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I. Introduction

A. Background

The U.S. EPA's Office of Pesticide Programs (OPP), is in the process of conducting an exposure assessment on the chromium and arsenic components of Chromated Copper Arsenate (CCA) to determine the potential non-dietary exposures to children that may occur from contact with CCA-treated wood playground structures and CCA-contaminated soils. CCA preservatives, containing chromium, copper, and arsenic as pesticidal compounds, protect wood from deterioration and are predominantly used to pressure treat lumber intended for outdoor use in constructing a variety of residential landscape and building structures, as well as home, school, and community playground equipment.

OPP is aware of increased concerns raised by the general public and state/federal regulatory agencies regarding the safety of CCA-treated wood for residential applications, since children may be potentially exposed to the dislodgeable arsenic and chromium residues present on the surfaces of CCA-treated wood structures and in soil matrices adjacent to such structures. OPP is evaluating: 1) the current sources of data available for estimating pesticide residues from wood/soil media, 2) exposure assumptions and equations used to develop the child exposure scenarios and calculate dose estimates, and 3) critical data gaps/uncertainties in the assessment.

OPP issued a draft preliminary assessment May 30, 2001 for selective internal/external peer review comment as an interim report intended to address child residential "playground" exposures exclusively. This is separate from the more thorough review of residential and occupational exposures to CCA which the U.S. EPA is evaluating under the reregistration process within OPP. Once OPP completes the reregistration review for CCA, it will release the Reregistration Eligibility Decision (RED) document for Chromated Arsenicals, which will include a more comprehensive assessment of the potential human and environmental exposures/risks attributed to the use of CCA-treated wood and related inorganic chromated arsenical pesticides. It is anticipated that the outcome of OPP's human health assessment will be pivotal in the risk management and reregistration eligibility decisions for CCA.

B. Regulatory History of CCA

Regulatory actions involving inorganic arsenical wood preservatives, including CCA, began nearly 25 years ago. An administrative review process was initiated in 1978 to consider whether the registration of certain wood preservative chemicals (pentachlorophenol; coal tar, creosote and coal tar neutral oil; and inorganic arsenicals) should be canceled or modified. A separate Notice of Rebuttable Presumption Against Registration and Continued Registration (RPAR) was issued for each heavy-duty wood preservative under consideration. An RPAR was issued when the Agency determined that a pesticide met or exceeded any of the risk criteria relating to acute and chronic toxic effects, as set forth under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Registrants then have the opportunity to submit evidence in rebuttal of the Agency's risk presumptions. The RPAR for inorganic arsenicals (43 FR 202) was published on October 18, 1978, along with a supporting Position Document (PD 1). According to that document, the risk criteria met or exceeded by inorganic arsenicals were: oncogenicity, mutagenicity, and fetotoxic/teratogenic effects. The RPAR generated substantial registrant comment, but these risks remained unrebutted after the RPAR process.

The Agency issued a Preliminary Notice of Determination (PND), concluding the RPAR process, which was published in the Federal Register of February 19, 1981 (46 FR 13020). This notice, along with the supporting Position Document (PD 2/3), stated the Agency's determination that the wood preservative chemicals continued to exceed the risk criteria which provided the basis of the RPARs. To reduce the risks, the Agency proposed certain modifications to the terms and conditions of registration, including certain protective clothing requirements, classifying all inorganic aresenical wood preservatives as Restricted Use (available to certified applicators only), and a mandatory program to provide users of treated wood with handling, use and disposal precautions.

The preliminary determinations described above were submitted to the FIFRA Scientific Advisory Panel (SAP) and the U.S. Department of Agriculture (USDA) for review. Comments were also solicited from registrants and any other interested persons. The Agency considered the comments received and made modifications to the proposed decision announced in the PND. A public meeting was conducted on April 14, 1983, to allow interested persons to comment on the proposed changes. Their comments were considered in the development of the final determination, which was a Notice of Intent to Cancel (NOIC), published in the Federal Register of July 13, 1984 (Vol. 49, No. 136), along with a supporting Position Document (PD 4).

Several trade associations and numerous registrants requested hearings to challenge the Agency's determinations in the July 13 NOIC. The Agency published a Federal Register Notice on October 31, 1984 (49 FR 43772), postponing the effective date of the labeling modifications for those registrants who filed applications for amended registration in response to the NOIC. On January 30, 1985, the Agency published an additional Federal Register Notice (50 FR 4269) announcing that persons other than registrants could continue to sell and distribute existing stocks of wood preservative products with existing labeling until further notice. Pre-hearing meetings were held between the Agency and some of the major parties who had requested hearings, during which alternative, mutually acceptable, mechanisms for achieving the regulatory goals set forth in the NOIC were discussed. After careful consideration of some of those alternatives, the Agency concluded that certain changes to the July 13, 1984 NOIC were appropriate and consistent with the Agency's goal of protecting the public from unreasonable adverse effects resulting from pesticide use. An Amended Notice of Intent to Cancel announcing these changes was published in the Federal Register of January 10, 1986 (Vol. 51, No. 7). The modifications were mostly minor in scope, with the exception that the previous mandatory Consumer Awareness Program (CAP) was deleted from the labeling requirements. The wood preservative industry agreed to a voluntary CAP to educate consumers in proper use and precautionary practices for treated wood.

Arsenic, chromium, and chromated arsenical compounds used as wood preservatives were evaluated under the Registration Standards Program in 1988. This program was established in order to provide a mechanism for pesticide products having the same active ingredient to be reviewed and brought into compliance with FIFRA.. The outcome of the Registration Standard for arsenic, chromium, and chromated arsenical wood preservatives was:

- classification of inorganic arsenic and hexavalent chromium as Group A carcinogens
- acknowledgement that both arsenic and chromium have demonstrated the potential to cause teratogenic/fetotoxic effects through peritoneal exposure
- requirement of a reproduction study using a formulated chromated arsenical product to address the teratogenic/fetotoxic effects unless a metabolism study demonstrates that blood levels of chromium and arsenic are not increased above background levels
- requirement of metabolism data to assess the bioavailability of chromium and arsenic after exposure to a formulated product
- acknowledgement that short-term assays indicate that hexavalent chromium and both trivalent and pentavalent arsenic are mutagenic
- requirement of additional ecological effects and environmental fate data
- reiteration of label restrictions set forth in the prior NOICs

Currently, the only remaining use of arsenic acid is for wood preservation. The last remaining agricultural use of arsenic acid, as a dessicant on cotton, was voluntarily cancelled in 1993 (Federal Register of May 6, 1993, Vol. 58, No. 86). The voluntary cancellation was enacted following a NOIC issued for the cotton dessicant use of arsenic acid (56 FR 50576, October 7, 1991) due to the cancer risks to workers. The voluntary cancellation allowed the sale of existing stocks until December 31, 1993, after which they could be lawfully disposed of or sold to the wood preservative industry for reformulation or repackaging into registered wood preservative products.

C. Use Profile of CCA

CCA preservatives protect wood from deterioration from a variety of insects, fungi and rot organisms. There are currently 32 CCA-containing wood preservative products registered with the EPA. CCA can be applied to wood via pressure treatment, brush, spray, low-pressure injection, soak, or bandage treatment, but the predominant use is for pressure treating lumber intended for outdoor use in constructing a variety of residential landscape and building structures, as well as home, school, and community playground equipment. CCA-treated wood, predominantly of Southern yellow pine, represents the majority of pressure-treated dimensional lumber marketed to the general consumer via lumberyards/hardware stores and other retailers. In some cases, CCA-treated lumber is recycled into wood chips which are stained, then sold to consumers as landscape mulch. Major commercial installations include utility poles, highway railings, roadway posts/barriers, bridges, bulkheads, and pilings. Industry cites advantages of CCA-treated wood over other pressure-treated wood, including superior durability, low-odor, and dry “non-oily” surfaces which can be painted or sealed.

There are three formulations of CCA, each containing varying ratios of arsenic pentoxide, chromic acid, and cupric oxide. CCA treatment solutions are typically classified by the American Wood-Preservers' Association (AWPA) as either type A, B, or C, with CCA type C (CCA-C) being the formulation most commonly used for pressure treating dimensional lumber for residential applications. AWPA's P5 Preservative Standard requires CCA-C composition to be 34.0% arsenic pentoxide (As_2O_5), 47.5% chromic acid (CrO_3), and 18.5% cupric oxide (CuO)(AWPA, 1998).

After pressure treatment and fixation, arsenic and chromium can be retained in the wood from 0.25 to 2.50 pounds per cubic foot (pcf), based on the retention of CCA-C in wood following AWPA treatment standards. Typical retention levels achieved depend on the intended applications of the treated lumber. Lower retention values are required for plywood, lumber and timbers used for above-ground applications (0.25 pcf), and for ground or freshwater contact uses (0.40 pcf). Higher retention levels are required for load bearing wood components such as pilings, structural poles, and columns (0.60 - 0.80 pcf). The highest levels are required for wood foundations and saltwater applications (up to 2.50 pcf).

D. Overview of CCA Chemistry

CCA contains chromium, copper, and arsenic, each of which contributes to the wood-preservative properties of the compound. Copper acts as a fungicide in the CCA formulation and the arsenic protects against insect damage. Chromium, in the form of chromic acid, acts as a fixative (binding agent), whereby the *Cr*, *Cu*, and *As* metal ions present in the wood are fixed to the wood fibers.

1. Speciation

Metals go through various changes in environmental compartments such as soil, water, plants, and animals. This process of speciation of metals depends on sorption, desorption, redox reactions in soil and water, precipitation reactions, complexation reactions, etc. The different species of arsenic and chromium vary in their ability to be absorbed into the body and metabolized within the body, and therefore differ in their toxicological profiles. It is important, therefore, to consider the species of arsenic or chromium present in soils surrounding CCA-treated wood and on the surface of the treated wood itself when assessing the exposure to these chemicals.

2. Fixation

After undergoing pressure treatment with CCA wood preservative, the chromium, copper and arsenic penetrate into the wood and become bound or fixated in the wood. The term, fixation, refers to the series of chemical reactions that take place after the wood has been pressure treated with CCA. These reactions render the CCA less likely to leach from the wood during service. The use of metal oxides in CCA formulations has been shown to aid in the fixation process. Fixation precedes the actual action of CCA to act as a wood preservative. The CCA penetration/fixation process preserves and protects the wood from pest attack. The absorption and fixation of CCA occurs in the cellulosic and lignin components of the wood. Since lignin is thought to be a primary binding site for chromium to form chromium-lignin complexes, the use of woods with an increased lignin content may result in improved treatment. Softwood species, which have a high lignin content often perform better than hardwoods in terms of preservative treatment. Studies have shown that all of the three metals are fixed into the wood structure.

The initial reaction of fixation is the absorption of the CCA preservative into the cellulosic and lignin components of the wood. A second reaction occurs which converts Cr^{+6} to Cr^{+3}. This second reaction continues for a period of several hours to a few days. The reduction of Cr^{+6} to Cr^{+3} is important in the formation of insoluble complexes in CCA-treated wood. Additionally, Cr^{+3} is less toxic than Cr^{+6}. The third reaction is the conversion of copper arsenate in the wood to basic copper arsenate with an arsenic valence state of +5. The complete fixation reaction may even take several months. Studies with treated pine have indicated that the copper and arsenic components of the CCA metals are "fixed" more rapidly than chromium. Some researchers conclude that the fixation process is complete when the presence of Cr^{+6} is no longer detected in the leachate or compressate of the treated wood.

3. Leaching

The fixation process binds much of the chromium, copper and arsenic into the wood fibers; however, some of the metals will not be "fixed" and will remain "free" on the surface of the treated wood. These will be susceptible to dislodging through washing off or by physical contact with other objects, including humans who have physical contact with the wood. The fixated metals can also slowly be leached from the treated wood by water.

Playground equipment constructed with treated wood can be in the form of many different types of items including swing sets, climbing bars, etc. The chromium, copper and arsenic in/on the treated wood can be leached from the wood so that the metals fall vertically onto the soil under the equipment and the metals can also leach laterally into the soil from the vertical pieces of treated wood that have contact with the playground soil. Metals also leach from ground-contact horizontal pieces of CCA-treated wood fabricated into playsets and related structures. Playground equipment may also have mulch placed under the equipment, and the mulch will receive leachate from the treated equipment pieces. Children playing on such equipment can be exposed to the CCA leachates either through contact with the CCA-treated wood or through contact with soil or mulch either under the equipment or immediately adjacent to the equipment.

A large amount of data is available regarding the leaching of chromium, copper and arsenic from treated wood. Much of the data is from studies that are not directly applicable to leaching from playground equipment. Some of the available data that are most applicable to playground equipment and decks constructed of CCA treated wood are summarized below.

Leaching of chromium, copper and arsenic from treated wood in an aqueous medium, which is most likely to simulate the playground use (where rainfall occurs), appears to be most rapid from freshly treated wood and is in the order of Cu > As > Cr. The release rate is also higher under acidic conditions; this would mean that leaching would be faster in the areas of the United States which have acid rain, such as the northeastern states. One study has shown that the leaching process from treated wood is aided by slow or drizzling rain rather than heavy showers. Leaching rates are generally lowest in wood that has been kiln-dried at high temperatures.

Most of the leaching from treated wood appears to take place in the first few days after treatment but does continue slowly over time. Leaching rates depend on the size of the wood, type of wood and on the fixation process. CCA leaches from hardwood more than soft wood. Pressure treated red pine leaches more than lodgepole pine and Douglas fir. A scheme has been proposed in the literature for the long term leaching mechanism of CCA from wood: reversible disassociation of ion-exchanged metals and their redistribution to the wood surface and their loss; and physical or biological decay of the wood.

No leaching information was found to address the question as to whether the CCA metals leach from treated wood as copper or copper arsenate or as complexes with inorganic or organic ligands or as derivatives of wood-metal moieties or as water soluble extracts. Water mobility for the metal ions from the product, CCA, depend on many factors which give rise to a number of pathways. The metals can diffuse through the soils as complexes, simple salts or free ions, or can percolate through soils as insoluble substances.

Little data was found to estimate the level of CCA residues in soil or mulch under playground equipment constructed of treated wood. A Canadian study involved wooden play structures consisting mostly of CCA-treated lumber of various dimensions constructed in a range of designs. The structural elements were comprised of beams and planks fastened together. Poles were cut and used to form rungs, ramps and ladders. Treated wood pieces were used to construct tower-like structures and to connect to swings, slides, ladders or horizontal monkey bars. Some structures incorporated hut-like shelters. Treated wood pieces were placed in vertical, horizontal and angled positions. Some structures were coated with an oil-based stain which had worn off in some areas. The structures were up to ten years old.

The ground under the structures and surrounding the structures usually consisted of a layer of sand at least 25 cm deep which is replaced or replenished from time to time. The sand is carried onto the the structures and contributes to the abrasion and wear on the treated wood pieces.

Sand and soil samples were taken from under each of the treated playground structures and a control soil sample was taken at a distance of ten meters (33 feet) from the the treated playground structure. The sand samples were taken at similar locations under each structure; at the bottom of a slide, next to a support post, at the bottom of a support post holding the main structure and underneath a wooden platform or underneath a structure approximately one meter from the wooden post. The samples were all taken in late fall and on a cloudy day. A sketch was made, a photograph taken and a general description of each structure was noted.

