HEALTH CONSIDERATIONS RELATED TO ARSENIC IN SOIL UNDER PLAYGROUND EQUIPMENT CONSTRUCTED OF CCA-TREATED WOOD

Prepared for:

Hopping Green Sams & Smith
Tallahassee, FL

and

American Wood Preservers Institute
Fairfax, VA

Prepared by:

Hazardous Substance & Waste Management Research, Inc.
Tallahassee, Florida

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1. OVERVIEW

Recent discussions in Florida and elsewhere have raised questions concerning the potential health significance of arsenic that is found in wood which has been treated with chromated copper arsenate, or CCA. This focused report addresses the question of the potential significance of arsenic residues which may be found in soil beneath playground equipment that was constructed with CCA-treated wood, by determining health-based values against which appropriate soil samples can be compared. There are a number of potentially applicable scenarios that could be developed; however, this report describes a reasonable and protective comparison for playground soils. Arsenic may be identified in such soils as a consequence of washoff or abrasion from the treated wood used in the construction of the playground equipment (AWPI, 1995; Stilwell and Gorny, 1997; Stilwell, 1998; Rhodes, 2000), though the levels that have been reported vary widely. It is not clear to what extent this variability may be a function of several factors including, sampling techniques (i.e., depth and location of samples), analytical techniques, soil types, or other factors such as method or construction of the playground equipment, age, and maintenance history.

2. NATURAL OCCURRENCE AND BACKGROUND CONCENTRATIONS OF ARSENIC

Arsenic is a naturally occurring element. Pure arsenic is a gray metal-like material (e.g., solid) that is usually found in the environment combined with other elements such as oxygen and sulfur. Arsenic is ubiquitous in nature and is found in detectable amounts in nearly all soils and in many rocks and minerals. The arsenic content of most rocks and minerals is similar to that found in soils, except for sulfide ores, sedimentary iron ores, manganese ores and phosphate rock which may contain as much as hundreds to thousands of parts per million arsenic. Phosphate deposits, which are a common and an important commercial resource in Florida, exhibit 10 to 40 ppm arsenic (NAS, 1979). Coal over the U.S. typically contains on the order of 0.05 – 5 ppm arsenic (NCRDS, 2000) with other reports as high as 25 ppm of arsenic (Walsh and Keeney, 1975). The units of parts per million (ppm) are equivalent to milligrams per kilograms (mg/kg). Similarly, units of parts per billion (ppb) are equivalent to micrograms per kilogram (ug/kg).

Because arsenic is a natural component of the environment, varying levels of arsenic are present in soil, water, food and air, as well as many common products available to and used by the general public, including fertilizers, pesticides, and some types of tobacco products. As the 20th most abundant element in the Earth's crust, arsenic has been detected in virtually all foods that have been evaluated (NAS, 1977). The typical concentrations of arsenic in major food items are up to 0.1 ug/kg (e.g., 0.1 part per billion, or ppb; Nraigu and Azcue, 1990). Estimated daily dietary intake of inorganic arsenic in the general U.S. population ranges from 8.3 ug/day to about 50 ug/day in the United States (Yost et al., 1998; Adams et al., 1994; ATSDR, 2000). Mean levels of arsenic in ambient air in the U.S. have been reported to range from <1 to 3 ng/m^3 in remote areas and from 20 to 30 ng/m^3 in urban areas (ATSDR, 2000). Surveys of arsenic concentrations in rivers and lakes indicate that most values are below 10 ug/L, although individual samples may range up to 1,000 ug/L (ATSDR, 2000). Arsenic levels in groundwater average about 1-2 ug/L, although levels up to 3,400 ug/L have been observed in some western states which have volcanic rock and sulfidic mineral deposits which are high in arsenic (ATSDR, 2000). Thus, people typically take in arsenic in the air they breathe, the water they drink, and the food they eat to varying degrees (ATSDR, 2000).

