UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
PREVENTION, PESTICIDES, AND
TOXIC SUBSTANCES

December 12, 2001

MEMORANDUM

SUBJECT: Transmittal of the Final Report for the FIFRA Scientific Advisory Panel (SAP) Meeting Held October 23 - 25, 2001

TO: Marcia E. Mulkey, Director
Office of Pesticide Programs

FROM: Olga Odiott, Designated Federal Official
FIFRA Scientific Advisory Panel
Office of Science Coordination and Policy

Larry Dorsey, Executive Secretary
FIFRA Scientific Advisory Panel
Office of Science Coordination and Policy

THRU: Vanessa T. Vu, Ph.D., Director
Office of Science Coordination and Policy

Please find attached the Report for the FIFRA SAP open meeting held October 23-25,2001: **Preliminary Evaluation of the Non-dietary hazard and Exposure to Children from Contact with Chromated Copper Arsenate Treated Wood Playground Structures and Contaminated Soil.**

cc:

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OPP Docket

SAP Report No. 2001-12

FIFRA Scientific Advisory Panel Meeting, October 23- 25, 2001, held at the Sheraton Crystal City Hotel, Arlington, Virginia

A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding:

Preliminary Evaluation of the Non-dietary Hazard and Exposure to Children from Contact with Chromated Copper Arsenate (CCA)-treated Wood Playground Structures and CCA-contaminated Soil.

SAP Report No. 2001-12

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Olga Odiott, M.S.
Designated Federal Official
FIFRA Scientific Advisory Panel
Date: December 12, 2001

Stephen M. Roberts, Ph.D.
FIFRA SAP Session Chair
FIFRA Scientific Advisory Panel
Date: December 12, 2001

NOTICE

This report has been written as part of the activities of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Scientific Advisory Panel (SAP). This report has not been reviewed for approval by the United States Environmental Protection Agency (Agency) and, hence, the contents of this report do not necessarily represent the views and policies of the Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute a recommendation for use.

The FIFRA SAP was established under the provisions of FIFRA, as amended by the Food Quality Protection Act (FQPA) of 1996, to provide advice, information, and recommendations to the Agency Administrator on pesticides and pesticide-related issues regarding the impact of regulatory actions on health and the environment. The Panel serves as the primary scientific peer review mechanism of the EPA, Office of Pesticide Programs (OPP) and is structured to provide balanced expert assessment of pesticide and pesticide-related matters facing the Agency. Food Quality Protection Act Science Review Board members serve the FIFRA SAP on an ad-hoc basis to assist in reviews conducted by the FIFRA SAP. Further information about FIFRA SAP reports and activities can be obtained from its website at http://www.epa.gov/scipoly/sap/ or the OPP Docket at (703) 305-5805. Interested persons are invited to contact Larry Dorsey, SAP Executive Secretary, via e-mail at dorsey.larry@.epa.gov.

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Scientific Advisory Panel Meeting
October 23 –25, 2001

Preliminary Evaluation of the Non-dietary Hazard and Exposure to Children from Contact with Chromated Copper Arsenate (CCA)-treated Wood Playground Structures and CCA-contaminated Soil.

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INTRODUCTION

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Scientific Advisory Panel (SAP) has completed its review of the set of scientific issues being considered by the Agency pertaining to its review of the Office of Pesticide Programs' (OPP) Preliminary Evaluation of the Non-dietary Hazard and Exposure to Children from Contact with Chromated Copper Arsenate (CCA)-treated Wood Playground Structures and CCA-contaminated Soil. Advance notice of the meeting was published in the *Federal Register* on September 19, 2001. The review was conducted in an open Panel meeting held in Arlington, Virginia, October 23- 25, 2001. The meeting was chaired by Stephen M. Roberts, Ph.D. Ms. Olga Odiott served as the Designated Federal Official.

The scientific issues addressed by the FIFRA SAP were complex and varied. Panel members were selected to serve because of their expertise in one or more of the subject areas being discussed. The Panel was asked to evaluate the scientific soundness and OPP's evaluation of the exposure and hazard data available to the Agency for CCA. Specifically, the Panel was asked to 1) review the exposure scenarios and hazard endpoints that the Agency intends to use in its CCA-risk characterization for children; and 2) provide recommendations concerning additional data needed to reduce the uncertainties of this risk characterization.

CHARGE

Issue: Short- and Intermediate-term Endpoint Selection for Inorganic Arsenic

For inorganic arsenic, the data of Franzblau et al (1989) and Mizuta et al (1956) using a LOAEL value of 0.05 mg/kg/day is proposed for selection of short-term and intermediate-term incidental oral endpoints as well as short-term and intermediate-term dermal endpoints. An acceptable Margin of Exposure value of 100 is also proposed. The acceptable Margin of Exposure value includes a 10x factor for intraspecies variation as well as a 10x factor for use of a LOAEL value and the severity of the effects observed in the Mizuta study.

Question 1: Please comment on the Agency's selection of the 0.05 mg/kg/day LOAEL value for use in assessing risks to the general population as well as children from short-term and intermediate-term incidental oral and dermal exposures, and the appropriateness of the use of a 10x factor for severity of the toxic effects observed in the Mizuta study. Please provide an explanation and scientific justification for your conclusions as to whether the presented data are adequate or whether other data should be considered for selection of this endpoint.

Issue: Relative Bioavailability of Inorganic Arsenic

The bioavailability of inorganic arsenic is dependent on the matrix in which it exists. For purposes of this discussion, the relative bioavailability of inorganic arsenic after ingestion of arsenic-contaminated soil is defined as the percentage of arsenic absorbed into the body from soil compared to that of arsenic administered in drinking water. Arsenic in drinking water is in a water-soluble form, and bioavailability by this route is high (i.e. 95-100%). Arsenic in soil, however, has reduced bioavailability due to existence in a water-insoluble form or its interaction with other soil constituents that impair absorption.

