Environment International 82 (2015) 35–40

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Full length article

Cleaning-induced arsenic mobilization and chromium oxidation from CCA-wood deck: Potential risk to children

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ARTICLE INFO

Article history:
Received 15 December 2014
Received in revised form 29 April 2015
Accepted 30 April 2015
Available online 22 May 2015

Keywords:
Dislodgeable arsenic
Hexavalent chromium
Chromated copper arsenate
Soil
Exposure

ABSTRACT

Concern about children's exposure to arsenic (As) from wood treated with chromated-copper-arsenate (CCA) led to its withdrawal from residential use in 2004. However, due to its effectiveness, millions of American homes still have CCA-wood decks on which children play. This study evaluated the effects of three deck-cleaning methods on formation of dislodgeable As and hexavalent chromium (CrVI) on CCA-wood surfaces and in leachate. Initial wipes from CCA-wood wetted with water showed 3–4 times more dislodgeable As than on dry wood. After cleaning with a bleach solution, 9.8–40.3 μg/100 cm^2 of CrVI was found on the wood surface, with up to 170 μg/L CrVI in the leachate. Depending on the cleaning method, 699–2473 mg of As would be released into the environment from cleaning a 18.6-m^2-deck. Estimated As doses in children aged 1–6 after 1 h of playing on a wet CCA-wood deck were 0.25–0.41 μg/kg. This is the first study to identify increased dislodgeable As on wet CCA-wood and to evaluate dislodgeable CrVI after bleach application. Our data suggest that As and CrVI in 25-year old CCA-wood still show exposure risks for children and potential for soil contamination.

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1. Introduction

Chromated copper arsenate (CCA) is a pesticide that extends the service life of wood products by 20–40 years. CCA-C is the most common formulation for residential use and is comprised of 48% CrO_3, 34% As_2O_5 and 19% CuO by weight, with final As concentrations being 2000–5000 mg/kg (AWPA, 1998). During treatment, CCA binds to wood fiber, leading to reduction of carcinogenic hexavalent chromium (CrVI) to the non-carcinogenic trivalent form (CrIII) (Radivojevic and Cooper, 2008). CCA-wood structures around homes include fences, decks, and staircases. Between 1995 and 2003, 11 million new single-family homes were built in the US, with 3.4 million having decks constructed from CCA-wood. It is estimated that more than 21 million homes in the US had decks made from CCA-wood in 2007. Use in new residential construction ended in 2004, but ~150 million pounds of CCA were used by the wood treatment industry in 2010, primarily for use on farms, commercial properties and for export (Shupe, 2012).

Arsenic is ubiquitous in the environment and typical concentrations in US soils are 3–4 mg/kg (ATSDR, 2007). Exposure to As in the residential setting most commonly occurs through ingestion of contaminated water and foods, with health problems such as skin disease, peripheral neuropathy, diabetes and cancer associated with chronic exposure (ATSDR, 2007). Currently, there is a concerted effort to reduce As exposures, as many people are exposed to levels associated with health effects (EFSA, 2009; WHO, 2010). Like As, hexavalent Cr (CrVI) is a known human carcinogen and has non-cancer effects such as pulmonary disease, gastrointestinal symptoms, hematological, and immune-system problems (ATSDR, 2012).

Initial concerns about exposure to CCA-wood focused on children's exposure to dislodgeable As on the wood surface while playing on CCA-wood playsets, with dislodgeable As values ranging from tens to hundreds of μg/100 cm^2 wood surface (CPSC, 2003; Hemond and Solo-Gabriele, 2004). Probabilistic modeling of children's exposure to As from CCA-wood found an increased cancer risk, with the highest risk being associated with living in a home with a playset and deck in a warm climate (Zartarian et al., 2006). An assessment of children's exposure to As at apartment complexes with large CCA-wood staircases also found elevated risk through ingestion of dislodgeable As and contaminated soil in adjacent areas (Gress et al., 2014). Dislodgeable As has also been found on floors in homes with CCA-wood decks, representing another residential exposure route (Sigmon and Patch, 2010). Compared to As exposure from CCA-wood, little attention has focused on potential effects from CrVI exposure (USEPA, 2005). Hamula et al. (2006) evaluated the amount of dislodgeable Cr on children's hands following contact with CCA-wood playsets, finding elevated levels compared to non-CCA wood. Although there is no federal regulation on levels of dislodgeable CrVI, permissible levels of dislodgeable As and

