Assessing and Managing Exposure from Arsenic in CCA-Treated Wood Play Structures

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ABSTRACT

Background: Chromated copper arsenate (CCA)-treated wood has been widely used for outdoor play structures. There is a growing scientific concern about children's exposure to the arsenic that leaches from these structures. The purpose of this study was to measure arsenic from CCA-treated wood play structures owned by the City of Toronto to guide an appropriate exposure reduction strategy.

Methods: In the fall of 2002, 4 soil and 2 wood surface samples (dislodgeable arsenic) were collected from 217 play structures and analyzed for total arsenic content. Soil arsenic concentrations were compared to the federal soil guideline of 12 µg/g. Dislodgeable arsenic concentrations were compared to a Toronto Public Health-derived interim action level of 100 µg/100 cm^2.

Results: Soil arsenic levels in samples taken from within one metre of CCA-treated wood were low (mean 2.1; range 0.5-10 µg/g). However, the means of the arsenic level in the composite soil samples taken from beneath an elevated platform were significantly greater ($p<0.01$) than the background soil sample and soil from within one metre of the CCA-treated wood (mean 20.3; range 12.4-47.5 µg/g). Composite soil samples exceeded the federal soil guideline of 12 µg/g at 32 play structures. Dislodgeable arsenic values varied widely (mean 41.9 µg/100 cm^2; non-detectable to 521.5 µg/100 cm^2). 32 play structures had dislodgeable arsenic levels that exceeded the interim action level. Mean arsenic concentrations on vertical surfaces were significantly higher than on horizontal surfaces ($p<0.01$).

Discussion: Our soil analysis indicates that arsenic does not migrate laterally but accumulates under elevated platforms at levels that can exceed the soil guideline. Dislodgeable arsenic values varied greatly and were not a useful predictor of soil arsenic ($R^2 = 0.0015$).

La traduction du résumé se trouve à la fin de l'article.

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Acknowledgements: The authors gratefully acknowledge the assistance and support of the following staff in Toronto Public Health and Parks and Recreation: Dr. Fran Scott, Dr. Karl Kabasele, Elizabeth MacDougall, Karen Clark, Carol Cormier, Jamie Warren, and John Macintyre.

Young children in routine contact (~130 days/year) with pressure-treated wood containing arsenic may be at increased long-term health risk from exposure to inorganic arsenic.[1] Pressure-treated lumber is also known as CCA-treated wood because the wood preservative chromated copper arsenate (CCA) has been applied to enhance the longevity of wood for outdoor uses. CCA is a registered pesticide that contains forms of chromium, copper and arsenic. Three types of CCA solutions are used – types A, B and C. CCA-C is most commonly used in residential applications (composed of 34% arsenic pentoxide (As_2O_5), 47.5% chromic acid (CrO_3), and 18.5% cupric oxide (CuO)).[2]

Arsenic, in its inorganic form, is a known poison that can be fatal at very high doses. At lower, chronic exposure levels, inorganic arsenic is classified as a known human carcinogen linked with increased risk of skin cancer and internal tumours of the bladder, kidney, liver and lungs.[3,4] Arsenic is also toxic to the nervous system and is linked to skin lesions and reproductive problems in humans.[5] In animals, inorganic arsenic is also toxic to the immune system.[5] The health risk to children from play structures made of CCA-treated wood is difficult to quantify because of the many exposure variables that affect the arsenic dose ingested. Arsenic exposure depends upon the degree to which arsenic leaches out of the wood and is present as dislodgeable arsenic residues on the wood surface or contaminates the base material (such as soil) below the structure. Leaching is influenced by rainfall and temperature, amount of wear on the wood surface and age of the structure.[6] The amount of time that a child is in contact with the wood and base material, the arsenic bioavailability from soil and the child's hand-to-mouth activity pattern will also influence exposure to arsenic. For example, oral bioavailability of arsenic in soil has been reported in *in vitro* studies as ranging from 3 to 50% due to decreased solubility. In contrast, more soluble forms of inorganic arsenic have been shown in humans to be up to 95% bioavailable.[5] Organic arsenicals, generally viewed as less toxic, are those widely used in agriculture and have been found to accumulate in fish and shellfish.[5]