Inorganic arsenic comprises approximately 20 to 40% of total dietary arsenic intake, and arsenic in food exhibits a range of bioavailability (Yost et al., 1998). Based upon the Food and Drug Administration (FDA) Total Diet Study (FDA, 1993; Adams et al., 1994) and the more recent report on the FDA Total Diet Study (Tao and Bolger, 1998), food accounts for about 93% of the total arsenic exposure for most people, with water, air, and soil making additional contributions. These reports also suggest that 90% of the 93% of the total dietary arsenic is contributed by seafood. The Tao and Bolger study (1998) suggests that approximately 10% of the arsenic in seafood is inorganic and that 100% of the arsenic in the rest of the food items is inorganic. Foods sampled by the Canadian Ministry of the Environment indicate that inorganic arsenic comprises most of the arsenic found in meats (75%), poultry (65%), dairy products (75%) and cereals (65%). Organic forms predominate in fruits, vegetables and fish/seafood with inorganic arsenic contributing 10%, 5% and 0-10%, respectively (Borum and Abernathy, 1994).

Arsenic is found naturally in surface soil to varying degrees across the state of Florida as a result of natural soil composition as well as human activities. Industrial, commercial, and agricultural activities have gradually introduced additional arsenic into the environment, resulting in moderately elevated arsenic concentrations in soil in some locations. Nationwide, background arsenic concentrations in soil range from about 1 to 40 ppm, with a mean value of about 5 ppm (ATSDR, 2000). Soils overlying arsenic-rich geologic deposits in some areas of the U.S., such as sulfide ores, may have soil concentrations as much as two orders of magnitude higher, on the order of 100 mg/kg or more (ATSDR, 2000).

The geometric mean concentration of arsenic in 40 Florida soil profiles (94 samples) was 1.1 mg/kg, which is lower than the reported average of U.S. soils (Ma et al., 1999). However, review of this and related reports by the same authors (Ma et al., 1997; Chen et al., 1999) have raised some serious concerns regarding statistical issues and interpretation of the data. Without confidence in the correctness of the computed descriptive statistics for the background soil studies, it is difficult to confirm the validity of the conclusions. For example, one of the major apparent flaws in the document is the sequential effect of excluding data at several steps. This exclusion has the eventual effect of artificially defining background against which the presumably “affected” soil data are compared. In this study, a total of 210 samples were randomly selected from a pool of 448 samples collected from 51 counties in Florida. Statistical conclusions drawn based on these random samples chosen from the 51 counties are heavily dependent on whether the 16 excluded counties were randomly deleted. These points are not clarified in the report.

3. CHARACTERISTICS OF ORGANIC & INORGANIC ARSENIC

Arsenic combined with elements such as oxygen and sulfur is termed "inorganic" arsenic. Arsenic combined with carbon and hydrogen is termed "organic" arsenic. Inorganic arsenic occurs naturally in many kinds of rock, especially in ores that also contain other metals such as copper or lead. When these ores are heated to release or extract the copper or lead, much of the arsenic enters the air as a fine dust and is collected at the smelter and is purified. One major use of the collected arsenic is for use as a preservative for wood products, in combination with copper and chromium, to make the wood resistant to rotting and decay (ATSDR, 2000).

Soluble forms of inorganic arsenic, whether naturally occurring or introduced anthropogenically, usually exists as either arsenate (As^{5+}) or arsenite (As^{3+}; ATSDR, 2000). Arsenic sulfides exhibit low solubility and, thus, may limit transport and availability. However, concentrations of arsenic detected in environmental media are generally reported as "total" arsenic (i.e., without regard to speciation; U.S. EPA, 1983; U.S. EPA, 1986a; U.S. EPA, 1986b). The literature generally shows that arsenites are somewhat more acutely toxic than arsenates (ATSDR, 2000). In addition, once absorbed, both arsenate or arsenite can be converted to the other valence state in varying degrees, which confounds the toxicological distinction between the two species (ATSDR, 2000).