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http://dx.doi.org/10.1016/j.envint.2015.04.012
0160-4120/Published by Elsevier Ltd

CrVI in the workplace are established by Brookhaven National Laboratory at <15 μg/100 cm^2 for As and <7.5 μg/100 cm^2 for CrVI (BNL, 2014).

CCA-wood has been recognized as a point source of soil As contamination, with concentrations around CCA-wood structures commonly elevated 10–30 times above background levels (Stilwell and Gorny, 1997; Chirenje et al., 2003; Townsend et al., 2003). Arsenic enters the soil as rainwater washes away surface residues and through abrasion of the wood surface (Townsend et al., 2005). For example, based on a mini-deck of 2.92 m^2 and 159 cm/year rainfall, Khan et al. (2006) found a daily As loss of 2 mg/m^2 of deck and an As concentration of 600 μg/L in leachate. Similarly, Shibata et al. (2007) reported concentrations of As at 0.11–4.71 mg/L and Cr at 0.01–0.47 mg/L in leachate from 3-year old CCA decks.

Application of sealants reduces dislodgeable As on CCA-wood surfaces by >90%, but dislodgeable As returns to pre-sealant levels within 2 years (CPSC, 2005; USEPA, 2008). To reduce exposure to dislodgeable As, it is advised to seal CCA-wood decks every 1–2 years (CPSC, 2011). Prior to sealing, bleach and/or pressure washing has often been used. Taylor et al. (2001) reported that application of bleach, which contains 5.25% NaOCl at pH of 12–13, on CCA-wood induces formation of CrVI. A batch study found 2–3 times more As leached from weathered wood at pH 13 than pH 11, with CrVI being leached above pH 9 (Solo-Gabriele et al., 2004).

The objective of this study was to evaluate the impacts of wood-cleaning methods on metal leaching from aged CCA-deck, which represents a significant proportion of residential use of CCA-wood. Our specific objectives were to 1) determine the amounts of dislodgeable metals on weathered CCA-wood surfaces, and As and CrVI in leachates from different cleaning methods; 2) estimate soil As enrichment under a hypothetical deck of 18.6 m^2 after cleaning; and 3) assess potential As exposure doses in children ages 1–6 after 1 h of contact with wet CCA-wood. This research evaluated the potential of CCA-wood cleaning methods in increasing human exposure to As and CrVI around homes, which is relevant to the millions of Americans living in homes with CCA-wood decks and walkways.

2. Materials and methods

2.1. CCA-wood samples

The CCA-wood used in this study was from a residential deck in Florida that was constructed ~25 years ago. Twenty uniformly weathered wood planks were cut into 45.0 cm × 13.5 cm sections. The wood was randomly assigned to three different cleaning methods, with nonCCA-wood used as a control. Sawdust was digested using EPA Method 3050B and analyzed for metal content with inductively coupled plasma mass spectrometry (ICP-MS; Perkin Elmer, NexION 300). The CCA-wood had mean concentrations of 2092 mg/kg Cr, 1512 mg/kg As, and 1143 g/kg Cu (data not shown).

2.2. CCA-wood cleaning methods

Based on deck cleaning instructions and recommendations made by painting professionals, a common wood cleaning method includes applying a bleach-based cleaning solution followed by scrubbing and/or rinsing with either a pressure washer (PW) or a garden hose. In this study, three wood cleaning methods were compared, including 1) applying 25 mL of tap water to the wood surface and pressure washing after 15 min (Water/PW); 2) applying 25 mL of a 1:2 bleach:water solution and pressure washing after 15 min (Bleach/PW); and 3) applying 25 mL of a 1:2 bleach:water solution, scrubbing with a 6 × 3 cm plastic brush with moderate pressure 5 times back and forth after 15 min, and then rinsing with 500 mL tap water (bleach/scrub).