The soil samples were stored in plastic bags and taken to the laboratory for analyses. The samples were oven dried and analyzed using inductively couple plasma mass spectrophotometry for total nitric acid soluble arsenic (not speciated). Neither chromium nor copper were analyzed in the sand and soil samples.

The background levels of arsenic present in the control sand samples were generally less than 0.3 parts per million (ppm). The authors of the paper reported that the average arsenic residue level from samples taken from below the treated structures was 3.0 ppm with a range of 0.032 - 9.6 ppm. However, sand samples taken from other areas around the playground structures showed arsenic residues ranging from 0.13 ppm to 113.5 ppm under a structure next to a post. It should be noted that arsenic residues in sand sampled next to a treated post were less than 10 ppm except in the one playground with the high 113 ppm value. That study showed significantly higher sand residues than the other playground studies. There is no explanation for this difference, but could be due to reasons such as samples being taken near newly treated and replaced wood posts. Additionally, sand had been placed under the structures and leaching from wood posts into the sand may be rapid and spread further from the post than would be the case for arsenic leaching into a clay soil. It could also be argued that if wood mulch rather than sand had been placed under the playground structures that, because of the surface area to weight relationship for this organic material, any arsenic residues leaching from treated wood could result in even higher arsenic residues in the mulch under the playground equipment.

The playground where arsenic residues were highest was ten years old and constructed of wood that had been stained but on which the stain had been worn off. There does not appear to be a correlation between residue levels in the sand under and around the playground structures regardless as to whether the equipment had been stained or painted or was left unsealed.

There are also data available showing soil residue levels that occur under wooden decks that have been constructed from CCA-treated wood. Children can play in the soil under and around a treated deck. While the deck data may exaggerate residue levels in soil compared to what would be expected under playground equipment, the data do show that the level of CCA metals in soil under treated wood structures is greater than the background level of the metals in soil from the study location and show residue levels in soil where children could play.

In one study conducted by Stilwell and Gorny (1997), soil from under seven decks constructed from CCA-treated wood were analyzed. Chromium levels ranged as high as 154 ppm under the treated decks and averaged 43 ppm whereas the control soils had an average of 20 ppm of chromium. Arsenic levels ranged as high as 350 ppm under the treated decks and averaged 76 ppm whereas the the control soils had an average of 3.7 ppm of arsenic. No data are available for mulch under the treated deck, but residues in mulch may even be higher because of the surface area weight relationship of mulch. The same study shows that those decks that had received a coating tended to show a lesser degree of leaching of CCA metals. However, the degree of leaching from a deck that had been coated or sealed would most likely be dependent on the coating product used and on the age of the coating. The same study also showed that the age of the deck was a factor in the leachate residues found under the treated deck with the older deck showing higher soil residues under the treated deck. This study does not reflect the soil CCA residue levels that could occur under treated playground equipment, but the generalization can be made that CCA residues in soil under treated playground equipment will be higher than soil background levels of the CCA metals in the surrounding area. The residue data from this study do not speciate the metals but determine total copper, chromium and arsenic

Lateral and vertical migration of CCA metal residues can also occur from vertical pieces of the playground equipment that have contact with the soil. In a study conducted by DeGroot et.al., treated southern pine wooden stakes were placed in sandy soil and the lateral and vertical migration of CCA metal residues was measured after 30 years. Both arsenic and chromium residues leached into the top six inches of a soil core; arsenic as high as 108 ppm and chromium as high as 25 ppm. Some increase in arsenic level , but not chromium was seen in the six to twelve inch core. In the twelve to eighteen core, there did not appear to be any increase in the arsenic and chromium level. In soils which have a high clay or organic content, the metal leaching would be expected to be lower because of the metal binding to the soil particles. Lateral movement of residues in the soil surrounding the stakes appeared to be limited to the zero to three inch area surrounding the treated stakes. Based on the findings in this and other studies, CCA metal residues are not likely to leach from vertically- placed wood structures placed in contact with the soil to depths greater than twelve inches or to lateral distances from these treated wood pieces of greater than three inches.

In another study conducted with CCA-treated decks (Townsend and Solo-Gabriele et al., 2001.) conducted in Florida, nine decks were studied (one deck could not be confirmed as treated with CCA). The decks were located in Gainesville, Miami and Tallahassee and the sampling was done in 1999.The decks varied in age from two to nineteen years old.

A grid was set up under each deck before sampling was done and soil samples were collected in these grids. Surface samples from the top inch of soil and soil core samples of approximately seven inches in depth were taken. Soil control samples were also taken at locations away from the grid.

The soil samples were digested and analyzed for total arsenic, copper and chromium. Analyses were performed using an atomic absorption spectrophotometer. This method determines the total metal residue level and does not speciate the metals.

Arsenic residues were found in the soil beneath all of the CCA-treated decks. The average surface arsenic level was 39 ppm and the maximum level under one deck was 217 ppm. The maximum arsenic residue found under any of the other decks was 88 ppm. The maximum arsenic residues present in soil core samples were in the top two inches but were present at levels of approximately 2-20 ppm over the depth range of two to eight inches. Control arsenic values average 1.5 ppm.

The average surface copper residues found in the soil beneath all of the CCA-treated decks was 40 ppm and the maximum level under one deck was 216 ppm (soil from the same deck reported high arsenic levels). The maximum copper residue found in soil under any of the other decks was 156 ppm. The maximum residues present in soil core samples were generally higher in the top few inches of soil, and higher than those levels in control samples.

The average surface chromium residues found in the soil beneath all of the treated decks was 34 ppm and the maximum level under one deck was 198 ppm (soil from the same deck that reported high arsenic levels). The maximum chromium residue found in soil under any of the other decks was 114 ppm. The average control level was 9.8 ppm. Average chromium levels of up to 11.7 ppm were reported at depths of 4.5 inches.

The soils under the CCA-treated decks are described as ranging from beach sand to being dark in color with a sponge-like consistency and with a high percentage of volatiles given off during analysis. This latter seems to indicate a soil with high organic content. The site with the highest arsenic level was characterized as having relatively high volatile solids, and this correlation can be found in five of the nine deck sites. The lowest arsenic residues were found at sites with low volatile solids content (Townsend et al., 2001).

This study indicates that CCA-treated decks increase arsenic, copper and chromium levels in soil beneath treated decks.

Based on the available information from both CCA-treated playground equipment and decks, it appears that the primary source of soil exposure to children from playing on playground equipment constructed of CCA treated wood or playing under treated decks would occur from the leaching of CCA metal residues from horizontal pieces of treated wood in the playground equipment and deck wood onto the soil. Maximum residue levels would likely be less than 200 ppm arsenic, copper and chromium and on the average would be less than 50 ppm for each of the metals. Maximum residues of arsenic would likely occur in sandy soil under treated wood. However, if an organic material such as wood mulch with a high surface-weight relationship were placed under CCA-treated playground equipment, residues of the metals could be absorbed and retained in the material with slow leaching out from the mulch.

All three of the leaching studies described above are suitable to show that residues of copper, chromium and arsenic leach from treated wood onto the soil under playground equipment and decks constructed of treated wood. Additional studies would be desirable which reflect the use of CCA-treated wood in playground equipment, specifically, studies designed to sample soils beneath/adjacent to CCA-treated playground structures from different (representative) geographic regions of the United States.

4. Environmental Fate

Many studies in the recent literature (Stilwell 1997 and 1998, Solo-Gabriele 2001, and Osmose 2001) report on leaching into soils. These studies have shown that none of the three metals migrate large distances (twelve inches vertically and three inches laterally from the treated wood structure). Some studies have shown that the contamination level is elevated in the soil compared to the natural background levels of these metals. Such studies indicate that metals can be persistent in the soils, particularly on the soil surfaces, and can result in environmental exposure. The metals show various speciation characteristics in soils, depending on the types of soil .

The metals migrating into water bodies can result in aqueous contamination. Metals also show a tendency to speciate in water, and various species will be present in water depending on the pH of water as well as the salinity.. If water is highly acidic, the leaching rates and amounts of leachates increase. Generally, in soil and water, the amounts of metals released are in the order of Cu> As > Cr. In some recent cases it has been shown that the order of release rates are: As>Cu>Cr. In all cases, the amounts of chromium released is least of the three metals.

Numerous studies on bioaccumulation in various aquatic organisms have also been carried out over a period of time. A number of these species have shown a degree of bioaccumulation and toxic effects have been observed. The studies were conducted under varying conditions and very few studies reported depuration rates.

An overall robust fate assessment cannot be made at this time, as the studies were conducted under different laboratory or field conditions, which were not standardized. Hence, while one can determine the exposure and hazards of these metals on humans, plants, aquatic organisms, a complete fate assessment is not possible.

II. Parameters and Input Factors Used in Exposure Assessment

The child exposure assessment presented herein evaluates exposure routes and pathways realistically anticipated based on the activity patterns and behavior of young children in residential playground settings. Exposure may occur to children through touching CCA-treated wood and CCA-contaminated soil near treated wood structures, mouthing hands after touching CCA-treated wood, and through eating CCA-contaminated soil. OPP has determined that the arsenic and chromium components of CCA pose the most significant human health concerns, due to their carcinogenicity. Copper, which is not a recognized or suspected carcinogen, is considered to pose much less of a health concern. Therefore, the assessment focuses on evaluating potential exposures to children from Arsenic as *As(V)*, and Chromium as *Cr(VI)* by selecting for each scenario, the appropriate data and equations to be used in calculating the average daily dose (ADD) for the non-cancer assessment, and the lifetime average daily dose (LADD) for the cancer assessment.

A. Routes of Exposure

This exposure assessment estimates potential child exposures from contact with CCA-treated wood used for playground equipment and related residential applications. Due to their unique physiology and behavior, children often differ from adults in their susceptibility to hazardous chemicals. This can influence the extent of their exposure (ATSDR, 1998) to arsenic and chromium pesticide residues remaining on surfaces of treated wood, as well as to residues leached into the soil surrounding these treated wood structures. The exposure routes and pathways assessed here are based on realistic activity patterns and behavior of young children. Exposure may occur to children through touching CCA-treated wood and CCA-contaminated soil near treated wood structures, mouthing hands after touching CCA-treated wood, and through eating CCA-contaminated soil.

OPP has determined that there are potential dermal and incidental oral exposure concerns relating to child exposure to CCA residues from treated wood playground structures and resulting from leaching of arsenic and chromium compounds into surrounding soil matrices. The potential for adverse dermal and oral exposures to arsenic as *As(V)* and chromium as *Cr(VI)* has prompted the need for this child residential exposure assessment.

OPP does not propose to evaluate potential exposures via the inhalation route for the child residential exposure assessment. The Agency anticipates that the inhalation potential from contact with either CCA-treated wood or CCA-contaminated soil is negligible. Neither arsenic *As(V)* nor chromium *Cr(VI)* residues are volatile on the surfaces of treated wood, nor readily available as respirable airborne particulate concentrations. During play activities in CCA-contaminated soil, any airborne soil-bound residues that a child might inhale through the nose or mouth are not anticipated to contribute significantly to the overall exposure (i.e., exposure will be insignificant compared to the oral dose attributed to soil ingestion or hand-to-mouth activities). Concerns regarding inhalation of arsenic and chromium residues from treated wood surfaces are associated with occupational exposures at wood treatment plants following pressure treatment, as well as occupational and adult residential exposures to airborne particulates during fabrication of treated wood (i.e., inhaled wood dust/saw dust during cutting, sawing, drilling, and sanding (Arsenault, 1977 and van Raaij, 1998).

B. Duration of Exposure

A duration of 6 years was assumed as the time a child typically spends, over the course of a lifetime, engaged in activities on/near residential playground structures. U.S. EPA Superfund (EPA, 2000) adopted the exposure duration of 6 years as an Age-Adjusted Dermal Exposure Factor for children ages 1-6, when dermal exposure to soil is expected through childhood and into adulthood. Superfund also recommended 6 years (9 years for adults) as an exposure duration based on the central tendency for children in residential sites and engaged in water contact scenarios such as swimming and bathing. For the long term exposure assessment, OPP considers an exposure duration of 6 years appropriate for children exposed to soils and treated wood at playgrounds as a central tendency value based on human factors for children 1-6 years old.

C. Exposure Frequency

For this assessment, exposure estimates will be derived for short-, and intermediate-term incidental oral and dermal scenarios, and possibly long-term dermal exposure scenarios. These estimates will be used by OPP to characterize acute, sub-chronic, and chronic hazards to children from contact with CCA residues in wood and soil matrices. OPP defines short-term exposure duration as lasting from 1 day to 1 month; intermediate-term exposure duration as lasting from 1 to 6 months; and, long-term exposure duration as lasting longer than 6 months (US EPA, OPP/HED Policy Document, June 4, 2001). The calculation of the LADD is similar to that of an ADD. The difference is that the dose is amortized over a lifetime. To evaluate an LADD, the average residue concentrations on wood and in soil will be used. An exposure frequency (EF) of 130 days/yr is proposed. The reasonable worst-case scenarios developed for this assessment assumes that short- and intermediate-term exposures of up to 130 days/year will occur from child contact with playground structures and soils. This is based on the CDHS's (1987) assumption that children visit playgrounds 5 times per week, 26 weeks per year (high end estimation). *(Winston - I thought you had said that this assumption is attributed back to EFH ?)* OPP considers the exposure time as one hour per visit (for 50 percentile) at school grounds and playgrounds (US EPA 1997a). Using the CDHS's assumption of 5 visits per week, 26 weeks per year, the exposure frequency of 130 days per year is considered a central tendency value. The exposure frequency will vary based on the climate and regional weather conditions which greatly influence child (ages 1-6 years) outdoor play activities.

D. Body Surface Area and Body Weight

Unlike adults, the ratio of surface area to body weight for young children (especially infants ages 0 to 2 years) changes significantly over time as a child's body grows and develops. Philips et al. (1993) observed a strong correlation (0.986) between body surface area (SA) and body weight (BW), and studied the effects of using these factors as independent variables in the LADD equation. According to Philips et al. (1993), SA/BW ratios should be used to calculate LADDs for dermal exposure by replacing the body surface area factor in the numerator of the LADD equation with the SA/BW ratio, and eliminating the body weight factor in the denominator of the LADD equation. Normally, OPP recommends using the 50^{th} and 90^{th} percentile surface area values and a standard adult body weight of 70 kg (and 15 kg for a 3 year-old child) for calculating the LADD via point estimation techniques. This approach has been used for dermal exposure targeted for the general population, and it does not include SA/BW estimations for young infant and toddler sub-populations.

E. Soil Adherence Factor

Contaminated soil under playground structures will adhere to the surface of the skin when children are playing on the soil. The Soil Adherence Factor (AF) is defined as the amount of soil which adheres to the skin, and can be used as a parameter for the dermal exposure scenario. The AF is highly dependent on the soil type, moisture content of soil and skin, amount of time the soil contacts the skin, and human activities at the time of measurements. The adherence levels vary with activity and different parts of the body. US EPA (1997a) summarized the relevant and key studies and also selected the activity versus the best representative values for the particular exposure scenarios (such as children in a daycare center, children playing in the soil) and found out the variation in soil levels per surface area was as high as a few orders of magnitude.

