taken in the most exposed workplaces and the effect of non-occupational sources in arsenic levels in urine should be considered as well.

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