Pressure washing involved using a 2000 psi commercial pressure washer held 46 cm from the wood surface for 10 s. In the bleach/scrub method, the scrub brush was cleaned in 500 mL of 2.5% HNO_3 and rinsed after each use.

2.3. Wipe sampling of CCA-wood for dislodgeable metals

Prior to cleaning, wipe samples were collected from the dry wood and then after the wood was moistened with 25 mL of DI water. The goal of wipe sampling was to remove dislodgeable metals on the wood surface (CPSC, 2005; USEPA, 2005). Following NIOSH Method 1900, a dry 50 cm^2 polyester wipe (Texwipe, TX 1009) was moved across the wood surface in an S-shaped pattern (BNL, 2014). A hand pressure of ~1.1 kg was applied by using a 1.1 kg steel disk.

After the wood was dried, they were cleaned using one of the three methods described above. To assess the effect of bleach on CrIII oxidation, half of the wood was wiped to assess dislodgeable CrVI levels. These wipes were placed in 50 mL distilled water (pH 7.5) for 5 min and shaken by hand. Then 10 mL of extractant was filtered using a 0.2 μm Nalgene syringe filter and analyzed by EPA Method 7196A, using 1,5-diphenylcarbohydrazide reagent and a spectrophotometer (UV160U, Shimadzu) within 10 min of sample collection. The other half of the wood was wiped to assess dislodgeable Cr, As and Cu using ICP-MS. These wipes were placed in digestion tubes to which 50 mL 10% HNO_3 was added and placed in a 65 °C water bath for 16 h before filtration with 0.45 μm polyester filters (Environmental Express, South Carolina). QA/QC for wipes included blanks and spikes (Stilwell et al., 2003; CPSC, 2005).

2.4. Leachate collection

For all three methods, either water or bleach solution was applied to the wood placed in a 5-gallon bucket and left for 15 min. For bleach/scrub method, after scrubbing, the wood was rinsed with 500 mL of tap water and, for water/PW and bleach/PW methods, the wood was power washed for 10 s. The wood was then wiped and leachate volume was recorded. Depending on the amount of water absorbed by the wood, leachate volumes ranged from 465 to 634 mL.

For all methods, 10 mL of leachate was filtered through a 0.2 μm filter and the filtrate was analyzed colorimetrically for CrVI using the USEPA Method 7196A. The remaining leachate was filtered with pre-weighed filter paper, which was then dried in a 100 °C oven for 48 h before digestion using USEPA Method 3050B. Both the digested leachate residue and filtrates were analyzed for total Cr, As, and Cu concentrations using ICP-MS. To assess changes in Cr speciation over time, unfiltered leachates from the bleach/scrub method were kept at room temperature for 11 d and CrVI concentrations were analyzed.

3. Risk assessment and data analysis

The amount of As ingested by children ages 1–6 after playing for 1 h on a wet CCA-wood was calculated following Hemond and Solo-Gabriele (2004):

$$\text{As}\ (\mu g/kg) = C \times MF \times SA \times HD \times TE \times B/BW \quad (1)$$

where C = mean amount of DA on hands (μg/cm^2) (7% per amount on dry wipe, Shibata, 2006); MF = mean outdoor mouthing frequency per hour in kids ages 1–6 (9; USEPA, 2011); SA = surface area of hand mouthed (20 cm^2; Hemond and Solo-Gabriele, 2004); HD = 1 h of playtime on CCA deck; TE = transfer efficiency per mouthing (100%; Hemond and Solo-Gabriele, 2004); B = As bioavailability (60%; USEPA, 2011); and BW = bodyweight for ages 1–2 (11.4 kg), 2–3 (13.8 kg), 3–6 (18.6 kg) (USEPA, 2011).