The available data on urinary and fecal recovery of arsenic after an intravenous dose of sodium arsenate in experimental animals compared to recovery after administration of sodium arsenate to experimental animals in soil was examined. Based on these data, a value of 25% bioavailability was selected for arsenic from soil ingestion. This value is based upon the data of Roberts et al. (2001) and Freeman et al. (1995) using non-human primates. These data were felt to best represent relative bioavailability of inorganic arsenic in soil based on the use of non-human primates and the physiological similarity in the pattern of metabolism with humans, and the use of CCA-contaminated soil in the study for estimation of bioavailability.

Question 2: Please comment on the choice of this data set and value chosen for representation of the relative bioavailability of inorganic arsenic from ingestion of arsenic-contaminated soil. Please discuss the strengths and weaknesses of the selected data and also provide an explanation as to whether this 25% value is appropriate for estimation of bioavailability in children.

Issue: Dermal Absorption Value for Inorganic Arsenic

A value of 6.4% for the dermal absorption of arsenic was selected to represent absorption from dermal contact with inorganic arsenic. This value is based upon the data of Wester et al. (1993) and represents percent absorbed dose of arsenic applied to the skin in a water solution. Although this value is slightly higher than the value of 4.5% obtained for arsenic applied in soil, the mean values for absorption from water and soil both showed significant variability (i.e. 6.4% ± 3.9% in water, 4.5% ±3.2% in soil) such that use of the 6.4% dermal absorption value was selected. It is observed in this study that a higher dose on the skin resulted in lower dermal absorption as noted above, but the data in this study suggests sufficient variability in the absorption such that use of the 6.4% dermal absorption value is sufficiently but not overly conservative.

Question 3: Please comment on the selection of the value of 6.4% for dermal absorption of inorganic arsenic and whether or not this value will be appropriate for use in all scenarios involving dermal exposure to arsenic from CCA-treated wood, including children's dermal contact with wood surface residues and contaminated soils.

Issue: Selection of Hazard Database for Hazard Characterization of Inorganic Chromium in CCA-Treated Wood

Hazard data show clearly that Cr (VI) demonstrates more significant toxicity than Cr (III). However, there is little data delineating the valence state of chromium in compounds that leach from in-service CCA-treated wood (Lebow, 1996). Interconversion of Cr (VI) and Cr (III) in the environment is observed (Cohen et al., 1999), and at least one study has reported measurable levels of hexavalent chromium in soils (Lebow, 1996). In-service CCA-treated wood contains mainly chromium (III), due to reduction of chromium (VI) during fixation. However, when fixation conditions are not ideal or when storage temperatures are low, Cr (VI) is observed to be present in leachate from the treated wood and in addition, conditions in some soil types can result in conversion of leached Cr (III) to Cr (VI).

Question 4: As available monitoring data do not differentiate among chromium species found in CCA dislodgeable residues on wood surfaces and in soils, and as Cr (VI) is the more toxic species of chromium, please comment on whether use of the

hazard data for chromium (VI) is the best choice for characterizing hazard and risk from exposure to chromium as a component of CCA-treated wood. Please provide a scientific explanation and justification for your recommendation on the choice of either the chromium (III) or chromium (VI) hazard database.

Issue: Short- and Intermediate-term Endpoint Selection for Inorganic Chromium

For inorganic chromium (VI), OPP proposes using the developmental toxicity study of Tyl (MRID 42171201) with a NOAEL value of 0.5 mg/kg/day [0.12 mg/kg/day chromium equivalents] and an MOE of 100 (10x for interspecies variation, 10x for intraspecies variation) for selection of short-term and intermediate-term incidental oral endpoints.

Question 5: Please comment on the Agency's selection of the 0.5 mg/kg/day NOAEL value for use in assessing risks to the general population as well as children from short-term and intermediate-term incidental oral exposures to inorganic chromium as contained in CCA-treated wood. Please provide an explanation and scientific justification for your conclusions as to whether the presented data are adequate or whether other data should be considered for selection of these endpoints.

Issue: Selection of Endpoints for Dermal Risk Assessments for Inorganic Chromium

Dermal exposure to chromium has been demonstrated to produce irritant and allergic contact dermatitis, and chromium is also one of the most common contact sensitizers in males in industrialized countries (IRIS, 2000). The relative potency of Cr (VI) and Cr (III) in causing dermal effects has been estimated to differ by approximately 50-fold (Bagdon,1991) but both produce irritation and dermal sensitization. In the OPP HIARC review of selection of dermal toxicity endpoints, it was concluded that skin irritation and skin allergenicity are the primary effects of concern from dermal exposure to Cr(VI), as these effects are the predominant response from dermal exposure to inorganic chromium. Thus, endpoints based on systemic effects from dermal exposure were not selected.

Question 6: Please comment on whether the significant non-systemic dermal effects from dermal exposure to inorganic chromium should form the basis of dermal residential risk assessments, and, if so, how the Agency should establish a dermal endpoint for such an assessment.

Issue: Selection of Parameters and Methodology for Characterizing Child Exposures

OPP intends to develop realistic exposure scenarios and dose estimates for characterizing potential dermal/oral ingestion exposures to children in playground settings from contact with dislodgeable *As* and *Cr* residues on CCA-treated wood playground structures and in CCA-contaminated soils. In keeping with EPA policy, OPP would like its estimates to

characterize both the middle and upper end of the range of potential exposure values. (The "high end" of exposure is defined as a level of exposure which is likely to be higher than experienced by at least 90% of the population, but not higher than the level experienced by the maximally exposed individual.) Following EPA guidance on conducting exposure assessments, OPP intends to rely on "mean value" (central tendency) data for calculating the lifetime average daily doses (LADDs) used for the cancer assessment, and "maximum value" (high end) data for calculating the average daily doses (ADDs) used for the non-cancer assessment.
OPP expects to use a combination of central tendency and high end values for the different parameters of the exposure equations, as identified below.