Studies of organic arsenicals in animals have demonstrated a fairly low order of toxicity, which has been further demonstrated in humans. The organic forms of arsenic found in food, particularly fish, present little or no hazard to human health (Adams et al., 1994). A recent unpublished review indicates that, although organic and inorganic forms of arsenic may be toxicologically distinct, it is not straightforward to measure the different arsenic forms as separate entities in soil at a site. The estimated risk attributable to the separate arsenic forms at a site would be relevant only for contemporary exposures, not for future exposure conditions. It is suggested that hypothetical conversion of organoarsenicals to inorganic forms over weeks or months could change organic and inorganic arsenic concentrations, altering the attendant risks (Tonner-Navarro et al., 1998). It is difficult to extrapolate to projected transformation rates in the environment, absent empirical data. In the case of environmental arsenic whose origin is CCA-treated wood, the form is inorganic; thus, the organic/inorganic toxicity comparison is less relevant.

4. HUMAN HEALTH

For this report, potential oral, dermal and inhalation exposure to arsenic which may be found in soil under playground equipment constructed of CCA-treated wood was considered. Hand-to-mouth exposure from touching the wood is another potential exposure pathway. The hand-to-mouth exposure scenario is considered in a separate evaluation. For purposes of clarity, the discussion concerning potential carcinogenic effects is presented separately from the discussion concerning potential noncarcinogenic effects in this section.

It is assumed for this case that the playground equipment of interest was constructed with wood, which was treated with CCA and was not coated or "sealed" with a water repellent surface sealing agent. The potential for exposure to soil under the playground equipment was considered. Contemporary literature does not offer any explicit data from which to develop specific assumptions such as the frequency of exposure for a playground soil scenario; however, for purposes of this report a reasonable case was developed to reflect protective conditions of potential exposure.

In this document, the linear slope factor has been used for assessing the potential carcinogenic effects of arsenic. This is a very conservative assumption. The U.S. EPA Expert Panel on Arsenic Carcinogenicity (U.S. EPA, 1997c) concluded that there is a sufficient body of evidence to support the use of a nonlinear or threshold model in describing the relationship between arsenic and skin cancer and that there is no evidence that arsenic acts as a direct carcinogen. According to the Panel, the possibility that arsenic is an essential dietary component also supports the hypothesis that low dose exposures do not pose a carcinogenic hazard to humans. In addition, some reports from animal studies have suggested that there is a threshold for arsenic methylation, which would imply that the dose-response curve for arsenic-induced cancer is sublinear at low doses (e.g., produces lower rates of cancer than would be predicted by a linear dose response). In concluding that the dose-response curve is probably nonlinear, the Panel reasoned that there is some low dose at which arsenic is probably safe, although that level is unidentified at present. For that reason, the calculations presented in this document address both potential carcinogenic effects of arsenic, based upon the U.S. EPA Cancer Slope Factor (CSF), <u>and</u> potential noncarcinogenic effects, based upon the U.S EPA Reference Dose (RfD).

4a. Noncarcinogenic effects

Human health considerations for potential noncarcinogenic effects related to arsenic in this report are based on a child visitor scenario using a minor derivation of the default case (age 2-6 years; 5 years) which is used by environmental agencies for residential applications. The minor modification reflects the likelihood that children <2 years of age would not regularly be in contact with or underneath wooden playground equipment. Children typically are assumed to be at greater risk for non-cancer health effects as a result of their greater reported soil ingestion rate combined with their lower body weight. Therefore, systemic effects (i.e., non-carcinogenic risks) were evaluated for a young child visitor.

A realistic site-specific condition was developed based on an assumption that the playground equipment constructed of CCA-treated wood has been in place for a period on the order of a few years, sufficient to affect soil concentrations of arsenic if that is going to occur. It is also reasonable to assume a common playground age range for a child visitor (assumed 2 through 6 years old). Appropriate input parameters [e.g., body weight (BW) and surface area (SA)] for the site-specific child visitor scenario were based on the data presented in the U.S. EPA Exposure Factors Handbook (U.S. EPA, 1997a).