Standard QA/QC protocols were followed, including blanks, standard reference material (NIST Montana 2710a), duplicates and spikes. Data were presented as the mean of all replicates with standard error. Using one-way analysis of variance, significant differences were determined by comparing means using Tukey's multiple range tests at $p < 0.05$ using JMP®10 PRO (SAS Institute Inc., Cary, NC, 1989–2010).

4. Results and discussion

As a water-soluble pesticide, it is known that water promotes As leaching from CCA-wood (Shibata et al., 2007); however, it has not been quantified in a residential exposure scenario. Earlier studies on children's exposure to dislodgeable As on playsets and decks identified several key variables that influence exposure doses but surface moisture was not among them (Zartarian et al., 2006). During the EPA re-registration of CCA in 2008, it was noted that residential exposure to As and CrVI from CCA-wood was not expected (USEPA, 2008). There is no regulation on allowable limit of CrVI, although Brookhaven National Laboratory has set a limit of 7.5 μg/100 cm^2 (BNL, 2014). Even though the amount of dislodgeable CrVI on newly cleaned CCA-wood was higher than 7.5 μg/100 cm^2, we did not estimate CrVI exposure doses because of the uncertainties in estimating the transfer of CrVI from wipes to that on human hands, which warrants further study.

4.1. Moist CCA-wood had 3–4 times more dislodgeable As and Cr

The average amount of dislodgeable As and Cr on dry wood was 15.4 ± 1.15 and 11.3 ± 1.00 μg/100 cm^2 (Fig. 1). The dislodgeable As was greater than the 10.3 μg/100 cm^2 found in a nationwide field survey of >1600 wipe samples from weathering CCA-wood structures (Patch and Maas, 2006). However, they were lower than those from 6-month old CCA-wood, with dislodgeable As and Cr being 27 and 32 μg/100 cm^2 on wipe samples of dry CCA-wood (Maas et al., 2002). The data suggested that dislodgeable As and Cr from CCA-wood decreased with weathering.

When CCA-wood was wetted with water for 15 min, the levels of dislodgeable As and Cr on the wood increased 3–4 times, indicating rapid solubilization of As and Cr (Fig. 1). The dislodgeable As and Cr on the wet wood surface increased to 55.5 ± 2.36 and 76.2 ± 13.5 μg/100 cm^2. Although the amounts of dislodgeable Cr on the dry wood was only 13.6% greater than that of As, 37% more Cr than As was present on the wet wood, indicating more solubilization of Cr upon wetting. All Cr was present as CrIII as no CrVI was found on wipe samples (Fig. 1). In addition, no As or Cr was found on non-CCA wood control samples (data not shown).

In addition to As and Cr, we also determined the amount of dislodgeable Cu, which followed a similar trend with As and Cr. Dislodgeable Cu was 22.9 ± 6.41 μg/100 cm^2 on dry wood, which increased to 50.1 ± 10.3 μg/100 cm^2 on wet wood (Fig. 1). Dislodgeable Cu was not a concern in the residential setting, however, it may be of concern in an aquatic system as it is more sensitive to Cu toxicity. Unlike Cu, dislodgeable As on CCA-wood surfaces was a significant factor in dose estimation in the SHEDS-Wood probabilistic exposure modeling conducted by USEPA. Our study showed that children would have higher exposure to As and Cr when contacting wet CCA-wood than dry CCA-wood, which is a common occurrence in Florida due to its subtropical climate.

4.2. Dislodgeable CrVI was detected after bleach application

Bleach application coupled with pressure washing (bleach/PW) induced more mobilization of metals from CCA-wood than scrubbing plus low pressure wash (bleach/scrub) or water application plus pressure wash (water/PW) (Fig. 1). For example, the amounts of dislodgeable As and Cr were 54.2 and 81/100 cm^2 from wood after cleaning with the bleach/scrub method, and 49.7 and 77 μg/100 cm^2 from wood using water/PW method. In comparison, bleach/PW method solubilized 40–45% more As and 35–38% more Cr than the other two methods, which was at 90.7 and 125 μg/100 cm^2 (Fig. 1). The use of bleach and pressure washing to clean CCA-wood resulted in significantly more As and Cr being solubilized on the wood surface.