Exposure Parameters Proposed for Use in Conducting the Child Exposure Assessment

General Variables:	Age	3 yr old	central tendency
	Body Weight	15 kg	central tendency
	Surface Area: hands, arms, legs	1640 cm^2	high end
	3 fingers	20 cm^2	central tendency
	Playground activity: hours / day	1 hr	central tendency
	days / year	130 days	central tendency
	years / lifetime	6 yrs out of a 75 yr lifetime	central tendency
Scenario Specific Variables: • Dermal Contact with Soil	Soil Adherence Factor	1.45 mg/cm^2	central tendency
• Oral Ingestion of Residues from Hand-to-Mouth Contact with Wood	Exposure time (hrs/day spent for hand-to-mouth activity)	1 hr/day and 3 hrs/day	central tendency and high end
	Hand-to-Mouth Frequency (events/hour)	9.5 events/hr and 20 events/hr	central tendency and high end
	Fraction Ingestion	50% removal efficiency	central tendency
• Oral Ingestion of Soil Residues	Soil Ingestion Rate	100 mg/day and 400 mg/day	central tendency and high end

Question 7. Please comment on whether OPP's choices of central tendency and high end values for different parameters should, collectively, produce estimates of the middle and high end of the range of potential exposures. If the Panel thinks that OPP's approach may not estimate the high ends of the exposure range (because it produces values that are either higher or lower than the upper end of the exposure

range), please comment on what specific values should be modified to produce estimates of the high end of potential exposure.

EPA recognizes that there are many parameters that affect the level of potential exposure and that each of these parameters may vary. Probabilistic (e.g., Monte Carlo) techniques are capable of using multiple data sets which reflect the variability of parameters to produce estimates of the distribution of potential exposures. OPP has identified a number of data sets that contain information on the variability of parameters affecting the levels of exposure to CCA residues experienced by children as a result of their playground activities. Nonetheless, OPP intends to develop deterministic estimates of potential exposure using selected values (either central tendency or high end) for different parameters, in such a manner that the estimates describe both the middle and high end of the range of exposures.

Question 8: Please comment on whether the existing data bases on the variability of the different parameters affecting potential exposure are adequate to support the development of probabilistic estimates of potential exposure. If the Panel regards the data bases as adequate for that purpose, please identify which parameters should be addressed using a distribution of values and which data bases should be used to supply the distribution for particular parameters.

Issue: Transfer of Residues from Wood Surface to Skin

In lieu of appropriate data on residue transfer from wood to skin surfaces, OPP proposes to rely on assumptions for residue transfer from turf as a surrogate. A one-to-one relationship is assumed between the transferable residues on turf and the surface area of the skin after contact (i.e., if the transferable residue on the turf is 1 mg/cm^2, then the residue on the human skin is also 1 mg/cm^2 after contact with the turf). This is based on OPP's Residential SOP's (April, 2000). OPP plans to apply this one-to-one relationship to the current assessment, assuming a one-to-one relationship between the dislodgeable residues on the wood surface and the surface of the skin after contact.

Question 9: OPP is assuming that a one-to-one relationship applies to the transfer of residues from wood to skin. The Panel is asked to address whether this is a reasonable assumption, and if not, to provide guidance on other approaches.

Issue: Selection of a Soil Adherence Factor

The Soil Adherence Factor (AF) is defined as the amount of soil which adheres to the skin. 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. OPP adopted a dermal exposure scenario for children touching CCA-contaminated soil which relies on an AF of 1.45 mg/cm^2 (U.S.EPA's Superfund RAG, 1989) for hand contacting commercial potting

soil in lieu of playground soil. A recently drafted report (U.S.EPA's Superfund RAG, Part E., Supplemental Guidance for Dermal Risk Assessment, draft, 2000), recommended an activity-specific surface area weighted AF value for a child resident at a day care center (1 to 6 years old) of 0.2 mg/cm^2.

Question 10: The Panel is asked to comment on whether the proposed AF of 1.45 mg/cm^2 for hand contact with commercial potting soil is a realistic value for use in estimating the transfer of residues from playground soil to skin in this assessment.

Issue: Variability of Residue Data Available for Soil and Wood.

The soil and wood residue data being considered for this assessment has been generated over the last 25 years. There are several variables influencing the consistency of the data:

- Data were gathered and analyzed by several different research laboratories
- Data were collected at different geographic sites
- Differences in wood types and treatments between data sets

Additionally, the leaching rates of arsenic and chromium (to both the wood surface and the soil) are highly dependent on factors such as wood type, degree of weathering, age of wood, moisture content, pressure treatment process and retention time, use of coatings/sealants, and variations in the analytical and sampling techniques between laboratories.

OPP summarized the residue data by selecting and recommending some of the mean and maximum values from each study in order to compare the degree of leaching from the wood and the level of contamination in the soils. The "mean" data will be used to develop the lifetime average daily doses (LADDs) for the cancer assessment, and "maximum" data used in developing the average daily doses (ADDs) for the non-cancer assessment.

Question 11: OPP will need to calculate intermediate-term, and possibly long-term exposures in this assessment using available wood/soil residue data. The Panel is asked to recommend a credible approach for selecting residue data values for use in OPP's risk assessment, taking into consideration the inherent variability of the data sets. Please advise us on which values are best for representing central tendency and high-end exposures. Also, the Panel is asked to discuss the feasibility of combining data from individual data sets.