Most of the currently available studies on soil contamination were conducted beneath residential decks, not beneath/around playground equipment. No data are available for the specific dermal adherence value to best represent 1-6 year-old children playing underneath CCA-treated-wood structures (e.g., decks, playground equipment). OPP notes that draft guidance does exist for dermal exposure assessments in the Superfund program (U.S. EPA, Superfund, 2000). This guidance includes results of a study conducted with children in a daycare center, and provides the results of activity specific surface area weighted AFs (see Table 1, below). However, the document does not provide critical details about the data (e.g., which samples were taken from indoor activities versus outdoor activities), which would enable OPP to determine which values most closely represent CCA-contaminated playground soil scenarios.

Table 1: Activity Specific Surface Area Weighted AFs (U.S. EPA, Superfund, 2000)

Exposure Scenario	Age (year)	Weighted AF (mg/cm^2)[1]	
		50^{th} %	95^{th} %
Children playing in dry soil	8-12	0.04	0.2
Children playing inside a day care center	1-6.5	0.06	0.2
Children playing in wet soil	8-12	0.2	2.7
Kids-in-mud	9-14	(22)*	(123)*

* Significant overestimation and will not be used
[1]Weighted AF based on exposure to face, forearms, hands, lower legs and feet

Considering the above, OPP is proposing to use another available AF, which was determined from a study using hand contact with commercial potting soil (Superfund RAG, 1989 " Residential Exposure: Dermal Contact with Chemicals in Soil"). OPP has selected the AF value of 1.45 mg/cm^2 determined in this study because we believe the commercial potting soil scenario used may more closely represent those soils a child may contact when playing in a playground.

F. Exposure Scenarios

Exposures to "playground equipment" are considered representative of worst-case child residential exposures to CCA-treated wood, compared to exposure to CCA-treated wood decks. OPP has developed four exposure scenarios, which are outlined below. A detailed description of each scenario is provided in Tables 2 and 3.

- Child Dermal Contact with CCA-Treated Wood Playground Structures;
- Child Dermal Contact with CCA-Contaminated Soil;
- Child Incidental Ingestion of Residues Due to Hand-to-Mouth Contact with CCA-Treated

Wood Playground Structures; and

- Child Incidental Ingestion of CCA-Contaminated Soil.

Table 2. Child *Dermal* Exposure Scenarios in Residential Playground Settings

Exposure Scenarios	Scenario Descriptions/Assumptions
DERMAL EXPOSURE ROUTE	
(1) Child Dermal Contact with CCA -Treated Wood Playground Structures (i.e., outdoor residential playground equipment and related fabricated play-area structures);	Scenario involves the contact of child skin surfaces (i.e., hands, legs, and arms) with CCA-treated wood playground equipment during normal play activity. Assumes a 3 year-old child (weight 15 kg) wears typical clothing for outdoor warm weather play [e.g., a short-sleeved shirt, short pants (shorts), and shoes]. Assumes a one-to-one relationship of dislodgeable residues transferred from the surface of the wood to the exposed skin. Surface wipe sampling data on dislodgeable residues used. The dermal absorption values of 6.4% for *As* and 1.3% for *Cr* applied. The exposure frequency is 130 days per year and the exposure duration is 6 years out of a 75 year lifetime.
(**2) Child Dermal Contact with CCA-Contaminated Soil** (e.g., soil contaminated by leaching of CCA from nearby CCA-treated wood playground structures).	Scenario involves the contact of child skin surfaces (i.e., hands, legs, and arms) with CCA-contaminated soil near playground equipment during normal play activity. Assumes a 3 year-old child (weight 15 kg) wears typical clothing for outdoor warm weather play [e.g., a short-sleeved shirt, short pants (shorts), and shoes]. Soil sampling data used for levels of *As* and *Cr* compounds in soils near CCA-treated wood. Adherence Factor of 1.45 mg soil/cm^2 of skin is used for the transfer of soil particles to the exposed skin. The dermal absorption values of 6.4% for *As* and 1.3% for *Cr* applied. The exposure frequency is 130 days per year and the exposure duration is 6 years out of a 75 year lifetime.

Table 3. Child *Oral* Exposure Scenarios in Residential Playground Settings

Exposure Scenarios	Scenario Descriptions/Assumptions
ORAL INGESTION ROUTE	
(3) Child Incidental Ingestion of Residues Due to Hand-to-Mouth Contact with CCA-Treated Wood Playground Structures;	Scenario involves the contact of a 3 year-old child's (weight 15 kg) skin surfaces (i.e., three fingers of the hand as 20 cm^2) with CCA-treated wood playground equipment during normal play activity, followed by the transfer of *As* and *Cr* residues to the mouth from hand-to-mouth activity. This 3-year old child spends 1 hour per day (central tendency) or 3 hours per day (as upper end) engaged in play activities/potential hand-to-mouth activities. Surface wipe sampling data on dislodgeable residues used. Assumes one-to-one relationship of dislodgeable residue transfer from the surface of wood to skin and the removal efficiency of residues from hands by human saliva is 50% for inorganic metals such as arsenic or chromium. The rate of hand-to-mouth activity is 20 events per hour (upper end) and the mean rate is 9.5 events per hour. The exposure frequency is 130 days per year and the exposure duration is 6 years out of a 75 year lifetime.
(4) Child Incidental Ingestion of CCA-Contaminated Soil.	Scenario involves a 3 year-old child (weight 15 kg) using hands or utensils to pick up and eat CCA-contaminated soil near playground equipment as part of normal play activity. Soil sampling data used for levels of *As* and *Cr* compounds in soils near CCA-treated wood. The soil ingestion rate is 100 mg/day as the typical rate and 400 mg/day as the maximum rate. A bioavailability factor of 25% is applied for As from soil ingestion. The exposure frequency is 130 days per year and the exposure duration is 6 years out of a 75 year lifetime.

G. Exposure Assumptions

1. Overview of available data

Children may come into contact with pressure-treated wood containing chromated arsenicals (CCA compounds) during daily outdoor activities in residential settings. Examples of CCA-treated wood structures that a child may be exposed to include playground equipment, decks, telephone poles, fencing, landscape ties, and fabricated outdoor furniture (i.e., tables, benches and chairs). Children are considered the most sensitive population for assessing the exposure and safety of CCA-treated lumber for residential applications. Also, children would be more likely than adults to exhibit behavior (e.g., hand-to-mouth activity, mouthing and eating soil) that would result in greater potential for adverse exposure. Children have relatively high surface area to body weight ratios for dermal contact with CCA-treated materials, a higher incidence of ingestion of residues on fingers and hands than adults, relatively low body weights, and potentially increased sensitivities.

Playground equipment and wood decks constructed with pressure- treated wood are expected to represent the most common sources for child exposures and would likely result in the highest contact and exposure frequency. This child exposure assessment focused on exploring exposure scenarios in playground settings since OPP assumed that wood intended for the fabrication of both decks and playgrounds are similar in nature (e.g., both predominantly Southern pine); subject to the same CCA treatment formulations and pressure treatment procedures (e.g., vacuum pressures, retention levels of 0.40 pcf, and fixation steps). It was also assumed that a child would have a higher affinity for contact with CCA-treated “playsets” over “decks” and that through normal play activities exposures would involve more body surface areas, exposure time, and greater potential for hand-to-mouth behaviors. Also, in residential playground settings, children are apt to play in CCA-contaminated soils surrounding these “playsets”, whereas home “decks” are usually raised above ground level, many with obstructed access to CCA-contaminated soils directly underneath them by a lattice at the base and around the perimeter of the deck.

OPP considered the human factors related to child activity patterns on/near outdoor “playsets” in home, school, and municipal playground (or other “residential”) sites. To develop the playground exposure scenarios OPP chose to characterize activity patterns and assumptions anticipated for a typical 3-year old toddler, weighing 15 kg, as representative of children ages 1 through 6. Variability in age-related play behaviors is expected to add a degree of complexity in conducting an exposure assessment representative of most exposed child populations. Also, due to limited data on child playground behaviors, OPP relied heavily on Agency guidance documents such as the EPA/ORD Exposure Factor’s Handbook, EPA/OPP’s Residential SOPs (Standard Operating Procedures), and EPA/Superfund’s RAG (Risk Assessment Guidance) to develop the inputs/assumptions for the four toddler scenarios. An overview of the child activity and exposure assumptions being evaluated in the assessment is presented in Table 4 .

Table 4: Summary of Exposure Assumptions for the Assessment of Non-Dietary Exposures and Risks to Children from Contact with CCA-Treated Wood Playground Structures and CCA-Contaminated Soil

Exposure Scenario	Child Activity/Exposure Assumptions	Exposure Characteristics	Source
	DERMAL EXPOSURE ROUTE		
(1) Child Dermal Contact With CCA-Treated Wood Playground Structures Medium to high uncertainties associated with the parameters used in this scenario stem from the assumptions regarding the transfer of dislodgeable surface residues to the skin during a child's normal play activities. The input values for exposure frequency, duration, body weight, and lifetime are considered to be central tendency.	***Age:*** 3 years old ***Body Weight:*** 15 kg	*mean values:* representative of children ages 1-6	U.S.EPA Exposure Factors Handbook (1997)
	Surface Area: 1640 cm^2	*upper percentile:* exposed skin surfaces (hands, legs, arms)	
	Lifetime: 75 years	*mean value*	
	Dermal Absorption: 6.4% for arsenic, 1.3% for chromium	percutaneous absorption from water	U.S.EPA Recommendation to HIARC (2001)
	Exposure Frequency: 130 days/year	*central tendency*	U.S.EPA Exposure Factors Handbook (1997) ~~California Department of Health Services- CDHS (1987)~~
	Exposure Duration: 6 years	*central tendency*	U.S.EPA Risk Assessment Guidance for Superfund (1989)
(2) Child Dermal Contact With CCA-Contaminated Soil Medium to high uncertainties associated with the parameters used in this scenario stem from the assumptions regarding the transfer of soil residues to the skin (i.e., soil adherence rate) during a child's normal play activities. High uncertainties also associated with the lack of transfer coefficient data from different type of soils to the skin, and also information on regional soil types/conditions. The input values for exposure frequency, duration, body weight, and lifetime are considered to be central tendency.	***Age:*** 3 years old ***Body Weight:*** 15 kg	*mean values:* representative of children ages 1-6	U.S.EPA Exposure Factors Handbook (1997)
	Surface Area: 1640 cm^2	*upper percentile:* exposed skin surfaces (hands, legs, arms)	
	Lifetime: 75 years	*mean value*	
	Dermal Absorption: 6.4% for arsenic, 1.3% for chromium	*mean*: percutaneous absorption from water	U.S.EPA Recommendation to HIARC (2001)
	Adherence Factor: 1.45 mg/cm^2	soil adherence rate	U.S.EPA Risk Assessment Guidance for Superfund (1989)
	Exposure Frequency: 130 days/year	*central tendency*	U.S.EPA Exposure Factors Handbook (1997) ~~California Department of Health Services- CDHS (1987)~~
	Exposure Duration: 6 years	*central tendency*	U.S.EPA Risk Assessment Guidance for Superfund (1989)

Exposure Scenario	Child Activity/Exposure Assumptions	Exposure Characteristics	Source
ORAL INGESTION ROUTE			
(3) Child Incidental Ingestion of Residues Due to Hand-to-Mouth Contact With CCA-Treated Wood Playground Structures Medium to high uncertainties associated with the parameters used in this scenario stem from the assumptions regarding the transfer of dislodgeable surface residues to the skin during a child's normal play activities. High uncertainties are also associated with the number of hand-to-mouth events per hour from different groups of children, based on age and gender. The input values for exposure frequency, duration, body weight, and lifetime are considered to be central tendency.	***Age:*** 3 years old ***Body Weight:*** 15 kg	*mean values:* representative of children ages 1-6	U.S.EPA Exposure Factors Handbook (1997)
	Exposure Time: 1 hour/day (mean) and 3 hours/day (upper-end)	*central tendency to upper percentile*: time spent in hand-to-mouth activity	
	Lifetime: 75 years	*mean value*	
	Surface Area: 20 cm^2	skin surfaces of three fingers on a hand associated with hand-to-mouth activity	U.S.EPA Draft SOPs for Residential Exposure Assessments (2000)
	Hand-to-Mouth Frequency: 9.5 events/hour (mean) and 20 events/hour (upper-end)	*mean to upper percentile:* frequency of events for child finger-mouthing activity	
	Fraction Ingestion: 50% removal efficiency of residues from fingers	*mean to upper percentile:* efficiency of human saliva on skin as ingested fraction	
	Exposure Frequency: 130 days/year	*central tendency*	U.S.EPA Exposure Factors Handbook (1997) ~~California Department of Health Services-CDHS (1987)~~ California Department of Health Services-~~CD~~HS (1987)
	Exposure Duration: 6 years	*central tendency*	U.S.EPA Risk Assessment Guidance for Superfund (1989)
(4) Child Incidental Ingestion of CCA- **Contaminated Soil** Medium to high uncertainties associated with the parameters used in this scenario stem from the assumptions regarding the ingestion rate of contaminated soils during a child's normal play activities. The input values for exposure frequency, duration, body weight, and lifetime are considered to be central tendency	***Age:*** 3 years old ***Body Weight:*** 15 kg	*mean values:* representative of children ages 1-6	U.S.EPA Exposure Factors Handbook (1997)
	Soil Ingestion Rate: 100 mg/day (mean) and 400 mg/day (upper-end)	*mean to upper percentile*	
	Lifetime: 75 years	*mean value*	
	Bioavailability Factor: 25%	estimation based on gastro-intestinal absorption in non-human primates	US EPA Recommendation to HIARC (2001)
	Exposure Frequency: 130 days/year	*central tendency*~~-~~	~~California Department of Health Services-CDHS (1987)~~
	Exposure Duration: 6 years	*central tendency*	U.S.EPA Risk Assessment Guidance for Superfund (1989)

2. Equations and Input Values OPP will consider using in the exposure assessment

The average daily dose (ADD) and lifetime average daily dose (LADD) equations and input variables being considered by the Agency for assessing child exposures are presented below by scenario. These data are considered at present, the "best available" information for use as exposure factors associated with child playground activity patterns during dermal/oral contact with *As(V)* and *Cr(VI)* residues from CCA-treated wood playground structures and in CCA-contaminated soil.