During wood treatment, almost all carcinogenic CrVI was reduced to the non-carcinogenic CrIII during fixation, so CrIII is the dominant form in CCA-wood (Radivojevic and Cooper, 2008). The relatively low leachability of Cr from the CCA-wood was consistent with its presence as insoluble CrIII. This was confirmed in this study as no dislodgeable CrVI was detected from wood using water/PW method (Fig. 1). However, 7.0 and 49% of the dislodgeable Cr was present as CrVI (9.8 and 40.3 μg/100 cm^2) on the wood using bleach/PW and bleach/scrub methods. This was because bleach contains 5.25% NaOCl with an elevated pH at 12–13, causing CrIII oxidation to CrVI. A similar observation was reported by Taylor et al. (2001). Although lower than dislodgeable As, dislodgeable CrVI from wood that received bleach application was 2–5 times higher than that permitted in the workplace (BNL, 2014). Hence, additional research is needed to investigate the amount of CrVI transferred by hand–mouth behavior in children.

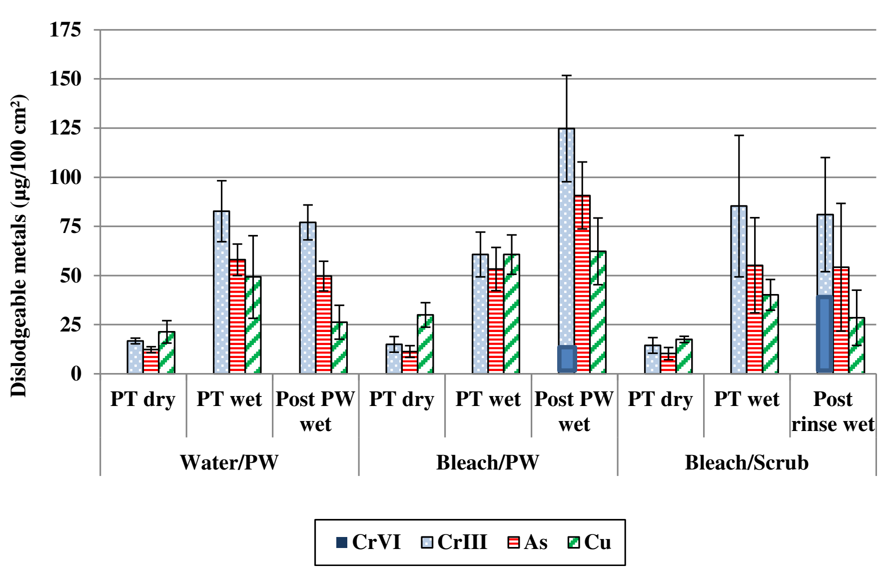

Fig. 1. Dislodgeable CrIII, CrVI, As and Cu on CCA-wood surface of pre-treatment (PT) dry and wet, and post cleaning using three methods: (1) applying tap water for 15 min followed by pressure wash (water/PW), (2) applying 1:2 bleach:water solution for 15 min and followed by either pressure wash (bleach/PW) or (3) scrubbing and rinsing (bleach/scrub). Error bars represent mean plus standard deviation (n = 3–6).