Issue: Combining Multiple Exposure Scenarios into a Comprehensive Estimate of Risk

Children playing on playgrounds containing CCA-treated wood structures will be exposed to arsenic and chromium residues on wood surfaces and in soils via oral and dermal routes. OPP has discussed four proposed exposure scenarios individually in the exposure assessment; however, to adequately assess the risks to children from exposure

to arsenic and chromium residues through playground contact with wood and soil media, all four scenarios must be considered concurrently.

Question 12: Does the Panel have any recommendations for combining the four scenarios (oral/wood, dermal/wood, oral/soil, dermal/soil) such that a realistic aggregate of these exposure routes may be estimated?

Issue: Inhalation Exposure Potential from Wood/Soil Media

The Agency has selected a NOAEL value of 2.4 x 10-4 mg/m^3 taken from the 1998 IRIS update for Cr(VI) using the study of Lindberg and Hedenstierna (Arch Environ Health 38(6):367-374) who observed ulcerations, perforations of the nasal septum and pulmonary function changes in 104 workers (85 males, 19 females) exposed in chrome plating plants at a concentration of 7.14 x 10-4 mg/m^3. The NOAEL value selected is intended to represent an endpoint for use in inhalation risk assessments representative of any duration of exposure.

OPP does not propose to evaluate potential exposures via the inhalation route for the child playground 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, or 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).

Question 13: Can the Panel comment on whether OPP should conduct a child playground inhalation exposure assessment, taking into consideration the hazard profile for chromium (VI) as an irritant to mucous membranes? If so, can the Panel comment on whether the endpoint described above is appropriate for assessing the risk to children from such an exposure?

Issue: Consideration of Buffering Materials as a Source of Exposure

The CPSC specifies suitable loose-fill surfacing materials (e.g., wood chips/mulch, sand, gravel, and shredded rubber tires) for use under and around public playground equipment as shock-absorbing buffers (i.e., "buffering materials") to protect children from injury during a fall. (Handbook for Public Playground Safety, U.S. CPSC, Pub. No. 325**).** Concerns surrounding use of these buffers include the potential for CCA compounds to leach from the CCA-treated playground equipment and absorb into the buffering materials. In addition, these buffers may include wood mulch products originating from recycled construction and demolition (C&D) debris that may contain varying quantities of 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 and chromium, posing greater human exposure and health concerns.

Leaching studies conducted in Florida by Townsend et al. (2001) on new CCA-treated wood samples (wood blocks, chipped wood mulch, and sawdust) indicated that the concentrations of metals in leachate solutions were higher for wood processed into chips/mulch or sawdust over wood blocks. The degree to which wood leaches appears to be dependent on particle size since wood chips/mulch have increased surface areas available for leaching, and consequently exposure, over dimensional lumber.

Currently there are limited data available which adequately address 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.

Question 14: Data on the effectiveness of reducing exposure by using buffering materials are limited. Does the Panel have recommendations as to whether additional studies to obtain this information are warranted? Does the Panel have suggestions on how OPP can best evaluate child exposures attributed to contact with CCA-contaminated buffering materials ?

Issue: Effectiveness of Stains/Sealants/Coatings at Reducing Leaching of CCA Compounds from Treated Wood

Several researchers have reported that stains/sealants/coatings can reduce the rate of leaching of CCA compounds from treated wood and that the effectiveness of these coating materials over time varies greatly, depending on the type of surface coating used and environmental conditions effecting the wood. Stilwell (1998) reported over a 95% reduction in dislodgeable arsenic residues from CCA-treated wood surfaces coated with polyurethane, acrylic or spar varnish, and an average of 90% reduction for oil-based alkyl resins for samples tested one year after a sealant was applied. CDHS (1987) reported 96%, and 82% reductions in dislodgeable arsenic from stained CCA-treated wood surfaces after one month and 2 years, respectively. Lebow and Evans (1999) reported that staining CCA-treated wood surfaces reduced leaching of arsenic by 25%.

Question 15: The Panel is asked to comment as to whether stains, sealants and other coating materials should be recommended as a mitigation measure to reduce exposure to arsenic and chromium compounds from CCA treated wood. If so, can the Panel comment on the most appropriate way for the Agency to recommend effective coating materials when the current data on long-term performance are limited and sometimes inconsistent, and should the Agency specify a time interval for the re-application of these selected coating materials? Can the Panel make recommendations for additional studies?

DETAILED RESPONSES TO THE CHARGE

Question 1 Please comment on the Agency's selection of the 0.05 mg/kg/day LOAEL value for use in assessing risks to the general population as well as children from short-term and intermediate-term incidental oral and dermal exposures, and the appropriateness of the use of a 10x factor for severity of the toxic effects observed in the Mizuta study. Please provide an explanation and scientific justification for your conclusions as to whether the presented data are adequate or whether other data should be considered for selection of this endpoint.

Recommendation

There was consensus by the Panel that 0.05 mg As/kg per day is an appropriate LOAEL for short- (1 to 30 day) and intermediate- (31 to 180 day) human ingestion of the chemical. The majority of Panel members expressing an opinion recommended a margin of exposure (MOE) of 30 from this LOAEL to afford protection from non-cancer health effects. Some Panel members thought an MOE of 10 would be adequate.

Discussion

Both Mizuta et al. (1956) and Fanzblau and Lilis (1989) described symptoms and clinical signs of arsenic poisoning in persons believed to have consumed 0.03 – 0.08 mg/kg per day for up to several weeks. Confidence in these dose estimates is low. Mizuta et al. (1956) did not provide information on their analytical method or on the basis for estimating the extent of arsenic consumption [from soy sauce] in patients experiencing arsenic toxicity. The information in Franzblau and Lilis (1989) pertaining to dose is derived in part from a retrospective estimate of water ingestion rates by two individuals who sporadically utilized an arsenic contaminated well.