CCA-treated wood has been widely used to construct play structures throughout

TABLE I

Summary of Arsenic Levels in Toronto Parks with CCA Play Structures

Number of Play Structures	Description	Arsenic Concentrations			
		Soil – Park Background[a] Mean (Range) - µg/g	**Soil – 1 Metre Beyond Play Structure[b]** Mean (Range) - µg/g	**Soil Below Play Structures[c]** Mean (Range) - µg/g	**Wood Surface of Play Structure[d]** Mean (Range) - µg/100 cm^2
32	Play structures exceeding Canadian federal soil guidelines[e]	3.2 (1 – 13)	4.0 (0.5 – 10)	**20.3†** **(12.4 – 47.5)**	53 (17.5 – 185)
32[g]	Play structures exceeding wood surface interim Toronto benchmark[f]	2 (0.5 – 4)	1.9 (0.5 – 10)	6 (0.5 – 22.9)	**194.9** **(105 – 521.5)**
58	Play structures exceeding soil guidelines and/or wood surface interim Toronto benchmark[e,f]	2.6 (0.5 – 13)	3 (0.5 – 10)	**12.8** **(0.5 – 47.5)**	**131** **(17.5 – 521.5)**
149	Play structures below soil guideline and wood surface interim Toronto benchmark[e,f]	2.3 (0.5 – 12)	1.8 (0.5 – 9)	3.7 (0.5 – 12)	27 (0.04 – 99.3)
217[h]	All Play Structures	2.4 (0.5 – 13)	2.11 (0.5 – 10)	6.2 (0.5 – 47.5)	41.9 (0.4 – 521.50)

(a) Based on one grab sample (range 0-30 cm; most were 0-15 cm) taken 10 metres from play structure
(b) Based on two grab samples (range 0-30 cm) taken 1 metre from play structure
(c) Based on one composite sample (0-5 cm) consisting of 10 subsamples taken from underneath an elevated platform; statistically different ($p<0.01$) from background (column #1) and grab samples (column #2)
(d) Based on 2 swab samples at each play structure (one vertical and one horizontal, where possible)
(e) Canadian Federal Soil Guidelines – 12 µg arsenic/gram soil
(f) Interim wood surface benchmark proposed by Toronto Public Health – 100 µg arsenic/100 cm^2 wood surface
(g) Six of the sites also exceeded the soil guidelines
(h) 217 (soil and/or wood surface); 207 (soil and wood surface); 9 (wood surface only); 1 (soil only)
† bolded sections denote the values that exceed the action levels.

North America, in parks, schools, child care centres and residential yards. However, with growing scientific concern about arsenic exposure, cities across North America and Europe are avoiding the use of arsenic-containing wood for constructing new play structures. Though there are no immediate risks to children's health, concern is currently focussed on the degree of long-term health risk posed by existing play structures made from CCA-treated wood, and what mitigative actions municipalities might take to lessen that risk.

In the City of Toronto (population 2.5 million), the Parks and Recreation Division has responsibility for more than 800 playgrounds, approximately 25% of which have play structures made with at least some CCA-treated wood. Department of Public Health staff worked with staff from Parks and Recreation to assess the exposure and potential health risk from arsenic in these playgrounds. The purpose of this study was to measure arsenic on the surface of the play structures and in the material below each structure (soil), and to use this information to guide development of an exposure reduction and risk management strategy.

METHODS

In the fall of 2002, the City tested for total inorganic arsenic at the 217 City-owned parks and child care centres containing play structures constructed with CCA-treated wood. Of these, 209 structures were in parks and 8 were in City-owned child care centres. A consulting firm was retained to collect the samples and arrange for arsenic analysis.

Four soil samples were collected at each site. Consistent with the Ontario Ministry of Environment recommendations for sampling at contaminated sites, one composite sample, consisting of 10 surface subsamples (0-5 cm depth), was taken under an elevated portion of the play structure within a 2-metre radius.[7] A composite sample is obtained by combining material from two or more spatially separated locations to obtain a better representative sample of the specific layer and area of interest. In order to assess lateral leaching, two grab soil samples were taken within a 1-metre radius of any piece of CCA-treated wood (0-30 cm depth). One grab control sample (range 0-30 cm depth; most samples were 0-15 cm) was taken from a minimum of 10 metres from each play structure (remaining within the park boundary). The control samples enabled assessment of background arsenic levels.