CHILD DERMAL CONTACT WITH CCA-TREATED WOOD PLAYGROUND STRUCTURES: (Scenario 1)

Equations:

$$ADD\ (mg/kg/day) = \frac{(C_{max} \text{ or } C_{avg})^{*} \times SA \times ABS \times CF}{BW}$$

$$LADD\ (mg/kg/day) = \frac{ADD \times EF \times ED}{LT}$$

*** C_{avg} is used for cancer and C_{max} is used for non-cancer exposure dose calculations**

Where:

ADD	**=**	**Average Daily Dose (mg/kg/day);**
LADD	**=**	**Lifetime Average Daily Dose (mg/kg/day);**
C_{max}	**=**	**Maximum concentration of residue (µg/cm^2) for non-cancer;**
C_{avg}	**=**	**Average concentration of residue (µg/cm^2)for cancer;**
SA	**=**	**Surface Area of skin exposed per day; legs, arms and hands (cm^2);**
ABS	**=**	**Dermal Absorption (unitless);**
CF	**=**	**Conversion Factor (0.001 mg/µg);**
ED	**=**	**Exposure Duration (years);**
EF	**=**	**Exposure Frequency (days/year);**
BW	**=**	**Body Weight (kg); and**
LT	**=**	**Lifetime (year x 365 days/year).**

Input Values:

C_{max}:	**µg/cm^2 maximum data for *As* and *Cr* (data source(s) selection pending)**
C_{ave} :	**µg/cm^2 average data for *As* and *Cr* (data source(s) selection pending)**
SA :	**1640 cm^2 for a 3- year old child (USEPA, 1997)**
ABS :	**6.4% for arsenic and 1.3% for Chromium (USEPA, 2001)**
EF :	**130 day/yr (USEPA, 1997a)**
ED :	**6 years for a child (USEPA, 1989)**
LT :	**75 years (USEPA, 1997a)**
BW:	**15 Kg (USEPA, 1997a)**
CF:	**1 x 10^{-3} to change from µg to mg**

CHILD DERMAL CONTACT WITH CCA-CONTAMINATED SOIL: (Scenario 2)

Equations:

$$ADD\ (mg/kg/day) = \frac{(C_{max}\ or\ C_{avg})^{*} \times SA \times AF \times ABS \times CF}{BW}$$

$$LADD\ (mg/kg/day) = \frac{ADD \times EF \times ED}{LT}$$

*** C_{avg} is used for cancer and C_{max} is used for non-cancer exposure dose calculations**

Where:

ADD	=	**Average Daily Dose (mg/kg/day);**
LADD	=	**Lifetime Average Daily Dose (mg/kg/day);**
C_{max}	=	**Maximum concentration in the soil (mg/kg);**
C_{avg}	=	**Average concentration in the soil (mg/kg);**
CF	=	**Conversion Factor (1E-6 kg/mg);**
SA	=	**Surface Area of skin exposed per day; legs, arms and hands (cm^2);**
AF	=	**Adherence Factor (mg/cm^2);**
EF	=	**Exposure Frequency (days/year);**
ED	=	**Exposure duration (years);**
ABS	=	**Dermal absorption (unitless);**
BW	=	**Body Weight (kg); and**
LT	=	**Lifetime (years x 365 days/year).**

Input Values:

C_{max}:	**mg/kg maximum data for *As* and *Cr* (data source(s) selection pending)**
C_{avg}:	**mg/kg average data for *As* and *Cr* (data source(s) selection pending)**
CF:	**1×10^{-6} to change from mg to kg**
SA :	**1640 cm^2 (USEPA, 1997a)**
AF:	**1.45 mg/cm^2 (USEPA, 1989)**
ABS :	**6.4% for arsenic and 1.3% for chromium (USEPA, 2001)**
EF :	**130 days/year (USEPA, 1997a)**
ED :	**6 years for a child (USEPA, 1989)**
LT :	**75 years (USEPA, 1997a)**
BW:	**15 kg (USEPA, 1997a)**

CHILD INCIDENTAL INGESTION DUE TO HAND-TO-MOUTH CONTACT WITH CCA-TREATED WOOD PLAYGROUND STRUCTURES: (Scenario 3)

Equations:

$$\text{ADD (mg/kg/day)} = \frac{(C_{max} \text{ or } C_{avg})^{*} \times SA \times CF \times FQ \times ET \times FI}{BW}$$

$$\text{LADD (mg/kg/day)} = \frac{ADD \times EF \times ED}{LT}$$

*** C_{avg} is used for cancer and C_{max} is used for non-cancer exposure dose calculations**

Where:

ADD	=	**Average Daily Dose (mg/kg/day);**
LADD	=	**Lifetime Average Daily Dose (mg/kg/day);**
C_{max}	=	**Maximum concentration of residue ($\mu g/cm^2$);**
C_{avg}	=	**Average concentration of residue ($\mu g/cm^2$);**
SA	=	**Surface Area of a child's hands per event (cm^2/event);Three fingers ;**
CF	=	**Conversion Factor (0.001 mg/μg);**
FQ	=	**Frequency (events/hr);**
ET	=	**Exposure Time (hr/day);**
EF	=	**Exposure Frequency (days/year);**
FI	=	**Fraction Ingestion (unitless);**
ED	=	**Exposure Duration (years);**
BW	=	**Body Weight (kg); and**
LT	=	**Lifetime (years x 365 days/year).**

Input Values:

C_{max}:	**$\mu g/cm^2$ maximum data for *As* and *Cr* (data source(s) selection pending)**
C_{avg} :	**$\mu g/cm^2$ average data for *As* and *Cr* (data source(s) selection pending)**
SA :	**20 cm^2 for a 3- year old child (USEPA, 2000)**
CF:	**1 x 10^{-3} to change from μg to mg**
EF :	**130 day/year (USEPA, 1997a)**
FQ :	**20 events/hr(upper end) and 9.5 events/hr(mean), (USEPA, 2000)**
ED :	**6 years for a child (USEPA, 1989)**
ET :	**1 hour(50^{th} percentile) and 3 hours(90^{th} percentile), (USEPA, 1997a)**
FI:	**0.5 (USEPA, 2000)**
LT :	**75 years (USEPA, 1997a)**
BW:	**15 kg (USEPA, 1997a)**

CHILD INCIDENTAL INGESTION OF CCA-CONTAMINATED SOIL: (Scenario 4)

Equations: $$ADD\ (mg/kg/day) = \frac{(C_{max}\ or\ C_{avg})^{*} \times IR \times CF \times BF}{BW}$$ $$LADD\ (mg/kg/day) = \frac{ADD \times EF \times ED}{LT}$$ *** C_{avg} is used for cancer and C_{max} is used for non-cancer exposure dose calculations**
Where: **ADD = Average Daily Dose (mg/kg/day);** **LADD = Lifetime average Daily Dose (mg/kg/day);** **C_{max} = Maximum concentration in the soil (mg/kg);** **C_{avg} = Average concentration in the soil (mg/kg);** **CF = Conversion Factor (1E-6 kg/mg);** **EF = Exposure Frequency (days/year);** **ED = Exposure Duration (years);** **BF = Bioavailibility Factor for As from soil ingestion** **BW = Body Weight (kg);** **LT = Lifetime (years x 365 days/year); and** **IR = Soil ingestion rate (mg/day).** **Variable Values:** **C_{max}: mg/kg maximum data for *As* and *Cr* (data source(s) selection pending)** **C_{avg}: mg/kg average data for *As* and *Cr* (data source(s) selection pending)** **CF: 1×10^{-6} to change from mg to kg** **EF : 130 days/year (USEPA, 1997a)** **ED : 6 years for a child (USEPA, 1989)** **LT : 75 years (USEPA, 1997a)** **BF : 0.25 (25%)** **BW: 15 kg (USEPA, 1997a)** **IR: 400 mg/day for non-cancer exposure dose calculation; and** **100 mg/day for cancer dose calculation (USEPA, 1997a)**

H. Pica Behavior

Soil ingestion is identified as a potential non-dietary oral exposure route for children while they are playing around CCA-contaminated soils. Studies have been conducted to estimate the amount of soil ingested by:

- Measuring the amount of soil ingested by measuring the amount of soil on the hand and making generalizations based on behavior; or

- Measuring the soil intake using a methodology that measures trace elements in feces and soil which are believed to be poorly absorbed in the gut.

The available studies on soil intake are summarized in the USEPA Exposure Factors Handbook (1997a). However, certain individuals exhibit habitual pica behavior, i.e., they eat nonfood items regularly. For soil ingestion, pica is defined as a deliberately high soil ingestion rate.

Calabrese et al. (1989) estimated that upper range soil ingestion values may range from approximately 5-7 grams/day. This estimate was based on observations of one pica child among the 64 children who participated in the study. In the study, a 3.5- year old female exhibited high soil ingestion behavior during one of the two weeks of observation. Intake ranged from 74 mg/day to 2.2 g/day during the first week of observation and 10.1 to 13.6 g/day during the second week of observation. The upper limit on soil ingestion of 5,000 mg/day recommended by Schaum (1984) has been suggested to be used as a maximum estimate of soil ingestion by a person with habitual pica (USEPA, 1984; Lagoy, 1987). CDC used a value of 10 g/day to represent the amount of soil that a child with pica soil ingestion behavior might ingest (Kimbrough et al., 1984). The USEPA Exposure Factors Handbook (1997) is proposing, with low levels of confidence, to use a value of 10 g soil ingestion /day for children with pica behavior for use in acute exposure assessments.

There is evidence that the person who exhibits pica soil ingestion behavior is in an abnormal physiological and/or psychological condition. Based on the data from the five key tracer studies (Binder et al., 1986; Clausing et al., 1987; Van Wijnen et al., 1990; Davis et al., 1990; and Calabrese et al., 1989), only one child out of the more than 600 children involved in all these studies ingested an amount of soil significantly greater than the range for other children. Based on the observation that the incidence erate of children with pica behavior in the general population is low, we propose no to consider pica soil ingestion behavior in the current risk assessment.

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I. Uncertainties and Limitations in Conducting an Exposure Assessment

The major uncertainties and limitations anticipated in conducting this exposure assessment are noted below.

- No data are available to determine the frequency of skin contact to treated vs. non-treated wood, or CCA-contaminated vs. non-contaminated soil, during typical outdoor play activity. In this assessment, these assumptions are based on limited data available. Therefore, medium to high uncertainties are expected.

- There are many significant variables that can affect the levels of dislodgeable arsenic and chromium in CCA-treated wood surfaces and in the soil surrounding the treated wood products. Variables specific to the child playground exposures include the following:

  - The fraction of arsenic and chromium retained in wood intended for playground structures or other residential applications [AWPA standard retention levels of CCA type C in wood can range anywhere from 0.25 (pcf) for lumber used above-ground (e.g., decking floor slats) to 0.40 pcf for ground contact timbers (e.g., decking foundation posts, and playset structures)];

  - The type of CCA formulation used to treat the wood since mixtures vary in the proportion of arsenic to chromium compounds. (CCA treatment solutions are typically classified as either type A, B, or C; however, CCA type C is the most commonly used to treat dimensional lumber for residential applications.)

  - The type of pressure treated wood - douglas fir, southern pine, western cedar, red oak, etc. Hardwoods do not generally fix CCA components as well as softwoods (Arsenault, 1975);

  - The particular use of the wood (decks, construction or utility poles, marine timbers, fence posts, wood foundation lumber, plywood, and wood for playground structures, etc.) may require more or less CCA;

  - The age of the wood from which residues are measured;

  - The degree that the wood has been sanded;

  - Conditions of weathering on the wood. (Acid rain can greatly increase the amount of dislodgeable residues). Studies indicate a large variability in weathered wood surface residues, with measured residue values of *As* (III) ranging from 8 to 108 percent (Woolson and Gjovik, 1981);

  - Variables in pressure treatment process that influence the retention of CCA in wood (e.g., temperature and pH, duration of air seasoning time, rapid removal of water, rapid oven drying, etc.); and

  - Moisture content of the wood (wet wood leads to more dislodgeable residue).

- In addition to the variables mentioned above, there is general consensus that wood finishes such as an oil stain, varnish, paint or water repellant/sealant (e.g., polyurethane, acrylic or spar varnish) applied to pressure-treated wood may decrease the amounts of dislodgeable residues on CCA-treated wood surfaces. There is a wide range of effectiveness over time, depending on the type of coating used to seal the wood surfaces. Dislodgeable surface residues can be reduced by 1 to 2 orders of magnitude with an appropriate sealant.

1. Uncertainties/weaknesses of exposure data

Children may differ from adults in their susceptibility to hazardous chemicals. They have higher surface area to body weight ratios, resulting in an increased exposure dose per unit body weight than would be expected for adults similarly exposed. Also, children would be more likely than adults to exhibit behavior (e.g., hand-to-mouth activity, mouthing and eating soil) that would result in greater potential for adverse exposure. Thus, children are considered in this assessment to represent the maximum exposed population of concern in evaluating residential exposures and risks from CCA-treated wood and CCA-contaminated soils.

In illustrating the critical scenarios in this assessment, the exposure assessor will encounter several types of uncertainties and variables associated with the sources and the use of surrogate data, including:(US EPA, 1997a)

a.) Scenario uncertainties: descriptor errors; misidentification of activities; incorrect and/or insufficient information for the exposed population; ages; human factors; percentages of treated vs. untreated wood; judgement errors; overlooking or overestimating specific pathways, etc. The frequency and duration of hand contact with treated and untreated wood would vary with the different parts of playsets (e.g., handrails, slides, posts, beams, swings, monkey-bars, etc.) Another factor would be the degree of pressure when children's hands are pressed on the wood and soils, which would vary with the ages and the body weights of children.

b.) Parameter uncertainties: incorrect or biased measurements; small or unrepresentative samples; normal variability in human activities; variability in chemical-specific surrogate data.

c.) Model Uncertainties: modeling and equation errors; exclusion of more relevant variables; data gaps in scientific theory; the adjustments needed to make predictions more precisely. The models used in this assessment are based on the four exposure scenarios and the exposure pathways.

This assessment assumes transfer of the dislodgeable residues from wood and soil to the skin of children's hands at the rate of one-to-one (100% transferability). Transfer abilities (from substrate to skin) will also vary depending on the type of wood or soil involved. No data are available to determine the frequency of skin contact to soils, or to treated or untreated wood, or to non-CCA contaminated soil during the entire outdoor playing activity. Data show that human contact with treated surfaces does not result in the immediate transfer of all residues initially deposited on the surface to the skin. OPP believes this assessment, using 1-to-1 transferability and a 50% removal efficiency from hand to mouth, may overstate exposure to a significant degree. This is especially true considering that these assumptions are based on the very limited available data. There are several reasons supporting this conclusion. First, the available data are limited to studies on organic chemicals, such as the pesticide chloropyrifos. Second, numerous studies have been conducted using a variety of sampling techniques to measure transferable residues; these show a relatively lower percent than would be obtained using the solvent extraction method. In addition, lack of studies or standard methodology to estimate the transfer coefficient for the specific activity from the surface of the wood to children's hands, creates still more uncertainty associated with these unknown scenarios.

2. Strengths of data

The data selected from the EPA/ORD Exposure Factors Handbook (EFH) (e.g., age, body weight, surface area and life expectancy), OPP's Residential SOPs (e.g., frequency of hand-to-mouth events), and Superfund's RAG (Risk Assessment Guidance) (e.g., soil adherence factor) currently represent the best available science information for risk assessment and risk characterization in a residential seetting. All the assumptions are based on either the summarized data on human behaviors and characteristics affecting exposure, or on single or multiple key scientific studies used to derive the recommended values. The variabilities and uncertainties of recommended values and assumptions also have been evaluated; several factors are rated as low, medium, and high confidence. The general criteria and the considerations used to rate confidence in the Exposure Factors Handbook are listed below. The recommended values are based on the following study elements:

a. Level of peer review
b. Accessibility
c. Reproducibility
d. Focus on factor of interest
e. Data pertinent to U.S. populations
f. Source of data (primary or secondary)
g. Validity of approach
h. Study sizes
i. Representativeness of the population
j. Variability in the population, etc.

All the data from Residential SOP's are either recommended from the Scientific Advisory Panel (SAP, 1997 and 1999) or from the survey of studies in the EFH (US EPA, 1997a). This information is used by several Agencies to estimate children's exposure duration at outdoor playgrounds.