Despite reservations about the dose estimates from these two studies, confidence in 0.05 mg/kg per day as an appropriate LOAEL is quite high in that several other clinical studies have reported the emergence of adverse signs and symptoms associated with the ingestion of inorganic arsenic at similar doses. These include accounts of gastrointestinal disturbances and less commonly mild peripheral neuropathy in individuals consuming medicinal preparations such as Fowler's solution or liquor arsenicalis at doses of 5 to 10 mg of arsenite per day over a period of days to months (Stockman, 1902; Pope, 1902; Harter and Novitch, 1967). Daily doses of arsenic that were probably in the range of 1 to 5 mg arsenite per day for weeks to months resulted in gastrointestinal and peripheral neurological findings during the Manchester beer epidemic of 1900 (Reynolds, 1901; Kelynack and Kirby, 1901). Arsenic exposure in drinking water for 1 to 4 months was observed to result in gastrointestinal, neurological, and skin symptoms at doses estimated to be > 0.05 mg/kg per day (Wagner, 1979 as summarized in Benson, 2001). While each of these studies individually has limitations in terms of establishing a LOAEL, there is reassurance in the relative consistency of the LOAEL value they collectively provide. Confidence is further enhanced by the large overall number of subjects, the ethnic diversity of the subjects, and the inclusion of potentially sensitive subpopulations (including

children) across studies.

Several members of the Panel expressed the opinion that the severity of symptoms noted in some patients near or moderately above a LOAEL of 0.05 mg/kg per day warranted a full uncertainty factor of 10. Reports of peripheral neuropathy, gastrointestinal bleeding, liver damage, low blood counts, CNS dysfunction, and abnormal electrocardiograms were mentioned as examples of signs and symptoms of concern in these patients. Humans appear to be more sensitive than most laboratory animals to arsenic toxic effects, and there is little information on the shape of the dose-response curve for these effects in humans. Without knowledge of the dose-response relationships, it is difficult to forecast acceptable margins of safety. This uncertainty contributed to the recommendation that a 10X uncertainty factor be applied to the LOAEL of 0.05 mg/kg/day.

The Panel was divided on whether the MOE should include an additional uncertainty factor. The majority of Panel members expressing an opinion recommended that a MOE include an additional intraspecies uncertainty factor of 3 to provide for protection of children. They pointed out that there may be subpopulations of children at special risk of arsenic toxicity, such as individuals with concomitant toxic exposures and/or vitamin and nutritional deficiencies that might impact arsenic kinetics. They noted that there is a paucity of information on the toxicokinetics of arsenic and its metabolites in children, and that it is unclear whether there are age-dependent differences in GI absorption or biotransformation of arsenic that might influence toxicity. It was acknowledged that data available at present generally indicate that responses of children and adults to arsenic do not differ significantly qualitatively or quantitatively. However, the opinion was expressed that these data pertain largely to effects on the skin, and that the immature central and peripheral nervous systems may be quite another matter. Short and intermediate term exposure to sufficiently high doses of arsenic are neurotoxic in adults, and data offering insight as to the arsenic doses associated with neurological effects in children were viewed by these Panel members as lacking. Specifically, an absence of adequate studies monitoring neurological indices in children exposed at or near the proposed arsenic LOAEL was cited. Some Panel members expressed concern for childhood exposure to arsenic in combination with other neurotoxic metals, and for synergy with other toxicants. Toxicity data on combinations of arsenic and other toxicants are extremely limited, and some Panel members questioned whether a NOAEL developed for inorganic arsenic alone is applicable under circumstances of exposure to other components of CCA.

Some Panel members argued that an additional intraspecies uncertainty factor of 3X was not required, and that an overall MOE of 10 would be adequate to protect human health. It was noted that an MOE of 30 would identify doses above 0.0017 mg/kg per day as having the potential to produce adverse non-cancer effects with exposures of 180 days or less. For a 15 kg child, 0.0017 mg/kg per day is equivalent to 25 micrograms of arsenic per day. Since it is estimated that the background diet of a 3 year old includes approximately 5 micrograms of inorganic arsenic (NRC, 1999), the 30-fold margin applied to a 15 kg child would be akin to expressing concern regarding short- or intermediate-term doses greater than an additional 20 micrograms of arsenic per day. There are no data demonstrating acute or subchronic noncancer effects at this approximate level of exposure. The United States experience with respect to

existing levels of arsenic in drinking water was cited as evidence for this. The US EPA has estimated that there are in excess of 1200 public drinking water systems in the United States that deliver drinking water with arsenic concentrations in excess of 20 ug/L (US EPA, 2001). Since the level of water consumption by some 3 year olds is 60 ml/kg (90th percentile estimate) (NRC, 2001), there appear to be many communities in the United States where young children have already been consuming >25 micrograms day. There are no reliable reports in the medical literature documenting or suggesting that adverse health effects from arsenic have occurred in these children. Several health surveys conducted in U.S. communities where the arsenic concentration in drinking water was several hundred micrograms per liter have also not detected adverse non-cancer effects (Harrington et al., 1978; Kreiss et al., 1983; Southwick et al., 1983). It was pointed out that both the Agency for Toxic Substances and Disease Registry (ATSDR) and U.S. EPA Region 8 have established health criteria for short- and intermediate-term exposure to arsenic of 0.005 mg/kg-day or higher, which is equivalent to an MOE of 10 or less [from a LOAEL of 0.05 mg/kg-day]. Finally, it was noted by one Panel member that clinical studies on children exposed to arsenic in drinking water associated the increased severity of observed multisystemic adverse effects in children compared to adults to a higher dose rate in children, and not to intrinsically increased susceptibility (Zaldivar, 1977; Zaldivar and Gullier, 1977; Zaldivar and Ghai, 1980).