It was assumed that a young child visitor would have access to and may have direct contact with soil (oral, dermal, and inhalation exposure routes) under the playground equipment for 3 days/week, year round or 150 days/year (3 days/week for 50 weeks/year) for the full 5 year period (2 through 6 years of age). In addition, it was assumed that the child visitor soil ingestion rate was 200 mg/day, a standard upper bound assumption for young childhood. This factor clearly depends on the texture of any material which may be covering the soil underneath the playground equipment. Coarse material such as sand or wood chips would likely be brushed off rather than adhering to skin and being ingested, rendering the 200 mg/day assumptions quite conservative. It is worth noting that in other evaluations, for example, the study of Carlson-Lynch and Smith (1998), a soil ingestion rate of 100 mg/day was used. If that assumption was made herein, the protective value would change in linear fashion (i.e., would be two-fold less restrictive). It also was assumed, for the young child visitor case, that the fraction contacted (FC) in the case of fully accessible playground equipment was 100% for the childhood exposure scenario. This means that the assumption is made that all of the child's soil exposure comes from soil containing arsenic.

4b. Carcinogenic effects

As noted earlier in this section of the report, substantial evidence indicates that arsenic is carcinogenic only above a threshold exposure level.

However, for purposes of this document, calculations are provided both for potential noncarcinogenic effects (Section 4a), as well as potential carcinogenic effects (Section 4b). For assessing potential carcinogenic effects, cumulative exposure may occur both as a child and as an adult for the same individual. In this situation, it is appropriate to use time-weighted values reflecting the continuum of both childhood and adult exposures. This person is termed an "aggregate visitor." In addition to the calculations for the young child visitor in a playground scenario, Exposure Equation 1 also presents exposure assumptions based on carcinogenic potential that has been attributed to arsenic for an "aggregate" visitor [assumes 5 years as a child (age 2-6)] as shown above and the remaining 25 years of the 30 year exposure duration as an adolescent or adult (age 7-31).

Exposure to an aggregate visitor was based on average exposure for contact with soil (oral, dermal, and inhalation) in all areas of the playground for 3 days/week or 150 days/year for 5 years (ages 2-6) and 1 day/week or 50 days/year for the remaining 25 years (age 7-31) giving an exposure frequency of 67 days/year. For the aggregate visitor, the fraction contacted (FC) was assumed to be 25% for the "under-deck" scenario (e.g., 100% for 5 years and 10% for the remaining 25 years). This reflects decreased exposure to older children, adolescents and adults, who are expected to have a much more varied activity pattern, and are less likely to spend appreciable time under deck structures on a regular basis. However, empirical information was not found in the literature concerning the frequency of such activities.

In addition, it was assumed that the aggregate visitor soil ingestion rate was 75 mg/day (e.g., 200 mg/day for 5 years and 50 mg/day for the remaining 25 years). It should be noted here that there is recognition that both children and adults have some level of soil ingestion on a daily basis. Thus, the quantity of soil assumed to be ingested is independent of whether it comes from a source with or without arsenic present. The dose of arsenic and, hence, the potential effects, are estimated on the basis of the EF and ED terms which represent days in which the soil is assumed to come from the contaminated source.

The inhalation rate for the aggregate visitor was calculated to be 18 m^3/day (e.g., 10 m^3/day for 5 years and 20 m^3/day for the remaining 25 years) and the fraction contacted was assumed to be 25% (e.g., 100% for 5 years and 10% for the remaining 25 years) for the aggregate visitor case. This reflects the fact that, while young children may focus their activities on playground equipment and associated soils, the older children, adolescents and adults will have a more varied activity pattern that will utilize areas of the playground unrelated to treated wood products.

4c. Bioavailability

Bioavailability of arsenic from soil also was considered in this evaluation. It is known that arsenates in soil may form insoluble compounds (e.g., calcium arsenate, formic arsenate, aluminum arsenate) which are poorly absorbed (ATSDR, 2000). Some bioavailability values found in the literature for arsenic in soils, indicated that the arsenic was 10-28% bioavailable (Freeman et al., 1993; Ruby et al., 1996). A 1996 report from U.S. EPA Region 10 indicates that the bioavailability of arsenic in soil varies from 56-111% (95% Upper Confidence Limit) with a mean of 78% (Lorenzana et al., 1996). The U.S. EPA Region 10 study was based on feeding soil, which contained arsenic to immature swine. The soil had been taken from a smelter site (Lorenzana et al., 1996). Another study reported that, based on urine arsenic excretion, the mean absolute bioavailability was 18.8±3.3% for soil administered orally to female Cynomologus monkeys (ATSDR, 2000). Due to the wide range of reported values for bioavailability (10% to 100%), a value of 25% which is near the average of the reported low range values(10%, 18.8% and 56%; average of 28%) was used for the exposure scenarios. These bioavailability values are influenced by soil type, arsenic form and other environmental factors, on which additional research currently is focused. Recent preliminary data from a University of Florida primate study indicates that oral bioavailability on the order of 25% or less occurred across a range of samples from different soils wherein the origin of the arsenic was known (Roberts, 2000).