III. Dislodgeable Residue and Soil Residue Data

A. Brief summary of available data sets

OPP has evaluated data from several sources for potential use in developing the child residential exposure scenarios. Residue data were submitted by registrants of CCA pesticides (i.e., Osmose, 1980, 1983, 1998, and 2000) in support of the CCA reregistration review process, and study data were available from certain regulatory agency assessments (e.g., U.S. CPSC, 1990 and CDHS, 1987) and published scientific literature sources. In addition, heightened media focus on child "playground" exposure issues related to CCA have prompted submission to OPP of several exposure/health risk assessments which OPP will take under consideration for future use in conducting the comprehensive residential exposure assessment for CCA.

The available studies (dislodgeable surface residue/soil concentration data) considered for use in estimating CCA exposures are summarized below. Also presented are summary tables (Tables 4 and 5) which provide an overview of the existing data reviewed by OPP for potential use in developing wood and soil residue concentration estimates for generating exposure dose calculations. OPP has grouped these data based on similarities in methodologies used (e.g., wet wipe vs. dry wipe data). A more detailed summary of these studies can be found in Appendix I, and a graphical presentation of arsenic dislodgeable surface and soil residues can be found in Appendix II.

1. Study Summaries: *As* and *Cr* Dislodgeable Surface Residues from CCA-Treated Wood

Following is a brief discussion of each of the major studies related to arsenic and chromium surface residues from CCA-treated wood. Strengths and weaknesses of each study are addressed in the table which follows.

a. Arsenault (1975): To conduct the study, Arsenault used two different CCA-treated lumber samples. One type was ½-inch FDN plywood which had been recently treated and kiln dried; and the other was two-year old treated plywood. These were cut into two foot square sections. One set of each type were hosed down before sampling to remove any surface dust and to simulate conditions of a rain event. Sampling consisted of wiping with either a dry hand or one wet with distilled water. The hand wiped the surface, was washed three times with a 5% detergent (Ivory) solution, scrubbed with a toothbrush, and rinsed in distilled water. A total of 150-200 mL of solution was collected. The samples were evaporated to dryness followed by wet oxidation of the organic matter for analysis. The samples were analyzed for chromium using atomic absorption, and for arsenic by the silver diethyldithiocarbamate colorimetric procedure. Control samples were collected from three additional individuals to determine the normal amount of arsenic and chromium found on hands.

b. Osmose (1980): This study was submitted by Osmose Research Division. Nine samples of commercially produced K-33-C treated southern pine dimensional lumber were obtained from seven different treatment plants and visually rated for cleanliness as either “visibly clean”, “slight deposit” or “moderate deposit”. The surface of each board was sprayed with distilled water and then brushed with a test tube brush which had been moistened with distilled water. The wood surface and the brush were then rinsed with distilled water, taking care to collect all the rinsate. The samples were filtered through a weighed crucible with a glass fiber filter approximately 20-30 minutes following collection of the rinsate samples. The crucible was then oven-dried and reweighed in order to determine the amount of insoluble residue. The filter was then digested and analyzed for total arsenic by the silver diethyldithocarbamate spectrophotometric method in order to determine the total amount of insoluble arsenic. The filtrate was also analyzed for arsenic by the silver diethyldithocarbamate spectrophotometric method in order to determine total soluble arsenic.

c. Woolson & Gjovik (1981): This study was submitted by Woolson and Gjovik. Twelve unweathered and weathered CCA-treated 2x4 planks were obtained for the study. The age of the weathered samples ranged from 6-36 years. Replicate surface areas of 100 cm^2 were delineated on the planks and analysis was carried out by moistening the surface area with distilled water, scrubbing with a clean test tube brush (duration not specified), rinsing, collecting the rinsate and then repeating the procedure two more times. The same surface areas were then treated in an identical manner using an acidic rinse (HCL pH 4). Both the water-soluble and acid-soluble solution were then filtered or allowed to settle to remove insoluble precipitates before sampling analysis. For each set of water-soluble and acid-soluble rinsates, samples were brought to 100 mL volume. Separate aliquots were removed for analysis of i) total arsenic (As^{+++} plus As^{V}) and ii) arsenite (As^{+++}). HPLC was used to isolate arsenite from arsenate (As^{V}); arsenite is eluted from the column in three minutes and arsenate elutes after 30 minutes. Subsequent quantification was carried out using a Perkin Elmer 603 atomic absorption spectrophotometer.
For weathered samples, there were 3 different types of CCA treatment, 3 samples of CCA-I(A), 2 samples of CCA-II(B) and 2 samples of CCA-III(C) .

d. Osmose (1983): In this study, submitted by Osmose, Inc., playground equipment was sampled with wet laboratory wipes (Kimwipes), applied with hand pressure. Values are corrected for a blank/background sample that was tested (sample value-blank value = corrected value reported).

e. CDHS (1987) This study was submitted by the California Department of Health Services (CDHS). The CDHS study was used by the State of California as scientific basis for establishing revisions to Division 20 of the California Health and Safety Code. Although there is an abundance of studies that have been conducted that analyze chromated arsenical residue wipe samples from pressure-treated wood, very few studies actually examine chromated arsenical residues on the skin. CDHS provided actual data on the residues found on adult’s hands. In this study, five volunteers rubbed treated playground wood on their hands for three minutes. Although limitations should be considered when using these data (i.e., the data were not thoroughly explained and the study did not provide supportive QA/QC information), the residue data, when converted to similar units, was comparable to results from wipe samples from other studies.

In addition, this CDHS report covers numerous data from analytical methods testing to field trial sampling studies. For instance, In this report 32 wipe samples, including blank samples, were collected by two individuals from a playground structure at Cedar Rose Park. Investigators placed an acetate sheet (having two 100 cm^2 cut out areas) on the wood playground structures. The cut-out area was wiped lightly with separate cotton pads, covering the area throughly. Each exposed pad was placed in a clean plastic bag with a label. A second sampler would collect an additional two samples within a few inches of the area where the first set of samples were collected.

CDHS collected wipe samples from a joggers exercise park to compare the wipe sample method versus the brush vacuum method. Samples were collected using a cotton pad wetted with deionized water and wiped lightly over 100 cm^2. The vacuum samples were collected with the same apparatus used in the Hiziroglu and Saur studies. The sampling rate was 1.0 liter/minute and samples were collected for five minutes on three different pieces of wood. A wipe and vacuum sample was collected on each piece of wood within two inches of each other.

CDHS also collected wipe samples from several wooden playground structures located in municipal playgrounds. No detailed information on the sampling methodology was provided in the study. Wipe samples from five other Berkeley city parks where the treatment and date of installation were unknown were included in the CDHS study. No detailed information on the sampling methodology of the wet wipes was provided.

CDHS reported data collected in the Michigan Technological University (MTU) Study. MTU used Whatman No. 42 filter paper moistened with distilled water for the wipe test. Both single and multiple wipes were used. No further information on the sampling methodology was provided in the CDHS study. CDHS reported data of a study conducted by the Monterey County Health Department in a response to an arsenical health incident. Wipe samples were collected at six locations on the fishing pier and analyzed for arsenic concentrations. Wet and dry samples were collected before and after the wood was washed.

f. CPSC (1990): This study was conducted by the U.S. Consumer Product Safety Commission (CPSC). According to CPSC, arsenic residue samples were collected from new playground wood samples from six major manufacturers of playground equipment. A minimum of 10 subsamples were collected per finishing per manufacturer. The wood for all playground equipment was pine and treated to a minimum retention of 0.40 lb/ft^3 (PCF as the other) with CCA. An unfinished sample of 0.40 lb/ft^3 CCA-treated Southern yellow pine was obtained from a hardware store for comparison. No dislodgeable arsenic was detected in samples of non-treated wood during methodology development. Therefore, untreated wood samples were not collected for testing. Of the 10 subsamples submitted to HSHL, 5 were selected for testing. Five replicates were performed on each subsample. Each replicate consisted of 10 repetitive wiping cycles (1 cycle= back and forth) across a measured 400 cm^2 area. The wipe was performed using a nylon material fastened to an 8 cm x 8 cm block (64 cm^2). The weight of the block was 1 kg. Wood splinters did not get stuck in the nylon material. Each nylon wipe was placed in 25 mL of 0.01 N HCl (pH 2) for 18-24 hr with occasional agitation to dissolve the acid soluble arsenic. The solution was then analyzed by inductively-coupled plasma spectrometry using the third arsenic line (235 nm). CPSC sampled commercial unfinished, sanded, southern pine wood, sanded only, and core cut/stained wood with a nylon wipe.

g. Riedel et al. (1991): Ten outdoor wooden playground structures built up to ten years previously with CCA-treated wood were utilized for this study submitted by D. Riedel et al. One meter of the wood surface (approximately 0.05 m^2 total surface area) was wiped with a 4 x 4 inch piece of 8-ply gauze which was dampened with 3 mL of distilled water. The gauze was folded in half and wiped over the same length of wood again for a total of 2 meters/wipe sampled. Shorter surfaces (length not specified) were wiped four times, folding the gauze each time, as described above for a total of 2 meters/wipe. Four samples were collected from each of the ten playground structures in places of frequent contact. Control samples were collected by dampening a gauze pad with 3 mL of distilled water (number of samples not specified). Following sampling, all of the wipes were placed in a 50 mL centrifuge tube, the gauze pads were equilibrated with 20 mL of 1 M nitric acid for 48 hours, centrifuged, and the sample solution was stored in a covered container at 4°C.

h. Doyle (1992) & Malaiyandi (1993): For sampling, a 10 x 10 cm piece of 8-ply gauze was used. The gauze was folded in half to create a 5 x 10 cm piece which was then attached to a holding block with spring clamps (total weight 575 g). The gauze was moistened with 3 mL of distilled water and wiped across a 5 cm by 1 meter area of wood. The gauze was folded and wiped over another 5 cm by 1 meter area, for a total of 0.1 m^2 sampled by each wipe. One sample was collected at five different locations on each structure for a total of 25 samples. Note: Data are values reported were collected from three studies. Malaiyandi (1993) is Phase 2 of the Doyle (1992) study.

i. Stilwell (1998): This study was submitted by David E. Stilwell. Seven sets of eight-foot CCA pressure-treated boards were used for the study. Each set consisted of 3 to 4 boards which were cut into 1 or 2 foot pieces referred to as “wood coupons”. The boards had been previously treated to a level of 0.4 pounds of CCA (Type C) per cubic foot. Three of the sets were pine boards treated with both CCA and a water repellent. To test for dislodgeable arsenic, a polyester cloth wipe was attached to an 8 x 13 cm wood block which was cushioned with rubber and sealed with polypropylene tape to minimize wood irregularities. The cloth was dampened in 1.5 times its weight with deionized water. Prior to sampling a 1.25 kg weight was placed on top of the block. The wipe samples were collected by pulling the weighted block back and forth across 28-30 cm of the test surface five times.

Additionally, wooden playscapes built with CCA-treated wood at three municipal parks were tested by Stilwell. A total of 45 wipe samples were collected from horizontal wood surfaces as described above. Stilwell also tested vertical support poles. A total of 12 samples were collected utilizing hand pressure on the wipe rather than the wood block and weight.

j. Osmose (1998): This study, submitted by Osmose, Inc., was conducted using 2"x6"x12" pieces of pressure treated lumber. The samples consisted of seven CCA-treated yellow pine samples with two aged (by at least 5 years) samples, one CCA-treated hemlock/fir, and one untreated yellow pine control. Five of the samples received one of the following additional treatments before testing: Superdeck™ Natural Redwood Stain, 3M Clear Sealer, Osmose Water Repellent, Osmose Brand Oxidizer, or Superdeck™ Acid Brightener. Kimwipe sampling of the lumber was conducted by rubbing the wipes firmly over 100 cm^2 of wood five times. Five additional unused Kimwipes were used as negative controls. The samples were treated using microwave digestion in 8N nitric acid then analyzed by GF-AAS as above for the presence of total arsenic, chromium and copper. Values reported do not include untreated yellow pine data, only the 8 CCA treated samples were incorporated into the analysis.

Table 5: Summary of Dislodgeable Surface Residue Data for CCA-Treated Wood

ARSENIC				
WET WIPES (UG/CM2)	**MEAN**	**MAX**	**MIN**	**N**
Cedar Rose Park (CDHS, 1987)[a]	0.89	3.14	0.03	28
Joggers Exercise Station (CDHS, 1987)[b]	1.37	1.70	1.20	3
Initial Survey (CDHS, 1987)[c]	2.77	33.27	0.001	21
Wet Wipes from Five Parks (CDHS, 1987)[d]	0.13	1.14	0.01	15
MTU (CDHS, 1987)[e]	0.70	1.62	0.17	8
Monterey Fishing Pier (CDHS, 1987)[f]	9.60	21.30	0.10	11
Lumberyard Cotton Gauze (CDHS,1987)[g]	0.89	2.54	0.27	16
Stilwell, 1998 **[h]	0.40	1.22	0.06	52
Stilwell 1998 **[hi]	0.09	0.45	0.02	45
Stilwell 1998 **[hj]	1.05	6.32	0.05	12
Riedel (Nov. 1991)[k]	0.09	0.64	0.00	40
Osmose (1980) [l]	1.20	5.11	0.12	9
Osmose (Sept. 1983)[m]	0.059	0.078	0.034	10
Osmose (Oct. 1983)[m]	0.062	0.222	0.001	20
Woolson & Gjovik (1981, unweathered)[n]	1.14	2.49	0.50	5
Woolson & Gjovik (1981, weathered)[no]	0.28	0.51	0.10	7
Doyle (1992), Malaiyandi (no date), Malaiyandi (1993)[p]	0.07	0.19	0.004	66

CHROMIUM				
WET WIPES (UG/CM2)	**MEAN**	**MAX**	**MIN**	**N**
Cedar Rose Park (CDHS, 1987)[a]	1.04	3.88	0.07	28
Riedel (Nov. 1991)[k]	0.06	0.51	0.002	40.00
Osmose (Sept. 1983)[m]	0.052	0.10	0.032	10
Osmose (Oct. 1983)[m]	0.092	0.222	0.035	20
Doyle (1992), Malaiyandi (no date), Malaiyandi (1993)[p]	0.08	0.25	0.003	66.00
ARSENIC				
DRY WIPES (UG/CM2)	**MEAN**	**MAX**	**MIN**	
Monterey Fishing Pier (CDHS, 1987)[f]	10.98	25.67	0.04	11
Hiroziroglu,1985 (cited within CDHS, 1987)**[q]	1.78	NA	NA	21
U.S. CPSC, 1990 **[r s]	0.69	NA	NA	NA
U.S. CPSC, 1990 **[r s]	0.22	NA	NA	NA
U.S. CPSC, 1990 **[r s]	0.32	NA	NA	NA
U.S. CPSC, 1990 **[r t]	<0.062	NA	NA	NA
Osmose (1998)[u v]	0.18	0.96	0.019	40
CHROMIUM				
DRY WIPES (UG/CM2)	**MEAN**	**MAX**	**MIN**	
Osmose (1998)[u v]	0.19	0.75	0.037	40
ARSENIC				
VACUUM BRUSH (UG/CM2)	**MEAN**	**MAX**	**MIN**	
MTU (CDHS, 1987)[w]	6.18	10.81	2.84	16
MTU Field Test Parks (CDHS, 1987)[x]	2.43	16.40	0.41	20
Hiroziroglu,1985 (cited within CDHS, 1987)** [q]	0.63	NA	NA	21
MTU-Clean (cited within CDHS, 1987)***[y]	1.60	NA	NA	NA
MTU-Light Residue (cited within CDHS, 1987)***[y]	4.11	NA	NA	NA
MTU-Heavy Residue (cited within CDHS, 1987)***[y]	8.07	NA	NA	NA
MTU-Visibly Dirty (cited within CDHS, 1987)***[y]	23.18	NA	NA	NA
MTU Lumberyard (CDHS, 1987)[x]	13.76	75.05	0.43	14
Joggers Exercise Station (CDHS, 1987)[b]	1.22	1.60	0.57	3
Saur et al. 1983 (cited within CDHS, 1987)**[z]	0.18	1.27	0.002	27
ARSENIC				
DRY HAND WIPES (UG/CM2)	**MEAN**	**MAX**	**MIN**	
Arsenault, 1975[aa]	0.008	0.026	0.001	8
MTU-Clean (cited within CDHS, 1987)***[bb]	0.23	NA	NA	NA
MTU-Light Residue (cited within CDHS, 1987)***[bb]	0.403	NA	NA	NA
MTU-Heavy Residue (cited within CDHS, 1987)***[bb]	1.033	NA	NA	NA
MTU-Visibly Dirty (cited within CDHS, 1987)***[bb]	1.80	NA	NA	NA
5 Volunteers (CDHS, 1987)*[cc]	0.26	0.43	0.13	5
Urine Arsenic Study (CDHS, 1987)[dd]	1.40	1.40	1.40	1
Osmose (1998)[ee]	0.045	0.17	0.003	78