Some Panel members cautioned that exposures above the MOE do not necessarily mean that health effects will occur and that the Agency should use the MOE in a screening level capacity only. That is, firm conclusions on the presence or absence of health effects should not be drawn solely on the basis of doses calculated to exceed the MOE.

Question 2: Please comment on the choice of this data set and value chosen for representation of the relative bioavailability of inorganic arsenic from ingestion of arsenic-contaminated soil. Please discuss the strengths and weaknesses of the selected data and also provide an explanation as to whether this 25% value is appropriate for estimation of bioavailability in children.

Recommendation

Panel members expressed a diversity of opinions regarding the designation of 25% as a value for the estimated relative bioavailability of inorganic arsenic from ingestion of arsenic-contaminated soil. Several members of the Panel felt that EPA should consider alternatives to a fixed value of 25% for the relative bioavailability of arsenic in soil in the vicinity of CCA contamination, while others felt that 25% was a reasonable interim value. Many members suggested an interim value of 50%. Several Panel members recommended that a range of values be considered: for some the suggested range was 25 to 50%, while another member suggested consideration of the full range of bioavailability for arsenic in soil reported in the literature (near zero to 98%).

In addition to oral absorption of arsenic from soil, consideration should be given to absorption of arsenic from nonsoil substances (such as wood chips or other buffer material) that might be subject to incidental ingestion.

Research is needed to obtain data on the relative bioavailability of arsenic from numerous sites that encompass the broad range of soil types and arsenic contamination specifically resulting from CCA-treated wood applications. These studies should be conducted in appropriate animal models preferably at doses that simulate the anticipated level of exposure of children playing on or around structures or sites subject to CCA contamination.

Discussion

There is general scientific consensus that a number of physical, chemical, and biological factors may impact the extent of gastrointestinal absorption of a substance present in ingested soil relative to absorption of the same substance ingested in solution. For arsenic, as with several other metals, solubility of the form of arsenic present in soil is a key factor, such that increased solubility or extractability of the metal from soil to an aqueous solution is positively correlated with increased absorption. Chemical and physical factors influencing the solubility or extractability of arsenic from the soil include 1) the molecular form of the arsenic species; 2) the nature of its chemical and/or physical interaction with the constituents of the soil matrix (e.g., chemical bonding, sorption, complexation, rinding, or encapsulation); and 3) the size, porosity, compaction, and surface area of the arsenic-containing soil particulates or agglomerations. Biological factors may also influence the absorption of an ingested metal present in soil, including 1) the species-specific metabolism of the metal, including metabolism by microflora within the gastrointestinal tract (Hall et al., 1997), 2) the physical condition of the animal at the time of ingestion (e.g., the effect of drugs, physical stress, toxins, nutritional perturbations, or disease states on the animal's physiology), 3) the presence of other ingested material (food, drugs, or other substances) in the intestinal tract, and 4) in some cases the age and/or developmental stage of the animal. The dose regimen that characterizes the ingestion of the metal and the soil matrix may also exert influence on the absorption, in terms of either absolute amounts or the percent of the dose administered. For example, data on absorption of lead from soils (Kierski, 1992; Mushak, 1998) suggest that bolus administration of a large mass of metal and/or metal-containing soil matrix may be associated with a lesser degree of gastrointestinal absorption, in terms of percent of total ingested amount, than might result from administration of the same mass in smaller, divided doses.

Members of the Panel expressed concern that the findings of Roberts et al. (2001) and Freeman et al. (1995) have not provided a sufficient basis to establish a relative bioavailability of 25% for arsenic present in soil as a consequence of CCA related release or contamination. The single, high dose, bolus administration of arsenate and arsenic-containing soils used in the studies by Roberts et al. (2001) and Freeman et al. (1995) does not reasonably simulate the relatively low dose, repeated ingestion of arsenic-containing soil that would be anticipated with hand-to-mouth behavior of a child playing in the vicinity of a CCA application. The arsenic concentration of the test soils (ranging from 101 to 743 mg/kg) appears high relative to those measured in the vicinity of CCA-treated structures in children's playgrounds in several recent investigations. The experimental design used by the investigators resulted in these soils being introduced into the monkey test subjects in single high mass boluses. For example, in the case of soil obtained from a "wood treatment site", it may be calculated that the soil-associated arsenic dose of 0.3 mg As/kg body weight was achieved by administering a 3 kg monkey a single oral dose of 9000 mg of soil. In like manner, in Freeman et al. (1995), the monkeys (which weighed between 2 to 3 kg)

were given single, oral doses of 3000 to 4500 mg of soil containing 410 ppm arsenic. Enhanced confidence in the generalizability of the relative bioavailability values from such studies might be obtained from experimental designs that utilize multiple, smaller soil doses spanning a range of relevant arsenic concentrations.

There is uncertainty regarding the extent to which the test soils used in the studies by Roberts et al. (2001) and Freeman et al. (1995) reflect arsenic speciation and chemical and physical characteristics of the soil matrix in the vicinity of CCA contamination at a playground. Although a soil sample from the investigation by Roberts et al (2001) was identified as coming from a "wood treatment site," this sample was not characterized further. The arsenic in that soil may have resulted in part from direct spillage of raw CCA product onto the soil, rather than leaching of arsenic from a weathered piece of CCA-treated wood.