In addition to soil samples, two wood surface swab samples were collected from each play structure in areas of the structure where a child's exposure to arsenic by contact was most likely. The sample handling procedures are detailed in the consultant's report.[8]

It is clear from review of field studies of existing structures that several methods have been employed to assess leaching from the wood. A recent study by the U.S. Consumer Product Safety Commission (U.S. CPSC)[1] concluded that swab sampling protocols can be reliably used and was the method chosen by Health Canada researchers to ensure comparability with other studies testing existing playground equipment in similar climatic conditions.[9]

All sample analyses were done by a Standards Council of Canada accredited laboratory using Method Reference EPA 7000 (Graphic Furnace AA Metals). The method detection limit (MDL) was 1.0 µg/g for soil samples. The MDL for the wood surface arsenic samples varied from 1 to 3 µg/g (converted to 0.08-0.25 µg/100 cm^2). For the purposes of statistical analyses, the MDL was assumed for the non-detectable samples.

Toronto Public Health selected two benchmarks with which to compare the arsenic levels in the soil and in the swab samples. For the soil samples, arsenic levels were compared to the federal soil guideline of 12 µg/g from the Canadian Council of Ministers of the Environment (CCME)[10] because it is the most health-protective. For the wood surface samples, in the absence of a provincial or federal guideline for dislodgeable arsenic, Toronto Public Health used an interim action level of 100 µg/100 cm^2 determined by comparison to maximum wood surface residue values from available Canadian studies.

The statistical tests included: a) comparing the soil arsenic concentrations present in background, play area and areas beneath

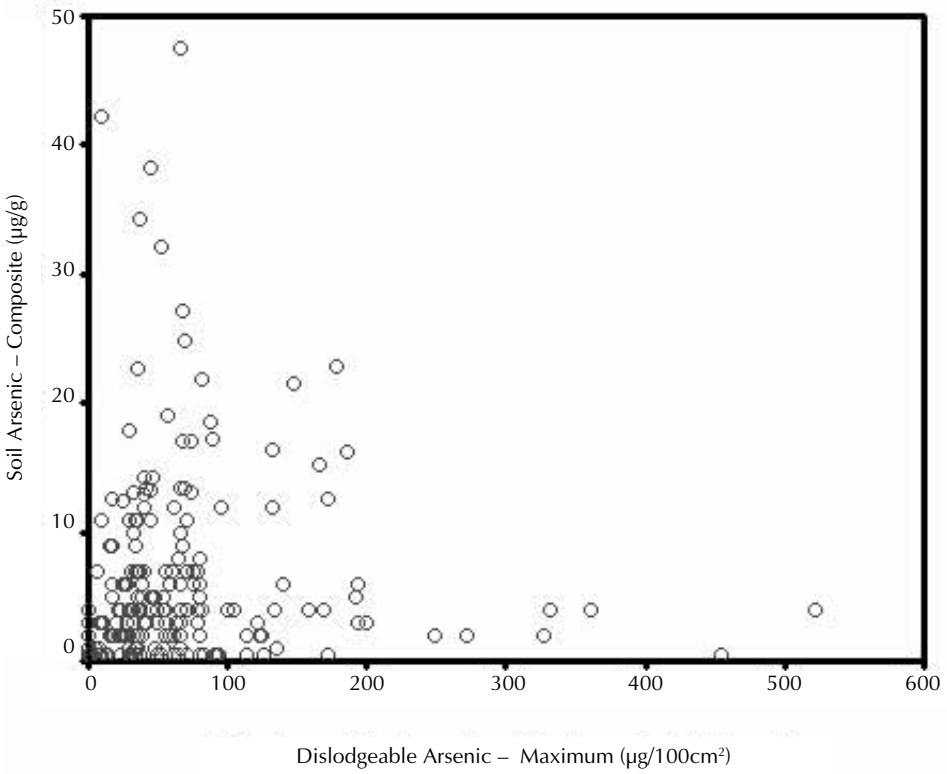

Figure 1. Maximum observed dislodgeable arsenic versus soil arsenic

elevated platform, b) assessing the correlation between the composite soil samples and the dislodgeable arsenic; and c) analyzing the differences in the means between dislodgeable arsenic samples taken on horizontal and vertical wood surfaces. Statistical Package for Social Scientists (version 11.5) was used to conduct the statistical tests (SPSS Inc., Chicago, Illinois).

The exposure reduction strategy consisted of soil removal and replacement, treating the wood with a sealant and developing education materials to advise the general public on individual exposure reduction measures.[11] The development of the strategy was informed by: a) the availability of regulatory standards/guidelines, b) the cost of soil remediation, c) availability, efficacy and cost of sealing the wood, and d) the relative cost of remediation and sealing versus replacing a structure through the capital replacement program.