CHROMIUM				
DRY HAND WIPES (UG/CM2)	MEAN	MAX	MIN	N
Arsenault, 1975[aa]	0.044	0.045	0.043	2
Osmose (1998)[ee]	0.044	0.15	0.002	79
5 Volunteers(CDHS, 1987)*[cc]	0.390	0.640	0.192	5
ARSENIC				
WET HAND WIPES (UG/CM2)	MEAN	MAX	MIN	N
Arsenault, 1975[aa]	0.22	0.57	0.08	8
CHROMIUM				
WET HAND WIPES (UG/CM2)	MEAN	MAX	MIN	N
Arsenault, 1975[aa]	0.49	0.67	0.31	2

N=Number of Replicates (i.e., Sample Size)
NA = Not available
*Converted from ug to ug/cm2 assuming the palm areas of hand is 450 cm2 and both hands contact wood giving a total surface area of 900 cm2
**No raw data. Data summary is only available.
***No raw data. Data summary is only available based on surface residue condition (e.g, clean, light residue, heavy residue, and visibly dirty)

a. This study was submitted by the California Department of Health Services (CDHS). In this study 32 wipe samples, including blank samples, were collected by two individuals from a playground structure at Cedar Rose Park. Investigators placed an acetate sheet (having two 100 cm^2 cut out areas) on the wood playground structures. The cut-out area was wiped lightly with separate cotton pads, covering the area throughly. Each exposed pad was placed in a clean plastic bag with a label. A second sampler would collect an additional two samples within a few inches of the area where the first set of samples were collected.

b. CDHS collected wipe samples from a joggers exercise park to compare the wipe sample method versus the brush vacuum method. Samples were collected using a cotton pad wetted with deionized water and wiped lightly over 100 cm^2. The vacuum samples were collected with the same apparatus used in the Hiziroglu and Saur studies. The sampling rate was 1.0 liter/minute and samples were collected for five minutes on three different pieces of wood. A wipe and vacuum sample was collected on each piece of wood within two inches of each other.

c. CDHS collected wipe samples from several wooden playground structures located in municipal playgrounds. No detailed information on the sampling methodology was provided in the study.

d. Wipe samples from five other Berkeley city parks where the treatment and date of installation were unknown were included in the CDHS study. No detailed information on the sampling methodology of the wet wipes was provided in the CDHS study.

e. CDHS reported data collected in the Michigan Technological University (MTU) Study. MTU used Whatman No. 42 filter paper moistened with distilled water for the wipe test. Both single and multiple wipes were used. No further information on the sampling methodology was provided in the CDHS study.

f. CDHS reported data of a study conducted by the Monterey County Health Department in a response to an arsenical health incident. Wipe samples were collected at six locations on the fishing pier and analyzed for arsenic concentrations. Wet and dry samples were collected before and after the wood was washed.

g. In a spin-off study of surface arsenic residue levels on wood, cotton gauze wipe samples were collected from wood a local lumberyard having treated wood from several sources. Samples were taken from different boards in a bundle of wood. The exact sampling method was not included in the CDHS study.

h. This study was submitted by David E. Stilwell. Seven sets of eight-foot CCA pressure-treated boards were used for the study. Each set consisted of 3 to 4 boards which were cut into 1 or 2 foot pieces referred to as “wood coupons”. The boards had been previously treated to a level of 0.4 pounds of CCA (Type C) per cubic foot. Three of the sets were pine boards treated with both CCA and a water repellent. To test for dislodgeable arsenic, a polyester cloth wipe was attached to an 8 x 13 cm wood block which was cushioned with rubber and sealed with polypropylene tape to minimize wood irregularities. The cloth was dampened in 1.5 times its weight with deionized water. Prior to sampling a 1.25 kg weight was placed on top of the block. The wipe samples were collected by pulling the weighted block back and forth across 28-30 cm of the test surface five times.

i. Additionally, wooden playscapes built with CCA-treated wood at three municipal parks were tested by Stilwell. A total of 45 wipe samples were collected from horizontal wood surfaces as described above.

j. Stilwell also tested vertical support poles. A total of 12 samples were collected utilizing hand pressure on the wipe rather than the wood block and weight.

k. Ten outdoor wooden playground structures built up to ten years previously with CCA-treated wood were utilized for this study submitted by D. Riedel et al. One meter of the wood surface (approximately 0.05 m^2 total surface area) was wiped with a 4 x 4 inch piece of 8-ply gauze which was dampened with 3 mL of distilled water. The gauze was folded in half and wiped over the same length of wood again for a total of 2 meters/wipe sampled. Shorter surfaces (length not specified) were wiped four times, folding the gauze each time, as described above for a total of 2 meters/wipe. Four samples were collected from each of the ten playground structures in places of frequent contact. Control samples were collected by dampening a gauze pad with 3 mL of distilled water (number of samples not specified). Following sampling, all of the wipes were placed in a 50 mL centrifuge tube, the gauze pads were equilibrated with 20 mL of 1 M nitric acid for 48 hours, centrifuged, and the sample solution was stored in a covered container at 4°C.

l. This study was submitted by Osmose Research Division. Nine samples of commercially produced K-33-C treated southern pine dimension lumber were obtained from seven different treating plants and visually rated for cleanliness as either “visibly clean”, “slight deposit” or “moderate deposit”. The surface of each board was sprayed with distilled water and then brushed with a test tube brush which had been moistened with distilled water. The wood surface and the brush were then rinsed with distilled water, taking care to collect all the rinsate. The samples were filtered through a weighed gooch crucible with a glass fiber filter approximately 20-30 minutes following collection of the rinsate samples. The crucible was then oven-dried and reweighed in order to determine the amount of insoluble residue. The filter was then digested and analyzed for total arsenic by the silver diethyldithocarbamate spectrophotometric method in order to determine the total amount of insoluble arsenic. The filtrate was also analyzed for arsenic by the silver diethyldithocarbamate spectrophotometric method in order to determine total soluble arsenic

m. In this study, submitted by Osmose, Inc., playground equipment was sampled with wet laboratory wipes (Kimwipes), applied with hand pressure. Values are corrected for a blank/background sample that was tested (sample value-blank value = corrected value reported).

n. This study was submitted by Woolson and Gjovik. Twelve unweathered and weathered CCA-treated 2x4 planks were obtained for the study. The age of the weathered samples ranged from 6-36 years. Replicate surface areas of 100 cm^2 were delineated on the planks and analysis was carried out by moistening the surface area with distilled water, scrubbing with a clean test tube brush (duration not specified), rinsing, collecting the rinsate and then repeating the procedure two more times. The same surface areas were then treated in an identical manner using an acidic rinse (HCL pH 4). Both the water-soluble and acid-soluble solution were then filtered or allowed to settle to remove insoluble precipitates before sampling analysis. For each set of water-soluble and acid-soluble rinsates, samples were brought to 100 mL volume. Separate aliquots were removed for analysis of i) total arsenic (As^{+++} plus As^{V}) and ii) arsenite (As^{+++}). HPLC was used to isolate arsenite from arsenate (As^{V}); arsenite is eluted from the column in three minutes and arsenate elutes after 30 minutes. Subsequent quantification was carried out using a Perkin Elmer 603 atomic absorption spectrophotometer.

o. For weathered samples, there were 3 different types of CCA treatment, 3 samples of CCA-I(A), 2 samples of CCA-II(B) and 2 samples of CCA-III.

p. For sampling, a 10 x 10 cm piece of 8-ply gauze was used. The gauze was folded in half to create a 5 x 10 cm piece which was then attached to a holding block with spring clamps (total weight 575 g). The gauze was moistened with 3 mL of distilled water and wiped across a 5 cm by 1 meter area of wood. The gauze was folded and wiped over another 5 cm by 1 meter area, for a total of 0.1 m^2 sampled by each wipe. One sample was collected at five different locations on each structure for a total of 25 samples. Note: Data are values reported were collected from three studies. Doyle (1992) and Malaiyandi (no data) are the same data. Malaiyandi (1993) is Phase 2 of the Doyle study.

q. CDHS reported data of a study conducted by Hiziroglu that compared the wipe test method with the vacuum brush test method. In this study, 21 wipe samples were collected on CCA-treated wood. No further information on the sampling methodology was provided in the CDHS study.

r.   This study was conducted by the U.S. Consumer Product Safety Commission (CPSC). According to CPSC, arsenic residue samples were collected from new playground wood samples from six major manufacturers of playground equipment. A minimum of 10 subsamples were collected per finishing per manufacturer. The wood for all playground equipment was pine and treated to a minimum retention of 0.40 lb/ft^3 (PCF as the other) with CCA. An unfinished sample of 0.40 lb/ft^3 CCA-treated Southern yellow pine was obtained from a hardware store for comparison. No dislodgeable arsenic was detected in samples of non-treated wood during methodology development. Therefore, untreated wood samples were not collected for testing. Of the 10 subsamples submitted to HSHL, 5 were selected for testing. Five replicates were performed on each subsample. Each replicate consisted of 10 repetitive wiping cycles (1 cycle= back and forth) across a measured 400 cm^2 area. The wipe was performed using a nylon material fastened to an 8 cm x 8 cm block (64 cm^2). The weight of the block was 1 kg. Wood splinters did not get stuck in the nylon material. Each nylon wipe was placed in 25 mL of 0.01 N HCl (pH 2) for 18-24 hr with occasional agitation to dissolve the acid soluble arsenic. The solution was then analyzed by inductively-coupled plasma spectrometry using the third arsenic line (235 nm).

s.   CPSC sampled unfinished, sanded, southern pine wood, sanded only, and core cut/stained wood with a nylon wipe. Listed in that order on the table.

t.   CPSC sampled commercial wood with a nylon wipe.

u. This study, submitted by Osmose, Inc., was conducted using 2"x6"x12" pieces of pressure treated lumber. The samples consisted of seven CCA-treated yellow pine samples with two aged (by at least 5 years) samples, one CCA-treated hemlock/fir, and one untreated yellow pine control. Five of the samples received one of the following additional treatments before testing: Superdeck™ Natural Redwood Stain, 3M Clear Sealer, Osomose Water Repellent, Osmose Brand Oxidizer, or Superdeck™ Acid Brightener. Kimwipe sampling of the lumber was conducted by rubbing the wipes firmly over 100 cm^2 of wood five times. Five additional unused Kimwipes were used as negative controls. The samples were treated using microwave digestion in 8N nitric acid then analyzed by GF-AAS as above for the presence of total arsenic, chromium and copper.

v. Values reported do not include untreated yellow pine data, only the 8 CCA treated samples were incorporated into the analysis.

w. The Institute of Wood Research at Michigan Technology University (MTU) conducted a brush vacuum study and reported that "statistical analysis of the optimization data show that down to a confidence level of 95%, none of the conditions of flow rate, length, diameter, and revolutions per minute had an effect on the results." MTU used the vacuum brush method to analyze wood samples from four different treatment plants. The raw data were not presented in the CDHS report.

x.   The Institute of Wood Research at Michigan Technology University (MTU) conducted a field test using its vacuum brush apparatus in the San Francisco Bay Area, where samples were collected from one municipal playground (age 17 years) on elementary school playground (age 3 years), and from wood treated at three treatment plants purchased at local lumber yards.

y. The Institute of Wood Research at Michigan Technology University (MTU) compared the efficacy of the vacuum brush to the wipe and water scrub method. In developing the equipment and procedures to collect samples, visibly dirty residues were intentionally produced in the laboratory. This comparison used "visibly clean" smooth and rough cut wood. No further detail on the vacuum brush method was provided in the CDHS Study.

z. The brush vacuum method was originally developed by Saur et. al (1983) to determine the amount of respirable and nonrespirable arsenic present on the surface of wood treated with arsenicals. CDHS (1987) described the brush vacuum method as follows: "The sampling apparatus consisted of a brush nozzle connected to a vacuum pump. The brush was swept over a specified area of the treated wood and the dislodged surface residues were trapped on a cellulose ester filter. The residue particles were differentiated into respirable (<10 μm) and nonrespirable sizes."

aa.   To conduct the study, Arsenault used two different CCA-treated lumber samples. One type was ½-inch FDN plywood which had been recently treated and kiln dried; and the other was two-year old treated plywood. These were cut into two foot square sections. One set of each type were hosed down before sampling to remove any surface dust and to simulate conditions of a rain event. Sampling consisted of wiping with either a dry hand or one wet with distilled water. The hand wiped the surface, was washed three times with a 5% detergent (Ivory) solution, scrubbed with a toothbrush, and rinsed in distilled water. A total of 150-200 mL of solution was collected. The samples were evaporated to dryness followed by wet oxidation of the organic matter for analysis. The samples were analyzed for chromium using atomic absorption, and for arsenic by the silver diethyldithiocarbamate colorimetric procedure. Control samples were collected from three additional individuals to determine the normal amount of arsenic and chromium found on hands.

bb. The Institute of Wood Research at Michigan Technology University (MTU) conducted another experiment to correlate the amount of arsenic collected by the vacuum brush method with the amount of arsenic picked up by rubbing the treated wood with a bare hand. No further detail on the bare hand method was provided in the CDHS Study.

cc. This study was submitted by the California Department of Health Services (CDHS). Samples from 5 volunteers were analyzed for CCA residues. CDHS (1987) describes the direct hand wipe method as follows: "Before any of the treated wood was touched, a volunteer washed his hands with about 100 ml of deionized water. The rinse water was collected and analyzed for total arsenic. The volunteer then rubbed his hands over the treated wood structure one time for just a few seconds. The hands were again washed with about 100 mL of deionized water and the rinse water collected for analysis. The hands were washed again to remove any residual arsenic. The volunteer rubbed his hands briskly over the same treated wood for about three minutes. The hands were washed twice and the rinse water was collected separately for analysis."

dd. This study was submitted by the California Department of Health Services (CDHS). To determine the amount of arsenic absorbed by humans, a 70 kg volunteer handled a CCA-treated playground pole (about 5500 cm^2 or 23 $\mu g/100cm^2$) for 5-minutes, washed the residues from his hands, and ingested the rinsed liquid. The urine sample was first reduced using sodiumborohydrate, so that arsenic (organic) from seafood was not measured.

ee. This study, submitted by Osmose, Inc., was conducted using 2"x6"x12" pieces of pressure treated lumber. The samples consisted of seven CCA-treated yellow pine samples with two aged (by at least 5 years) samples, one CCA-treated hemlock/fir, and one untreated yellow pine control. Five of the samples received one of the following additional treatments before testing: Superdeck™ Natural Redwood Stain, 3M Clear Sealer, Osomose Water Repellent, Osmose Brand Oxidizer, or Superdeck™ Acid Brightener. Hand sampling of the lumber was conducted with five adult volunteers firmly grasping the sample with both hands a total of ten times. Each hand was rinsed with approximately 15 mL of reagent grade water, acidified with nitric acid (pH not reported) and brought to volume in a 100 mL flask. Each hand was rinsed separately into individual flasks providing duplicate samples (left and right) for each treatment. The samples were analyzed in triplicate using graphite furnace atomic absorption spectrophotometry (GF-AAS) to test for total arsenic, chromium, and copper. Values reported do not include untreated yellow pine data, only the 8 CCA treated samples were incorporated into the analysis.