4.3. Elevated CrVI was observed in leachates

In addition to Cr speciation in dislodgeable Cr from CCA-wood, we also determined CrVI concentrations in leachates after cleaning using the three methods. Even though bleach plus pressure washing increased the amount of dislodgeable As and Cr and induced CrIII oxidation to CrVI, CrVI was largely removed from the wood surface by pressure washing, which was detected in the leachate. For example, total Cr concentrations in leachate from CCA-wood cleaned by bleach/PW and bleach/scrub method were 369 and 569 μg/L, with 27–30% being CrVI at 110 and 170 μg/L (Fig. 2). The data indicated that bleach induced a substantial oxidation of CrIII to CrVI during cleaning. Leachate CrVI concentrations were up to17 times higher than the 10 μg/L MCL established by California EPA in 2014. Elevated CrVI in leachate during cleaning could also pose a health risk to people from dermal contact or inhalation of aerosolized leachate. However, CrVI concentrations would vary depending on the amount of water used during cleaning.

Changes in Cr speciation in unfiltered leachates (pH 6.5–6.9) from the bleach/scrub method showed that CrVI concentrations either stabilized or declined over a period of 11 d as CrVI reduction to CrIII occurred (Fig. 3). However, the CrVI concentration in leachate from sample D continued to increase, reaching 832 μg/L after 11 d. Taylor et al. (2001) reported that bleach containing sodium hypochlorite (NaClO) and sodium percarbonate ($Na_2CO_3 \cdot 1.5H_2O_2$) resulted in accelerated Cr leaching from CCA-wood, with up to 62% being CrVI. Maas et al. (2002) tested the effect of three wood cleaning products on CrVI formation in leachate from 8.5-year old CCA-wood, showing disodium peroxydicarbonate ($C_2Na_2O_6$) and NaClO producing up to 160 μg/L CrVI.

Initial concentrations of CrVI in leachates in our study were comparable to those reported by Maas et al. (2002), yet the possibility of increasing CrVI concentrations in leachates over time could lead to higher than expected risk from CrVI (Fig. 3). Leachate generated during wood cleaning can contaminate adjacent soil. Song et al. (2006) evaluated CrVI reduction in soil and they found up to 50% of CrVI remains in the soil after 11 months. This illustrates the potential for human exposure to CrVI in soil contaminated by leachate from cleaning CCA-wood with a bleach solution.

4.4. Elevated As in leachates and residues

In addition to Cr, we also determined As concentration in the leachates, which varied with cleaning methods. Total As in leachate solutions increased from 104 μg/L in the water/PW method to 306 μg/L in bleach/scrub method and 351 μg/L in bleach/PW method (data not shown). Maas et al. (2002) reported As levels of 364–1414 μg/L in leachate after cleaning 8.5-year old CCA-wood with bleach-based cleaning solutions. Before analyzing As concentration in the leachate, the solution was filtered to remove residues, which were digested and analyzed. Most of the As leached from the wood surface by cleaning ended up in the residues (Fig. 4A). The amount of As in residues varied with cleaning methods and were 350 ± 80 μg/100 cm^2 with the water/PW method and 870 ± 312 μg/100 cm^2 with the bleach/PW method. The bleach/scrub method produced the highest amount at 1301 ± 891 μg/100 cm^2. The use of bleach with pressure washing resulted in the mobilization of significantly more As than tap water alone. The use of bleach with moderate scrubbing was highly effective at removing As-enriched residue, although amounts varied depending on how much grime was present prior to cleaning.

The total amount of As removed from the wood surface by each method was calculated by adding the amount in the leachate to the residue per 100 cm^2 wood (Fig. 4A). The amount of As released into soil under a hypothetical 18.6 m^2 deck from cleaning was 699 ± 78 mg from water/PW method, 1778 ± 300 mg from the bleach/PW method and 2473 ± 892 mg with the bleach/scrub method. The 18.6 m^2 deck

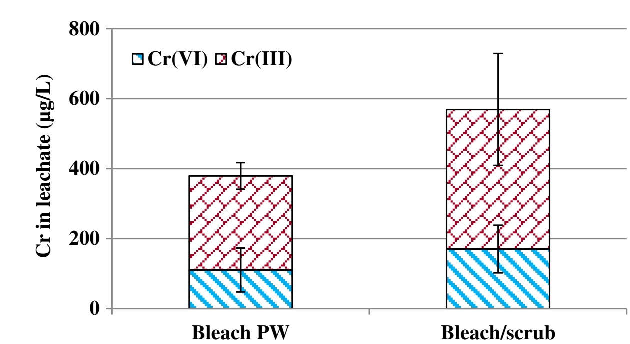

Fig. 2. CrIII and CrVI concentrations in leachates from cleaning CCA-wood with bleach solution followed by either pressure washing (bleach/PW) or scrubbing and low pressure rinsing (bleach/scrub).