RESULTS

Table I summarizes the arsenic results from Toronto parks and City-owned child care centres. The background arsenic level observed (mean 2.4; range 0.5-13 µg/g) was well below the Ontario Ministry of Environment (OMOE) 98th percentile for samples taken from old urban parkland – 17.0 µg/g.[12]

Arsenic levels in the composite soil samples taken from underneath an elevated platform (mean 6.2, range 0.5-47.5 µg/g) were significantly greater than both background samples and samples from within 1 metre of the play structure ($p<0.01$).

The arsenic level in the 1-metre area around play structures was also very low (mean 2.1; range 0.5-10 µg/g). The levels were no higher than background levels ($p=0.06$), indicating that arsenic did not leach laterally from the play structure and its supporting posts.

Dislodgeable arsenic measured at the play structures varied widely (non-detectable to 521.5 µg/100 cm^2) with a mean value of 41.9 µg/100cm^2. These findings are within the range of values from currently available, methodologically comparable studies and demonstrate similar overall variability in dislodgeable arsenic measures.[2] The average dislodgeable arsenic concentration calculated for all play structures differed significantly for horizontal and vertical wood surfaces (30.48 compared to 55.4 µg/100 cm^2; $p<0.01$).

It was determined that 32 of the 217 (~15%) play structures in parks and daycares had arsenic levels in the soil that exceeded the federal soil guideline. None of the City-owned day care centres exceeded the guideline. At all 32 sites, exceedances were observed in the composite soil samples taken from beneath an elevated platform. In addition, one location had a background soil sample that exceeded the soil guideline. It was determined that 6 of the 32 (19%) play structures also had dislodgeable arsenic levels that exceeded the interim action level. A further 26 sites exceeded the interim action level for dislodgeable arsenic alone.

The dislodgeable arsenic concentrations were highly variable at individual play structures. The highest value observed at each individual play structure was used for comparison to the interim action level. It is interesting to note that mean dislodgeable arsenic levels (195 µg/100 cm^2) for the sites that did not exceed soil guidelines were much higher than the mean dislodgeable arsenic levels (53 µg/100 cm^2) for sites that did exceed soil guidelines. A scatterplot of the maximum dislodgeable arsenic value observed at each structure and the soil arsenic in the composite sample, Figure 1, illustrates the lack of a linear relationship between the two variables ($R^2 = 0.0015$; $p>0.05$).

DISCUSSION

The presence of arsenic in City-owned play structures constructed using CCA-treated wood presents a significant challenge to municipalities. The lack of standards for dislodgeable arsenic on the wood surface as well as the lack of a standardized sampling protocol for dislodgeable arsenic complicates the assessment and determination of an appropriate risk reduction strategy.

The Toronto study sought to identify play structures and sites that posed an elevated risk of exposure to arsenic and thereby were targeted for remediation. Remediation options considered, in order of increasing cost, included: sealing on a regular basis; replacement of soil below the play structure; and accelerated replacement with an arsenic-free structure.

This study did not attempt to quantify a child's exposure dose or the potential long-term health impacts from routine use of CCA-treated wood play structures in Toronto. It is not possible at present to accurately quantify how much of the

arsenic transferred to a child's hand will be ingested and how much is bioavailable. The U.S. Environmental Protection Agency (EPA) draft probabilistic risk assessment for children coming in contact with CCA-treated wood play structures and decks, released in November 2003,[13] attempts to quantify the health impacts. The risks from dislodgeable arsenic exposure are estimated to be, on average, 7-fold greater than the risks resulting from soil exposure.[14] This assessment supports previous work[9] that estimated that the most significant exposure route is ingestion of dislodgeable arsenic via hand to mouth contact.

The Toronto study found that surface soil below elevated platforms of some CCA-treated wood play structures were above the federal soil guideline. Levels of arsenic below the soil surface in the 1-metre radius around the play structures and 10 metres away were, however, generally very low indicating insignificant lateral migration. Through soil and wood surface testing, it was determined that only about 25% (58 of 217) of sites with CCA-treated wood play structures required some form of remediation.

For the 58 sites requiring remediation, 32 sites were identified for soil replacement because soil guidelines were exceeded. The play structures at these locations will also be sealed to minimize arsenic leaching from the structure. In addition, another 26 play structures will be sealed (only) because the dislodgeable arsenic values exceeded the Toronto Public Health interim action level but not the soil guideline.