4d. Results

Exposure Equation 1 of Attachment A to this paper presents the input parameters and the calculation of the protective target level for arsenic based on noncarcinogenic effects for the child visitor exposure scenario and carcinogenic effects for the aggregate visitor. Exposure Equation 2 of Attachment A presents the calculation of the site-specific Particulate Emission Factor (PEF) used in the inhalation component.

As presented in Exposure Equation 1 (Attachment A), the calculated protective noncarcinogenic target concentration [Hazard Index (HI) of 1.0] for arsenic in soil based on protection of a young child visitor exposed to accessible soil under playground equipment constructed of CCA-treated wood is approximately 260 mg/kg. The calculated protective target range [Upper bound risk (UBR) of 1.0E-06] for arsenic in soil under playground equipment that is built with CCA-treated wood, based on the carcinogenic assumptions for the aggregate visitor scenario was approximately 90 mg/kg.

For comparative purposes, a single published study indicated the range of arsenic concentrations found in soil under an aged playscape constructed of CCA-treated wood was 0.032 - 9.573 mg/kg with a mean of 2.964 mg/kg (Galarneau et al., 1990). Other unpublished reports have cited similar concentrations of arsenic in school playground areas (<10 mg/kg). The conditions of those studies are not well understood and no systematic study has been conducted to our knowledge.

As another point of potential comparison, the potential intake of arsenic from drinking water containing arsenic at the maximum contaminant level (MCL) of 50 ug/L was calculated. This intake value was compared with the arsenic intake associated with soil from under playground equipment which might contain arsenic at the levels calculated based on the scenarios described in this report. For a child visitor, the intake from drinking one liter of water a day would be 0.05 mg arsenic/day (e.g., 0.05 mg/L x 1 L/day). As shown in Exposure Equation 3 (Attachment A), the intake from soil containing arsenic at 260 mg/kg (e.g., the calculated protective concentration for a child) would be 0.005 mg/day, a value which is 10 times less than the intake from drinking water. For the aggregate visitor, the intake from drinking 1.83 liters of water per day (e.g., 1 liter for 5 years and 2 liters for 25 years) would be 0.09 mg arsenic/day (e.g., 0.05 mg/L x 1.83 L/day). The intake from soil under playground equipment containing 90 mg arsenic/kg (e.g., the calculated protective concentration for an adult) would be 0.000033 mg arsenic/day. This value is approximately 2,700 times less than the intake from drinking water containing arsenic at the current MCL.

U.S. EPA currently is in the process of reviewing the MCL for arsenic. A linear change in the intake calculated here would result from any modification to the MCL value. That is, if the MCL was changed to 10 ug/L, the intake from drinking water one liter of water would be 0.01 mg arsenic/day for the child visitor and 0.018 mg arsenic/day for the aggregate visitor. Both of these values based on an MCL of 10 ug/L would be greater than the intake from soil under playground equipment, as described previously.

5. SUMMARY AND CONCLUSIONS

In summary, as shown on Table 1 (Attachment B), the proposed protective values for arsenic in soil under playground equipment that is constructed of CCA-treated wood based on children playing, or based on an aggregate adolescent/adult person, were about 260 mg/kg and 90 mg/kg, respectively. This evaluation is consistent with the recent summary material from the U.S. EPA Office of Pesticide Programs which specifically stated, “the EPA reviewed the use of CCA in pressure treated wood extensively during the 1980’s and concluded that pressure treated wood did not pose unreasonable risks to children or adults, either from direct contact with the wood (e.g., as used for playgrounds and decks) or from direct contact with surrounding soil where some releases may have occurred" (U.S. EPA, 1997b). U.S. EPA also reviewed a separate study that concluded that CCA does not pose a short-term or long-term toxic hazard to children playing on playground equipment (Lee, 1990; CPSC, 1990a; CPSC, 1990b; CPSC, 2000; U.S. EPA, 1997b).