2. Study Summaries: *As* and *Cr* Residue Concentration Data from CCA-Contaminated Soil

Following is a brief discussion of each of the major studies related to arsenic and chromium soil residues from CCA-contaminated soil. Strengths and weaknesses of each study are addressed in the table which follows.

a. Riedel et al. (1991): Ten outdoor wooden playground structures built up to ten years previously with CCA-treated wood were utilized for the study. At each playground site, four sand/soil samples were collected near or underneath the wooden structures. The depth of the soil sample was not provided. All of the samples were dried in an 80°C oven for 3 hours. Ten grams of each sample were placed in a 50 mL centrifuge tube, equilibrated with 20 mL of 1 M nitric acid for 48 hours, centrifuged, and the sample solution was stored in a covered container at 4°C. The samples were analyzed for arsenic by atomic absorption spectrophotometry using a Perkin-Elmer Sciex Elan Model 250.

b. Doyle (1992) & Malaiyandi (1993): For each fence unit (12 total) six samples were collected, one underneath each board, which were combined into one composite sample. Soil and sand samples were collected at the base of the vertical posts (6 x 6 inch) and sand samples were collected at the base of the diagonal supports (4 x 4 inch). A composite sample was made by combining individual samples from each of the four supports. The samples were analyzed for arsenic by ICP/MS using a Perkin-Elmer Sciex Elan Model 250. The soil/sand samples were also tested for chromium concentrations by flame atomic absorption spectrometry. Note: Data are values reported were collected from three studies. Malaiyandi (1993) is Phase 2 of the Doyle (1992) study.

c. Stilwell & Gorny (1997): Soil samples from under seven decks in Connecticut were collected for the study. A total of 85 randomly selected soil samples were taken from under decks ranging in age from 4 months to 15 years. The size of the decks ranged from 18 to 50 square meters. The soil area under the deck was divided into a grid pattern; and one sample per every 2 square meters was collected. Each sample consisted of approximately 100 grams of soil taken from the upper five centimeters. The samples were dried and prepared for analysis by microwave digestion and the metal content was determined by atomic spectroscopy.

d. Osmose (2000): Soil samples from under approximately ten decks from Northern Virginia were collected. Approximately 42 randomly selected soil samples were taken from under both the medium aged and the older decks. The soil area under the deck was divided into a grid pattern; each grid was two square meters. Each of the samples were duplicated, with another sample taken just adjacent to the first. Each soil sample consisted of approximately 500 grams of soil taken from the upper 5 centimeters.

e. Townsend and Solo-Gabriele (2001): Nine structures in Florida were utilized for the study. The ages of the wooden structures ranged in age from 2 to 19 years. Samples were collected from under the structures using the grid-method in which 65 samples were collected. All samples were collected within the top one inch of the surface. Samples were dried at 105°C and analyzed with a Perkin Elmer 5100 atomic absorption spectrophotometer.

Arsenic was determined with the graphite furnace technique. Chromium was measured by the flame-AAS technique.

Table 6: Summary of Residue Concentration Data for CCA-Contaminated Soil

ARSENIC				
SOIL (MG/KG)	**MEAN**	**MAX**	**MIN**	**N**
Riedel, 1991[a]	5.51	113.10	-0.04	40
Osmose (2000)[b]	23.97	85.0	5.14	73
Doyle (1992), Malaiyandi (no date), Malaiyandi (1993)- soil[c]	16.73	54.32	0.37	58
Doyle (1992), Malaiyandi (no date), Malaiyandi (1993)- sand[c]	12.71	27.21	0.24	56
Stilwell & Gorny (1997)[d]	76	350	3	85
Townsend & Solo-Gabriele (2001)[e]**	28.3	217	0.25	65
CHROMIUM				
SOIL (MG/KG)	**MEAN**	**MAX**	**MIN**	**N**
Doyle (1992), Malaiyandi (no date), Malaiyandi (1993)- soil[c]	11.33	45.58	0.27	58
Doyle (1992), Malaiyandi (no date), Malaiyandi (1993)- sand[c]	8.83	21.03	1.34	56
Stilwell & Gorny (1997)[d]	43	154	16	85
Townsend & Solo-Gabriele (2001)[e]**	30.5	198.5	0.71	65

N=Number of Replicates (i.e., Sample Size)
** No raw data. Data summary is only available.
NA = Not available

a. Ten outdoor wooden playground structures built up to ten years previously with CCA-treated wood were utilized for the study. At each playground site, four sand/soil samples were collected near or underneath the wooden structures. The depth of the soil sample was not provided. All of the samples were dried in an 80°C oven for 3 hours. Ten grams of each sample were placed in a 50 mL centrifuge tube, equilibrated with 20 mL of 1 M nitric acid for 48 hours, centrifuged, and the sample solution was stored in a covered container at 4°C. The samples were analyzed for arsenic by atomic absorption spectrophotometry using a Perkin-Elmer Sciex Elan Model 250.

b. Soil samples from under approximately ten decks from Northern Virginia were collected. Approximately 42 randomly selected soil samples were taken from under both the medium aged and the older decks. The soil area under the deck was divided into a grid pattern; each grid was two square meters. Each of the samples were duplicated, with another sample taken just adjacent to the first. Each soil sample consisted of approximately 500 grams of soil taken from the upper 5 centimeters.

c. For each fence unit (12 total) six samples were collected, one underneath each board, which were combined into one composite sample. Soil and sand samples were collected at the base of the vertical posts (6 x 6 inch) and sand samples were collected at the base of the diagonal supports (4 x 4 inch). A composite sample was made by combining individual samples from each of the four supports. The samples were analyzed for arsenic by ICP/MS using a Perkin-Elmer Sciex Elan Model 250. The soil/sand samples were also tested for chromium concentrations by flame atomic absorption spectrometry. Note: Data are values reported were collected from three studies. Doyle (1992) and Malaiyandi (no data) are the same data. Malaiyandi (1993) is Phase 2 of the Doyle study.

d. In this study a total of 85 soil sample replicates were collected in polypropylene containers from under seven decks built with CCA pressure-treated lumber. Both control and experimental data were collected. The deck sizes ranged from 22-50 m^2. The decks were between 0.3-15 years old, and two of the seven decks were coated with a sealer. A sample was collected in a two square meter area. The average weight of the samples was 100 g. The soil samples were dried by microwave digestion and the Cu, Cr, and As content was determined by atomic emission spectrometry (AES). The detection limits in soil were 1.2 (Cu), 1.6 (Cr), and 9 (As) mg/kg.

e. Nine structures in Florida were utilized for the study. The ages of the wooden structures ranged in age from 2 to 19 years. Samples were collected from under the structures using the grid-method in which 65 samples were collected. All samples were collected within the top one inch of the surface. Samples were dried at 105°C and analyzed with a Perkin Elmer 5100 atomic absorption spectrophotometer. Arsenic was determined with the graphite furnace technique. Chromium was measured by the flame-AAS technique.

IV. Sealants

A. Summary of Available Data Sets

Since leaching of the metals into soils and on wood surfaces is of concern from the exposure and health hazard points of view, it is important to find ways, if possible, to either eliminate or decrease the amounts of the metals leaching. One method would be to apply sealants to the CCA treated wood to decrease the amounts of leaching of the metals on the wood surfaces or leaching of metals into the soils. A few studies have been conducted which evaluate the effects of sealants.

1. California Department of Health Services (CDHS, 1987)

CDHS conducted studies on the leaching of the CCA components from treated wood and carried out a 'wipe study' on the dislodgeable residues of these metals on the wood surfaces of the playground equipment, and other structures like fishing piers, made out of CCA-treated wood. The studies also included estimation of residues of arsenic on the wood surfaces of the lumber which were treated with CCA and further treated with a polyurethane sealer.

a. Fishing Pier Study

A fishing pier in Monterey County was selected, as it represented a high exposure location because of its use pattern. Wipe samples were collected directly following application of a polyurethane sealant to the surface of this CCA-treated fishing pier. These were analyzed and it was shown that surface arsenic levels were less than 10 $\mu g/100\ cm^2$. Two years later, wipe samples from the same surfaces of the wood were collected again and these were analyzed for arsenic concentrations.

The wiping method used for collecting arsenic concentrations consisted of these major steps:

i. At specific areas on the structure a sampler would place an acetate sheet having two 100 cm^2 cut-out areas and wipe the wood 'lightly in each cut-out area with separate cotton pads to cover the area thoroughly'. Each pad was placed immediately in a labeled plastic bag.

ii. A second sampler would collect two samples from the area not too far from the first sampler's area.

iii. The samples so collected were then analyzed for arsenic amounts.

Table 7: Surface Arsenic Concentrations of Fishing Pier: Two Years After Sealing with Polyurethane (CDHS, 1987)

Sample	
1	12.0
2	31.7
3	65.3
4	50.8
Blank	Not Detected

b. Play Structure Study

CDHS also investigated the effect of a sealant (oil-based) on leaching of arsenic from a CCA-treated wood play structure. This study was carried out at the Cedar Rose Park in Berkeley

1. Before the oil-based stain (sealant) was applied, gauze wipe and hand wipe samples were collected and analyzed for arsenic (blanks).

2. After the stain was applied, gauze and hand wipe samples were again collected one month, six months, and two years later.

3. All samples were analyzed for arsenic concentrations. Table 3 summarizes the data.

Table 8: Arsenic Levels Determined on Rose Park Play Structure Before and After the Stain Applications[1] (CDHS, 1987)

Time After Sealing	Gauze Wipe(µg/100 cm^2)	Hand Wipe (Total µg)
Before Sealing	30.94-313.75	130-280
1 month	6.0-11.0	9.8
6 months	1.0-13	ns*
2 years	54	ns*

ns* not sampled

1. Reproduced from the CDHS Study, 1987

2. US Consumer Product Safety Commission (CPSC, 1990)

CPSC conducted a study on the dislodgeable arsenic from pressure-treated wood used for playground equipment. Part of the study included data on leaching of arsenic from CCA-treated wood on which sealants have been applied.

a. Summary of the study

All wood used for the study was southern pine and the retention pressure was determined to be 0.40 pounds per cubic foot (pcf). Two wood samples (in triplicate) were selected and treated with oil based stain or water repellent/sealant, which are commonly available in the market place. The coated samples were allowed to cure for one week. The samples were kept in a well-ventilated hood at room temperature.

Table 9: Dislodgeable Arsenic from Uncoated and Coated (Oil-based Paint and Water Repellent) Wood Samples. (CPSC, 1990)

Sample #	Coating	Dislodgeable Arsenic (μg/100 cm^2)
L830-8638	uncoated	21.9 ± 22.5 (av± sd)
	oil stain	9.7±3.0 (av±sd)
	repel/sealant	14.0±6.8(av±sd)
K860-6165	uncoated	32.1±22.2(av±sd)
	oil stain	53.0±35.0(av±sd)
	repel/sealant	52.5±26.4(av±sd)

The authors noted that " no statistical differences in dislodgeable arsenic levels within either wood samples were found by 1-way analysis of variance of oil stain vs. repellent/sealant or in before vs. after coating."

3. Riedel et al. (1991)

This group of Canadian scientists investigated the leaching of CCA metals from playground equipment**.** Part of the document presents data on the dislodgeability of arsenic and chromium from treated wood which has been coated with sealants.

a. Summary of the study

Playground structures chosen for the study were either uncoated or coated with stains/paints. Wipe samples were collected from all structures depending on the locations that were deemed as 'high traffic' areas. Generally the locations from where the samples were acquired were: handrail of slide, handrail of platform, handrail of stairs, step ladder, one particular rung, handrail of suspended bridge, second rung from the bottom of monkey bars etc. Wipes were made from cotton, $10cm^2$, 8-ply. The area of each wipe was approximately 0.05 m^2 (500 cm^2).

Table summarizes the data on the amounts of arsenic and chromium obtained from the wipe study on the playground structures.

Table 10: Analytical Amounts of Arsenic and Chromium Obtained From Wipe Samples (Riedel et al., 1991)

Wipe Sample	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Year of Construction	1986	1983	1980	1988	1980	1987	1978	1982	1979	1979
Coated/[1] uncoated/ painted	not painted	not painted or stained	stained but worn	painted	staine d but worn	stained/ not stained	stained/ stained/ worn	not stained	not painted/ stained good cond.	painted/ stained/ worn
Mean As (±sd)	31.1 (±15.7)	67.9 (±19.1)	64.0 (±25.7)	34.5 (±12.1)	25.2 (±5.7)	30.2 (±7.0)	13.4 (±10.8)	149.3 (±124.4)	4.8 (±5.0)	17.8 (±18.8)
Mean Cr (±sd)	11.3 (±4.3)	30.1 (±7.3)	20.9 (±8.6)	13.6 (±4.6)	10.2 (±3.9)	9.1 (±1.9)	25.7 (±12.6)	132.3 (±91.3)	5.0 (±5.0)	19.8 (±19.8)

Note: 1) In some cases there were two playground structures instead of one.

## 4.	Stilwell (1998)

Stilwell conducted studies on leaching of CCA ingredients into soils, specifically arsenic from CCA-treated wood structures like residential decks . (Stilwell, et al., 1997) and in 1998, he published a paper (Frontiers of Plant Science, 51(1), 1998) pp 6-8), which partially deals with the effect of sealants on leaching of arsenic from CCA-treated wood.

### a.	Summary of the study

Since the study was to estimate the dislodgeable arsenic from the wood surface which has been CCA-treated either with or without sealant, Stilwell first devised a 'standard method' of wipe-sampling from a wood surface. Whether sampling the dislodgeable arsenic from the wood surface of wood blocks, wood "coupons" (1-2 ft. pieces of treated wood) , horizontal deck plank surfaces, or vertical poles which support the playground structures, the procedure consisted of these steps:

1. Bottom of a block, wood coupons were cushioned with rubber, sealed with polypropylene tape.

2. Before sampling, a 1.25 kg weight was placed on top of the block, coupon etc .

3. Wipe sample was generated by moving the weight horizontally on the block back and forth to a maximum surface of 28-30 cm and this was repeated five times.