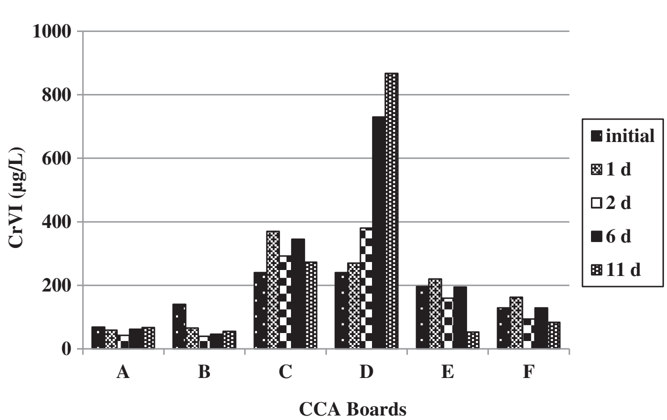

Fig. 3. Changes in CrVI concentrations in unfiltered leachates over an 11-d period from six pieces of CCA-wood that were cleaned using the bleach/scrub method.

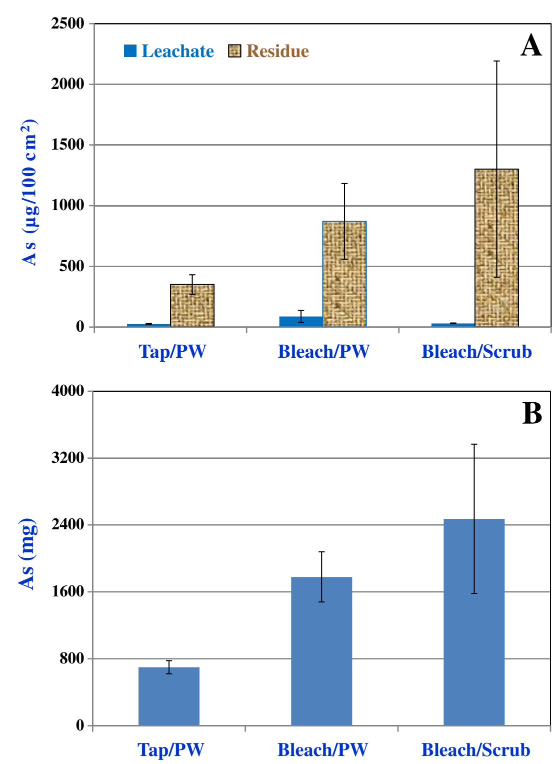

Fig. 4. Arsenic released from CCA-wood surface in residue and leachate (A) and amounts of As entering soil under 18.6 m^2 deck (B) after different cleaning methods including applying tap water for 15 min followed by pressure washing (water/PW), applying 1:2 bleach:water solution for 15 min followed by pressure washing (bleach/PW) or scrubbing after applying the bleach:water solution (bleach/scrub). Error bars represent mean plus standard deviation (n = 3–6).

Table 1
Estimated As doses in children playing on wet CCA-wood deck for 1 h as compared to estimated daily doses from dietary intake and USEPA reference dose.

Child ages	As dose from uncleaned wet deck (μg/kg)	As dose from post-bleach/pressure wash (μg/kg)[a]	Children's dietary intake (EFSA, 2014) (μg/kg/d)	USEPA As reference dose (μg/kg/d)
1–2	0.38	0.60	0.20–1.37	0.30
2–3	0.31	0.50		
3–6	0.23	0.37		

[a] 1:2 bleach:water solution was applied to CCA-wood for 15 min and followed by pressure wash (bleach/PW).

is the average size in the US. Assuming even distribution in the top 5 cm of soil, the leached As would elevate soil As concentrations by 0.28, 0.73 and 1.0 mg/kg after one cleaning (Fig. 4B).