As discussed earlier, the intake of arsenic from soil under playground equipment is from 10 (child visitor) to 2,700 times (adult; aggregate visitor) lower than the intake of arsenic from consumption of water at the current MCL of 50 ug/liter. Thus, additional incremental intake that may be contributed by incidental ingestion in association with soils under playground equipment would be a small contribution to total intake. Values presented in this report are not meant to be precise comparisons, but rather serve to illustrate that protective values typically are far above those reported to be present.

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7. ATTACHMENTS

ATTACHMENT A

Exposure Equations

Exposure Equation 1

Calculation of Arsenic Concentration in Soil under Playground Equipment Constructed of CCA-Treated Wood

$$C_{soil} = \frac{BW \times AT \times TR}{EF \times ED \times FC \times BA \times (A + B + C)}$$

where, for noncarcinogenic effec

$$A = \frac{1}{RfD_o} \times IR_o \times CF_1$$

$$B = \frac{1}{RfD_d} \times SA \times AF \times DA \times CF_1$$

$$C = \frac{1}{RfD_i} \times IR_i \times \frac{1}{PEF}$$

and, for carcinogenic effects:

$$A = CSF_o \times IR_o \times CF_1$$

$$B = CSF_d \times SA \times AF \times DA \times CF_1$$

$$C = CSF_i \times IR_i \times \frac{1}{PEF}$$

Exposure Parameter	Description	Scenario-Specific Values for the	
		Child Visitor Scenario (age 2 through 6 yrs)	Aggregate Visitor Scenario (age 2 through 31 yrs)
TR (noncarcinogens)	Hazard Index (HI) for noncarcinogenic effects (dimensionless);	1.00	**NA**
TR (carcinogens)	Carcinogenic Risk Levels (CRLs) for carcinogenic effects (dimensionless);	**NA**	1.0E-06
C_{soil}	Soil Concentration for arsenic expressed in mg/kg;	257	93
BW	Body Weight expressed in kg;	18	52
AT (noncarcinogens)	Averaging Time (period over which exposure is averaged) for noncarcinogens expressed in days;	1,825	**NA**
AT (carcinogens)	Averaging Time (period over which exposure is averaged) for carcinogens expressed in days;	**NA**	25,550
EF	Exposure Frequency expressed in days/yr;	150	67
ED	Exposure Duration expressed in years;	5	30
FC	Fraction Contacted (ingested or absorbed) from contaminated source (assumed 100% for the child visitor; 10% for the adolescent/adult);	1.0	0.25
A	Oral component equation expressed as kg^2/mg;	6.7E-01	1.1E-04
B	Dermal component equation expressed as kg^2/mg;	2.0E-03	8.4E-07
C	Inhalation component equation expressed as kg^2/mg;	4.7E-07	3.7E-09
RfD_o	Oral Reference Dose for arsenic expressed in mg/kg/day (U.S. EPA, 2000);	3.0E-04	**NA**
RfD_i	Inhalation Reference Dose for arsenic expressed in mg/kg/day (FDEP, 1999b);	2.85E-04	**NA**
RfD_d	Dermal Reference Dose for arsenic expressed in mg/kg/day (FDEP, 1999b);	2.85E-04	**NA**
IR_o	Oral Ingestion Rate for soil expressed in mg/day;	200	75
CF_1	Conversion Factor expressed in kg/mg;	1.0E-06	1.0E-06
SA	Skin Surface Area available for daily contact expressed in cm^2;	2,800	5,300
AF	Soil-to-skin Adherence Factor expressed in $mg/cm^2/day$;	0.2	0.1
DA (inorganics)	Dermal Absorption factor for inorganics (dimensionless);	0.001	0.001
IR_i	Inhalation rate (m^3/day);	10	18
PEF	Particulate Emission Factor expressed in m^3/kg (see Exposure Equation 2);	7.46E+10	7.46E+10
BA	Bioavailability (%);	0.25	0.25
CSF_o	Oral Carcinogenic Slope Factor for arsenic expressed in $(mg/kg/day)^{-1}$ (U.S. EPA, 2000);	**NA**	1.50E+00
CSF_i	Inhalation Carcinogenic Slope Factor for arsenic expressed in $(mg/kg/day)^{-1}$ (FDEP, 1999b); and,	**NA**	1.51E+01
CSF_d	Dermal Carcinogenic Slope Factor for arsenic expressed in $(mg/kg/day)^{-1}$ (FDEP, 1999b).	**NA**	1.58E+00