The sealant chosen for use was polyurethane (brand name Varathane®), based on US recommendations of the U.S. Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) Scientific Advisory Panel report that indicated the highest confidence in polyurethane – 70 to >95% reduction in dislodgeable arsenic.[15]

The current City of Toronto's application frequency, informed by current recommendations and research, is between 1 to 2 years.[15] The play structure maintenance program includes monitoring sealant integrity and identifying play structures for sealant reapplication, where weathering is apparent. Application frequency continues to be investigated by the U.S. CPSC and the U.S. EPA and as new information becomes available, the City policy will be reviewed. The City's remediation plan also includes annual testing of those sites remediated and those that were within 10% of the soil and surface action levels.

Arsenic exceedances in soil were a poor predictor of elevated arsenic levels on the wood surface and vice versa. The levels of arsenic in base material are, in part, a function of dislodgeable arsenic and it is expected that arsenic availability decreases with age of a structure and extent of its exposure to rainfall.[6] Available research indicates that many factors can affect both the rate of leaching (including factors during the preservation process itself) and the mobility of arsenic in soil (including soil composition and organic content).[16] The complex nature of surface leaching and soil mobility of arsenic from in-service structures makes it difficult to accurately predict the amounts available for exposure. However, it is reasonable to assume that there is a finite amount of arsenic that migrates from the wood to the soil.

This study reveals that relying on soil testing alone to develop a remediation strategy may not fully protect children's health and reinforces the need for a health-based action level for dislodgeable arsenic on wood to assist municipalities in prioritizing play structures in need of remediation. While CCA-treated wood play structures are but one source of inorganic arsenic in the environment, they present an exposure route that is amenable to mitigation through testing and targeted remedial action. The U.S. EPA and Health Canada's Pest Management Regulatory Agency concur that reducing exposure to arsenic is desirable.[17]

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RÉSUMÉ

Contexte : Le bois traité à l'arséniate de cuivre chromaté (ACC) a été largement utilisé dans la construction des structures de terrain de jeux. Or, l'exposition des enfants à l'arsenic qui fuit lentement de ces structures suscite de plus en plus de craintes dans les milieux scientifiques. Dans cette étude, nous avons cherché à mesurer l'arsenic provenant des structures de jeux en bois traitées à l'ACC appartenant à la Ville de Toronto afin d'orienter une stratégie pertinente de réduction de l'exposition.

Méthode : À l'automne 2002, nous avons prélevé quatre échantillons de sol et deux échantillons à la surface du bois (arsenic à faible adhérence) provenant de 217 structures de jeux et nous en avons mesuré la teneur totale en arsenic. Les concentrations d'arsenic dans le sol ont été comparées aux lignes directrices fédérales, qui prévoient une teneur maximale de 12 µg/g dans le sol. Les concentrations d'arsenic à faible adhérence ont été comparées au seuil d'intervention de 100 µg/100 cm^2 fixé à titre provisoire par le Service de santé publique de Toronto.

Résultats : Les niveaux d'arsenic détectés dans les échantillons de sol prélevés à moins d'un mètre de distance du bois traité à l'ACC étaient faibles (moyenne : 2,1; intervalle : 0,5-10 µg/g). Par contre, les niveaux moyens d'arsenic détectés dans des échantillons de sol composites prélevés sous des plates-formes aériennes étaient sensiblement plus élevés ($p<0,01$) que dans les échantillons du sol environnant et du sol situé à moins d'un mètre du bois traité à l'ACC (moyenne : 20,3; intervalle : 12,4-47,5 µg/g). Dans 32 des structures de jeux, la teneur en arsenic des échantillons de sol composites dépassait les lignes directrices fédérales de 12 µg/g pour le sol. La teneur en arsenic à faible adhérence variait considérablement (moyenne : 41,9 µg/100 cm^2; intervalle : non-décelable à 521,5 µg/100 cm^2). Ces 32 structures de jeux présentaient des niveaux d'arsenic à faible adhérence qui dépassaient le seuil d'intervention provisoire. La concentration moyenne d'arsenic sur les surfaces verticales était sensiblement plus élevée que sur les surfaces horizontales ($p<0,01$).

Discussion : D'après notre analyse des sols, l'arsenic ne fuit pas latéralement, mais s'accumule sous les plates-formes aériennes à des niveaux pouvant dépasser les lignes directrices pour le sol. La teneur en arsenic à faible adhérence varie beaucoup et n'est pas un prédicteur utile de l'arsenic dans le sol ($R^2=0,0015$).

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Received: June 19, 2003
Accepted: May 14, 2004