4. Wipe collected was digested in 10% nitric acid solution for two hours at 60 ^{o} C and analyzed by AA technique.

Four sealants were selected for the study. These were: 1) Polyurethane deck and porch enamel, 2) a latex acrylic solid color stain; 3) a spar varnish; 4) semi-transparent oil stain containing alkyl resins. The amounts of arsenic released were determined before the sealant application. For each sealant, four coupons were chosen. The study was conducted one year after the coatings were applied with these sealants. Coupons were made from eight foot-CCA-treated boards which were purchased from three different lumberyards over a period of one year. Each board was cut into 1 to 2 foot pieces, or coupons. Each coupon was CCA pressure treated with a preservative pressure of 0.40 pounds per foot (pcf).

The quantities of arsenic leaching out were markedly reduced after one year. The study showed a 95% reduction of arsenic dislodged from the application of polyurethane, acrylic or spar varnish on the wood surface .Reduction in the dislodgeable arsenic from the wood surface when oil-based alkyl resin was applied as a sealant was 80-97% with an average of 90%.

5. Lebow and Evans (1999)

a. Summary of the study

Lebow and Evans conducted a laboratory study on the effect of leaching of metals from CCA-treated hemlock which was prestained. CCA was made in the lab and its metal ratiosresemble CCA-C. The prestain was a water soluble acrylic polymer, with an iron-oxide-based rust. The prestain was brushed onto the hemlock boards 18 hour before the pressure treatment. The retention pressure was 0.40 pcf. The duration of the study was 17 weeks. An artificial rainfall scenario (32 inches, mimicking the national average) was used for the release rates of copper, chromium and arsenic. The study concluded that rate of arsenic release declined by 25-30% from the prestained wood samples compared to nonstained wood samples. Although the release rates for chromium and copper were also lower from the prestained wood samples than the nonstained samples, the differences in the rates were not significant. Table 10 summarizes the study data.

Table 11: Average Total Amounts of *Cu*, *As* and *Cr* Released from Unstained and Prestained Wood Samples: 17 weeks Data (Lebow and Evans, 1999)

Sample Type	Copper (mg)	Chromium(mg)	Arsenic (mg)
Unstained	9.15	2.15	5.70
Prestained	8.48	1.67	4.12

Table 12. Summary of Uncertainties, Strengths, and Recommendations from Available Data on Sealants

Studies	Recommendation	Uncertainties	
CDHS 1987	No, the uncertainties will generate large errors in data analyses and hence the overall risk assessment.	Small size of samples collected and analyzed. Wood type, age of treated wood and preservative pressure not mentioned. Samplers were identified as adults, not children, the actual pressure applied by children's hands and that of adults will be very different. The document does not indicate whether the study on wipe samples was conducted on wood structures treated with which type of CCA, is it CCA-A, CCA-B or CCA-C?. The term 'gentle rubbing' is a very subjective one and will be different for different hands, particularly in the case of children. 'Actual' pressure applied to do the wipe with gauze or hand wipe will vary from case to case .	The study covers areas of both exposure and hazard factors and risk assessments of both. A number of methods were devised and applied to determine the levels of arsenic on the wood surface, in wipes, stained, nonstained samples.
CPSC 1990	No, similar results resulted from limited sample size of coated and uncoated	Sample size of the study was too small. Number of sealants used was not enough to give good comparative analysis. Samples were only a week old and long range- effect of sealant/stain/water repellent can not be determined. Oil-based stain was not identified. It is not clear why the results of this study would be different from studies conducted by CDHS and Stilwell.	Wood type and retention pressure were identified. Method of application (spray method) was mentioned. Same type of wood used for both coated and uncoated samples.

Riedel et al. 1991	No, but more information is needed such as identity of types of stain and paints	Sample size is not large enough. Paints and stains not identified. It is not clear that the treated wood was CCA-treated. Although it is clear from the study that a reduction does take place in the amounts of arsenic and chromium when the treated wood is stained or painted, a clear pattern does not emerge from this study. Rationale for choosing to wipe only twice on the wood surface for sampling is not stated. It is not clear whether the same person(s) was involved in the wiping process or different persons conducted the wipe sampling. Each person would apply different hand pressures to obtain samples. It is not clear from the study if the playground structures were located in different parts of Ontario or in the same vicinity.	Very few studies done on playground equipment and this is one of them..Relevant background information about the structures provided (age, coated/not coated/painted).Wipe samples were collected from similar parts of the equipment. Analytical techniques used are reliable tools for such analyses**.**
Stilwell, 1998	Yes, but with modification	Sample size not large enough to make a sound scientific conclusion. Long range effects of the sealants were not clear..Tests of dislodgeability were not conducted with sealants applied to different preservative pressures..It is not clear if the tests were done on the coupons made from the same poles used for precoated coupons, the results of which are provided in Table 3 (page 7) of the paper. Rationale for choosing these sealants was not provided.	Wood type and preservative pressure were identified..Duration of the study was identified and a period of one year is a good one to see meaningful results. Wipe sample method was adequately explained. More than one sealant was used which provides a better insight into process of leaching of metals like arsenic. Coupons were made out of the same wood pole

Lebow and Evans, 1999	No, but will good for comparison for further risk mitigation measurement	Since it was a laboratory study, sample size could not have been large. The data from field and laboratory studies do not necessarily come out similar. Hence a comparison of this data with the field data can not be made and general conclusions can not be drawn.	The type of stain used for this study resulted in differentiating between the metal release rates which no other study showed. Decline in the release rates and the amounts released for arsenic was remarkable compared to the other metals. From the point of view that it was laboratory study, the duration is reasonable (four months).

V. Buffering Materials

Various materials (sand, gravel, shredded tires, and shredded wood products) are used to surface under and around playground equipment and to act as shock absorbers when installed and maintained at a sufficient depth.

Concerns surrounding these buffers include the potential for CCA to leach from the CCA-treated playground equipment and absorb into the buffering materials. In addition, these buffers may include wood mulch that contains CCA-treated wood. Coupling CCA-treated playground equipment with playground barriers made from recycled wood mulch containing CCA-treated wood may increase background levels of arsenic, chromium and copper, posing greater human exposure and health risks.

Some mulch products originate from recycled construction and demolition (C&D) debris that may contain varying quantities of CCA-treated wood. Preliminary research in Florida in 1999 found CCA-treated wood to make up between 9% and 30% of the recovered wood from C&D recycling facilities. This wood is used as a horticultural/landscape mulch, as a temporary road surface, for mud control in animal pastures, as a horse-arena surface material, as bedding for dairy cows and other animals, as a soil amendment and for erosion control.

When the C&D debris wood is processed for use such as mulch, the surface area for leaching is significantly greater. The smaller particle size also makes the direct human exposure pathway a realistic scenario. Also, the placement of the mulch represents the final disposition of the wood. The wood contained in the mulch will remain on the ground and ultimately become integrated into the underlying soil.

Because of these issues, it is important to gain a better understanding about how much CCA-treated wood is processed into mulch and the extent that mulch contaminated with CCA contributes to human exposure and health risks.

A. Available Data Sets

There is limited information available about the ultimate fate of CCA-treated wood and its use at C&D recycling facilities. Quantifying the fraction of C&D recovered wood waste comprised of CCA-treated wood is a necessary first step in addressing this issue. Research has been conducted in Florida to measure the percentage of CCA-treated wood present in recovered wood stockpiles at these facilities. In 1997, CCA-treated wood was documented to be in the recovered wood stream at C&D recycling facilities in Florida at approximately 6% (Tolaymat et al.2000). Research conducted in 1999 at three Florida C&D debris recycling facilities found CCA-treated wood to make up between 9% and 30% of the recovered wood (Solo-Gabriele et al. 2000).

Townsend et al., (2001) performed leaching tests on two different sets of samples: new CCA-treated wood and mulch collected from C&D debris recycling. The 10 new CCA-treated wood samples were characterized by different dimensions, different brands, and different standard retention levels. These samples were separated into four different particle sizes (sawdust, chipped wood, 5 20-g blocks, and 1 100-g block). There were 20 mulch samples, 13 were of processed C&D debris wood and 2 additional C&D mulch samples were obtained from retail establishments (original source of wood unknown), the remaining 5 mulch samples consisted of two samples of vegetative waste wood collected form recycling facilities and three non-C&D mulch controls (pine bark or cypress mulch purchased at local retail stores). To determine the leachability of the test samples, Townsend et al used U.S. EPA's Toxicity Characteristic Leaching Procedure (TCLP), plus four additional standard leaching tests.

Currently there are limited data available which adequately addresses the effects of leaching of CCA-treated wood compounds from playground structures to buffering materials used under and around these structures. A recent report released by Florida's Alachua County Board of County Commissioners (2001) presents soil and mulch data from limited arsenic sampling conducted by Environmental Protection Department staff at five county owned parks. Tire chip and wood mulch buffering materials sampled at half-depth (2"-6") from areas immediately adjacent to CCA wood playground borders, playground posts, and within playground areas (between borders/posts) yielded arsenic concentrations for wood mulch of 43.1 - 61.2 mg/kg (border) and 0.5 mg/kg (play areas), and for tire chips 3.5 - 70.3 mg/kg (border), 10.3 - 80.3 mg/kg (posts) and 0.4 - 0.9 mg/kg (play areas). Each park had a liner in place between the mulch material and the bare soil

Results on tests conducted using new CCA-treated wood showed that the three metals leached measurable concentrations in all samples. Arsenic concentrations measured the highest: 0.31 mg/l (100g block) to 12.5 mg/l (saw dust), followed by copper: 0.10 mg/l (100g block) to

5.14 mg/l (20g blocks), with chromium leaching the lowest concentrations: 0.26 mg/l (100g block) to 21.2 mg/l (chipped wood). As predicted, the concentration of metals that leach from CCA-treated wood is dependent upon the particle size. As the size of a particle decreases, the surface area that is exposed to the leaching solution increases. Conversely, the greater the particle size, the lower the concentration of heavy metal in the leachate (Townsend et al. 2001).

When looking at the entire sample data set, results from leaching tests conducted using C&D debris wood mulch showed the concentration of arsenic ranged from 10 μg/L to 558 μg/L. The chromium concentrations ranged from 10 μg/L to 229 μg/L and the copper concentrations ranged from 10 μg/L to 340 μg/L. Grouping the results by category show wood that is generated from C&D recycling operations leaches arsenic, copper and chromium at higher levels than any of the other types of wood tested (C&D debris samples, C&D mulch samples, yard waste facility, commercial mulch, colored mulch), with arsenic leaching at greater concentration than the other metals (Townsend et al., 2001).

Although CCA-treated wood is exempt from being a hazardous waste by federal rule, Townsend et al. compared the results of the leaching tests to the Federal Toxicity Characteristic (TC) limits under the Resource Conservation and Recovery Act (RCRA). Arsenic was the only metal that exceeded TC limits (5mg/l). Chromium never exceeded its 5 mg/l limit and copper does not have a TC limit. The TCLP leachates exceeded 5 mg/l of arsenic in 8 of the 10 samples tested. The average TCLP arsenic concentration was 6.7 mg/l (Townsend et al., 2001).

B. Uncertainties/Weaknesses of Data Sets

- Insufficient data are available to address the questions regarding the use of CCA-treated wood in playgrounds, especially the risk associated with CCA-contaminated mulch used as a buffering material.
- It is unclear how applicable the State of Florida’s data are to the rest of the US. This is because of the high use of CCA-treated wood relative to other states.
- We do not know what contribution wood mulch contaminated with CCA adds to the overall arsenic burden. We assume it is additive.
- We still do not know what percentage of CCA-contaminated wood buffering materials are used in playgrounds around the US.
- Leaching tests such as the TCLP provide insight into the science of leaching behavior from waste materials. However, they were designed as regulatory tests and the results of which have specific regulatory implications. TCLP results do not provide information useful for assessing potential dermal and incidental ingestion exposure of children to arsenic and chromium on/sorbed to the buffering material.
- There are no data available addressing the levels of leachate on/sorbed to other barrier materials being used on playgrounds (i.e.; gravel, shredded tires) that properly address the effects of leaching to these materials.

C. Conclusions

Arsenic does leach from CCA-contaminated C&D debris wood mulch. It is also likely that the continued application of CCA-contaminated mulch may result in increased soil arsenic concentrations.

VI. Summary/Conclusions

A. Data Selected for Use in this Exposure Assessment

OPP has identified current residue data available for consideration and assessed the suitability and limitations of each data set for use in the child exposure assessment. The results of the various studies evaluated indicated a high degree of variability for chromated arsenical residues on wood, based on the different methodologies chosen to generate the data, the different types of wood sampled and field test sites selected, the handling/finishing, age and condition of the CCA-treated wood, and the type of CCA formulations used to treat the wood as well as the CCA retention levels achieved.

Also, there is a high degree of variability in the soil sampling data sets evaluated since the type and characteristics of soils determine the degree to which *As* and *Cr* residues leaching from CCA-treated wood will bind with the soil and be available for dermal/oral contact and absorption. Also, as with the wood residue studies, the different methodologies chosen to generate the soil data were a factor in OPP's selection process.

The summary tables in Appendix I present the strengths of each data set evaluated along with the uncertainties and limitations impacting OPP decision to propose use of the data for the child exposure assessment. Data from the studies selected are considered the "best available data" for use in estimating the amount of dislodgeable *As(V)* and *Cr(VI)* residues from CCA-treated wood playground structures and CCA-contaminated soil. The general data requirements for dislodgeable data are normally specified under Agency Test Guideline Series 875.2100, 875.2200, 875.2300, and 875.2400 (U.S. EPA, 1998); however, these surface wipe/soil sampling studies were not designed to conform with Agency Series 875 guidelines, and are therefore proposed to the SAP as "surrogates."

B. Additional Data Needs

There are limited exposure data available on direct human contact with arsenic and chromium residues on CCA-treated wood surfaces and those found in CCA-contaminated soils. The data which OPP evaluated and proposes to rely on for the exposure estimates have uncertainties associated with them, based on certain inherent limitations in the scope and conduct of the studies from which these data were generated. OPP has determined that additional data relevant to child "playground" exposures are needed and intends to support future research in this area.

The Agency (OPP/AD) is currently engaged in a joint effort with the Consumer Product Safety Commission (CPSC) to develop appropriate study protocols for conducting analytical and field sampling studies on CCA residues from wood and soil matrices. Such sampling would provide data pertinent to an exposures assessment which could then be used in future risk calculations for children playing on CCA-treated playground equipment.

As part of the CCA-exposure evaluation, the Agency in conjunction with the CPSC intends to develop a sampling regime that addresses potential dislodgeable and soil residues of arsenic, chromium, (and copper) which may occur on CCA-treated playground equipment and in soils below/adjacent to these structures. This sampling regime will involve:

1. Identification of suitable test sites which contain either new or existing CCA-treated playground structures;

2. Obtaining access to identified sites from local, state, or federal authorities;

3. Collection of a specific number of wood wipe (cloth and hand) samples and soil samples at each site;

4. Storage and transport of samples to (a) laboratory (ies) for analyses;

5. Analyses of wipe/soil samples for total arsenic, chromium, and copper (with analyses for speciated forms when feasible); and

6. Review and reporting of such analyses in (a) report(s) which may support the Agency's exposure deliberations for the children's risk assessment for CCA-treated playground equipment.

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