Adapted from FDEP (1999a; 1999b; 2000); U.S. EPA (1995; 1997a; 2000).

Exposure Equation 2

Calculation of the Particulate Emission Factor

$$PEF = \frac{Q}{C} \times \frac{CF_2}{RF \times (1 - V) \times (U_m / U_t)^3 \times F(x)}$$

Exposure Parameter	Description	Value
PEF	Particulate Emission Factor expressed in m^3/kg;	7.46E+10
Q/C	Inverse of the mean concentration at the center of a square 0.5-acre source in Miami, Florida expressed in $g/m^2 \cdot s$ per kg/m^3 (U.S. EPA, 1996);	85.61
CF_2	Conversion Factor expressed in s/hour;	3,600
RF	Respirable Fraction expressed in $g/(m^2 \cdot hr)$;	0.036
V	Fraction of vegetative or manmade cover (e.g., buildings, asphalt; unitless);	0.9
U_m	Mean annual wind speed at 10 m height for Orlando, Florida expressed in m/s (8.5 mph, NOAA, 1995);	3.8
U_t	Equivalent threshold value of wind speed at 7 m expressed in m/s (11.32 m/s default value; U.S. EPA, 1996);	11.32
F(x)	Function dependent on U_m and U_t [$F(x) = 0.18 * (8x^3 + 12x) * e^{-x^2}$; U.S. EPA, 1996; Cowherd et al., 1985]; and,	0.030
x	Unitless variable equivalent to $0.886 * (U_t/U_m)$; Cowherd et al., 1985.	2.64

Adapted from Cowherd et al. (1985) and U.S. EPA (1996).

Exposure Equation 3

Intake Equation Based on Oral Exposure to Arsenic in Soil Under Playground Equipment Built with CCA-Treated Wood

$$CI = \frac{CS \times EF \times ED \times FC \times IR_o \times BA \times CF_1}{AT}$$

Exposure Parameter	Description	Scenario-/Chemical-Specific Values: Child Visitor	Scenario-/Chemical-Specific Values: Aggregate Visitor
CI	Contaminant Ingestion expressed in mg/day.	0.005	0.000033
CS	Concentration in Soil expressed in mg/kg.	260	90
EF	Exposure Frequency expressed in days/yr.	150	67
ED	Exposure Duration expressed in years.	5	30
FC	Fraction Contacted (ingested or absorbed) from contaminated source (assumed 100% for child and 17% for aggregate visitor).	1	0.25
IR_o	Oral Ingestion Rate for soil expressed in mg/day.	200	75
CF_1	Conversion Factor expressed in kg/mg.	0.000001	0.000001
BA	Bioavailability (%);	0.25	0.25
BW	Body Weight expressed in kg.	18	52
AT (noncarcinogens)	Averaging Time for noncarcinogens (period over which exposure is averaged) expressed in days.	1,825	10,950
AT (carcinogens)	Averaging Time for carcinogens (period over which exposure is averaged) expressed in days.	25,550	25,550

Adapted from: U.S. EPA, 1995.

ATTACHMENT B

Table 1

Table 1

Proposed Protective Values for Arsenic in Soil under Playground Equipment Built with CCA-Treated Wood

Exposure Scenario	Protective Range (mg/kg) Based on Scenario
Child visitor	260
Aggregate visitor	90