The animal model used in the studies by Roberts et al. (2001) and Freeman et al. (1995) were the Cebus apella monkey and the cynomolgus monkey, respectively. Intravenous dosing with sodium arsenate suggested that these nonhuman primates were similar to humans with respect to excreting absorbed arsenic almost entirely through the urine (<5% of the recovered dose occurred in the feces). Also, the extent of excretion of an oral dose of sodium arsenate in urine and feces was quite similar between these monkeys and humans. At this point in time, the Panel is not aware of information regarding the biomethylation patterns of arsenic species in these nonhuman primates. This is an issue of some concern for some Panel members because other nonhuman primates, such as the marmoset monkey, do not biomethylate arsenic and exhibit prolonged retention of some arsenic species in vivo. These Panel members thought that this could potentially result in an underestimation of relative bioavailability if a significant proportion of the arsenic specie(s) present in the test soils was retained in the body for a longer period of time *relative* to the reference material, sodium arsenate in solution. Underestimation could also result if arsenic present in the test soil underwent greater relative biliary excretion compared to sodium arsenate. Other Panel members acknowledged these possibilities but expressed the opinion that these factors were not likely to significantly affect the findings.

At the present time, little is known regarding differential absorption and metabolism of arsenic in juvenile versus adult animals. Some Panel members expressed concern that the developmental age of the animal model might be a potentially significant variable, since it is known that infants and even older children as well as very young animals, sometimes have the potential for increased uptake of contaminants. Although the swine models have utilized juvenile pigs, the current monkey bioavailability data were obtained with adult animals. To the extent that the nutritional or dietary status of children and experimental test animals may affect the uptake of other substances, the absorption of arsenic (particularly arsenate) in the face of phosphorous deficiency is of potential concern for these Panel members. They noted, for example, that arsenate uptake by cells has been shown to be increased in low phosphate media (Huang and Lee, 1996) and suggested the need for further research on the impact of nutritional and developmental factors on bioavailability determinations. Other Panel members pointed out that the absorption of arsenite and arsenate, in absolute terms, is already extensive in adult animals and humans. As a result, the potential for greater absorption in children is limited, and consequently they did not think that use of arsenic bioavailabilty values from adult animals was

a significant concern (the Panel members thought that arsenic bioavailability values from adult animals were applicable to immature subjects).

As discussed in more detail elsewhere in this report, the interactive effect of metal combinations may influence arsenic absorption, biotransformation, and excretion. For example, when administered together with selenite, some inorganic arsenic compounds undergo increased biliary excretion (Levander, 1977; Gailer et al., 2000)**,** a factor that may potentially serve to underestimate relative bioavailability in models that examine relative urinary excretion as a marker of relative bioavailability.

Panel members noted several other studies that have investigated the oral bioavailability of arsenic in soils. Widely divergent results for relative bioavailability have been reported, a finding that is not unexpected given the variability in soil-associated arsenic compounds, soil matrices, animal models, and experimental design. For example, Casteel et al. (2001), under the auspices of U.S. EPA Region VIII, recently examined the relative bioavailability of arsenic in soils from the VBI70 superfund site in Denver, CO. Using a swine model that investigated six soil specimens spanning a range of arsenic concentrations, the mean relative bioavailability was 31%, with a 95% upper confidence limit of 42%. This latter value (42%) has been utilized in risk calculations contained in the site's baseline risk assessment (US EPA, 2001). Other relative bioavailability studies have been noted or reviewed in the Inorganic Arsenic Report of the Hazard Identification Assessment Review Committee (HIARC, 8/21/2001), and a recent publication by Ruby et al. (1999). Results for relative bioavailability have ranged from near zero to 50%, with the exception of two soils from Aspen, CO, that yielded much higher results, albeit with extremely wide confidence intervals (62% ± 55, 98% ± 86; Casteel et al., 1997; Ruby et al., 1999).

Question 3: Please comment on the selection of the value of 6.4% for dermal absorption of inorganic arsenic and whether or not this value will be appropriate for use in all scenarios involving dermal exposure to arsenic from CCA-treated wood, including children's dermal contact with wood surface residues and contaminated soils.

Recommendations

The Panel recommends that EPA use a value less than 6.4%, probably in the range 2-3%, for dermal absorption of inorganic arsenic. The Agency should consider using a figure for absorption rate (e.g., percent exposure absorbed per hour) rather than a value for percent absorption.

Research, using arsenic in more appropriate chemical form (that it is present in dislodgeable CCA residues and in soil beneath CCA-treated sites) and in a relevant matrix, should be carried out to improve estimates of dermal absorption.

Discussion

The Panel accepted the EPA view that the publication by Wester et al. (1993) provided the most appropriate available data for addressing this question. This research included a study that used seven rhesus monkeys. The absorptions of the pentavalent arsenic species H_3AsO_4, radiolabeled with As^{73}, in water solution and added to soil, were compared. For both water and soil, a high-exposure and a low-exposure group were used. The low exposure groups represented "the minimum arsenic that could be used given the specific activity of the compound." These exposures were 0.00004 $\mu g/cm^2$ for the soil group and 0.000024 $\mu g/cm^2$ for the water formulation group. The high exposure group was described as "representative of what would be encountered in more contaminated areas." These exposures were 0.6 $\mu g/cm^2$ for the soil exposure group and 2.1 $\mu g/cm^2$ for the water group. The skin exposures were for 24 hours and confined within a non-occlusive cover. Urine was collected for seven days following the beginning of the exposure period. Results were adjusted for excretion by other routes than urine and for retention in the body using results from monkeys that had been treated with an intravenous dose of arsenic. The data showed that 80.1% of the intravenous dose administered to the monkeys was excreted in the urine over a period of seven days.

The Panel noted a number of limitations in the reporting of the design and conduct of the study by Wester et al. These included:

- Uncertainty whether separate monkeys had been used for the dose groups or the same monkeys had been reused. If the latter, then it raised the possibility of cross-contamination, such that there could have been continued "slow leaking" of arsenic from body reservoirs that would have affected latter parts of the experiment.