The wood used in this study came from one source and was uniformly weathered. Hasan et al. (2010) evaluated the leaching behavior of CCA-wood under field conditions typical of south Florida with annual rainfall of 176 cm, showing that >8700 mg of As was expected to leach annually from a 18.6 m^2 14-year old CCA-wood structure. In our study, the use of bleach to clean aged CCA-wood resulted in As release that was >20% of the annual amount from normal weathering based on Hasan et al. (2010) under a hypothetical 18.6 m^2 deck.

4.5. Children's exposure to As and CrVI

The highest risk of dermal exposure to dislodgeable As and CrVI occurs during and immediately after cleaning wood with bleach. Ingestion of soil contaminated with As and CrVI can also occur during and after cleaning. Children playing on and around such wood surfaces are vulnerable to these exposures.

Concern that children are already exposed to As levels associated with health effects through diet has pressured the US Food and Drug Administration to establish risk-based guidelines. The occasional increased exposure to As from cleaning CCA-wood with bleach is unlikely to significantly alter the overall cancer risk associated with living in a house with a CCA-deck but could result in a higher-than-usual daily dose of As. Comparative As dose estimations of children in different age groups were calculated (Eq. 1), with the dislodgeable As on uncleaned wet wood being 55.5 μg/100 cm^2 and cleaned wood being 90.7 μg/100 cm^2 using the bleach/PW method (data not shown). These were compared to daily dose estimations through dietary intake by the European Food Safety Authority (EFSA) in 2009 and 2014 (0.20 − 1.37 μg/kg/d) and the USEPA reference dose (0.30 μg/kg/d) (Table 1). The doses for uncleaned wet deck were 0.23 to 0.38 μg/kg compared to 0.37 to 0.60 μg/kg for cleaned deck using the bleach/PW method (Table 1). These conservative estimates showed that children who play on a wet or recently cleaned CCA-wood for 1 h could experience As exposure doses above the As reference dose of 0.30 μg/kg/d. This represents an additional As exposure pathway for children living in homes with CCA-wood decks.

5. Conclusion

Environmental impacts from CCA-wood are well-documented, however concern about human exposure to As from contact with CCA-wood diminished after its withdrawal from residential use in 2004. Assessments of potential health risks to children from contact with CCA-wood playsets and decks identify the amount of dislodgeable As on the wood surface, frequency of contact with CCA-wood, and climate to be influential variables when estimating exposure doses (Zartarian et al., 2006; Xue et al., 2006). In this study, the amounts of dislodgeable As were 3–4 times higher on wet wood than on dry wood, with exposure dose estimates in children after only 1 h of contact with moist CCA-wood close to or higher than USEPA's reference dose for inorganic As of 0.30 μg/kg/d. Actual exposure doses could be higher since only 7% of the dislodgeable As on the wipe samples was used to estimate the dislodgeable As on children's hands (Shibata, 2006). Other factors that could lead to higher exposure doses in children include eating while playing on the deck and dermal absorption after skin contact with wet wood surface.

Recognition that using bleach on CCA-wood promotes leaching and formation of CrVI occurred over a decade ago. Our study confirmed the oxidation of CrIII to toxic and mobile CrVI during bleach-based cleaning. The use of bleach to clean CCA-wood poses a potential risk of contamination to soil and increases human exposures to As and CrVI. With increasing awareness of the need to reduce exposure to As and CrVI, using bleach-based cleaning solutions on CCA-wood is inadvisable.

Acknowledgment

This research was supported in part by the University of Florida and Hinkley Center for Solid and Hazardous Waste Management. L.M. De Oliveira also received a scholarship (185313-9) from the CAPES (Brazilian Government Organization).

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