- The large particle size of the soil used. Particle size is likely to affect bioavailability because of differences in surface-to-volume ratio.

- The procedure by which arsenic was added to the soil was not described. The contact period prior to skin application appears likely to have been very short relative to the time that would be necessary for binding to the soil particles.

- The water in which the arsenic was dissolved was not adequately described in terms of its chemical characterization.

- There was no information on whether the cage was washed to collect radioactivity and, if so, how this was taken into account for the purposes of calculating the absorbed dose.

- To keep the soil on the skin, a device made of two aluminum eyeguards sandwiched around a Goretex membrane was taped over the soil after application to the skin. The soil used had a particle size distribution larger than would typically be expected to adhere to skin. It is likely that soil fell to the bottom of the dosing device (which had a larger volume than the volume of the soil applied) and was not uniformly distributed on skin.

- The applicability of soil and water data to arsenic residues derived from wood surfaces is unknown.

Results of the study by Wester et al. (1993) were as shown in the following table:

***In vivo* percutaneous absorption of arsenic from water and soil on Rhesus Monkeys**

Percent applied dose			
Water		**Soil**	
Low exposure	High exposure	Low exposure	High exposure
6.4 ± 3.9	2.0 ± 1.2	4.5 ± 3.2	3.2 ± 1.9

An inverse relationship between exposure concentrations and percent absorbed was noted. The lowest exposure (water formulation) was associated with the highest percent absorbed – 6.4%. This value was proposed by EPA as the default value for skin absorption.

The Panel considered that, on general toxicological principles, for the purpose of extrapolating the results to humans, it would be more appropriate to have results obtained using a more realistic level of exposure, namely the higher exposure level used in the experiment. In that regard, it was also noted that the soil group had a higher degree of arsenic absorption (3.2%) than the water formulation group (2.0%). There were two possible reasons why this might have happened: 1) a factor in the soil that promoted exposure or 2) random biological variation because of the small numbers of monkeys in the groups (three monkeys in the water formulation group and four in the soil group). The Panel considered the second reason the more likely.

On this basis, the Panel considered that a value for skin absorption in the range 2-3% would be more appropriate than 6.4%. However, it was felt that this was likely to overestimate actual absorption, because the monkeys had been exposed for 24 hours and the form of arsenic used in the experiment was probably more water soluble than arsenic from CCA treatment. Also, the treated soil had had no opportunity to "age," a process that could bind the arsenical molecules more tightly to the soil matrix and reduce absorption. The possibility of considering a measure of absorption that took into account time of exposure (i.e., absorption rate) was felt to be worthy of further consideration.

A separate *in vitro* experiment reported by Wester et al. involved measuring absorption of arsenic from water and soil on human skin. This gave a result of 0.76 % absorption from soil and 1.9 % from water.

It was also noted that there was a lack of information on the chemical form of arsenic in CCA residues. The assumption was that residues were likely to be in the pentavalent form. If there were trivalent arsenic present, then the kinetics of arsenic absorption could be different. However, there is no available information on skin absorption of trivalent arsenic compounds.

In view of the limitations of the research on which this evaluation was based, the Panel considered that there was an urgent need for further research on skin absorption of CCA residues, employing the form of arsenic found in dislodgeable residues and soil from CCA-treated installations.

The Panel also considered a proposal by two of the public presenters – Gradient and E^{X}ponent – to adjust the percent absorbed (as determined by Wester et al.) by a factor representing the relative bioavailability of gastrointestinal absorption of CCA arsenic residues. The rationale for this adjustment was that the Wester experiment had used a more water soluble form of arsenic than was present in CCA residues, and it had not had the opportunity to "age" after being added to soil. The Panel accepted that the form of arsenic used in the experiments by Wester et al. (1993) was not ideal, but considered it inappropriate to adopt this proposal for an adjustment factor, since it would involve a form of "double-counting" of soil-related factors that reduce absorption. It was felt that the recommended research would better address the issue identified by Gradient and E^{X}ponent.

Question 4: As available monitoring data do not differentiate among chromium species found in CCA dislodgeable residues on wood surfaces and in soils, and as Cr (VI) is the more toxic species of chromium, please comment on whether use of the hazard data for chromium (VI) is the best choice for characterizing hazard and risk from exposure to chromium as a component of CCA-treated wood. Please provide a scientific explanation and justification for your recommendation on the choice of either the chromium (III) or chromium (VI) hazard database.

Recommendation

It is the Panel's conclusion that, at present, there is no reliable evidence on either the presence or absence of Cr(VI) in dislodgeable residues on treated wood surfaces. Some measurable Cr(VI) probably exists in certain soils, but it is unlikely to be 100% of total chromium. One approach would be to use an estimate of 25 to 50% hexavalent chromium. Some Panel members suggested 5 to 10% would be conservative. In order to be health protective, it would be scientifically reasonable to use the Cr(VI) hazard database with respect to a range of chromium fractions. The Panel strongly recommends that EPA conduct studies of chromium speciation (in both dislodgeable residues and soil samples) in their proposed studies.

Discussion

There was little disagreement that available information on the valence state of chromium did not establish either the presence or absence of Cr(VI) in dislodgeable residues. The speciation data presented at this meeting are limited. However, the limited Florida data suggest that Cr(VI) may not be a major environmental hazard, even as we acknowledge that the hexavalent form of chromium is the more significant health hazard. Further research on valence speciation of chromium at sites where treated wood is being used is warranted.

Several members of the Panel noted that detection of Cr(VI) would be confounded by the fact that Cr(VI) in dislodgeable residues would be much more soluble and therefore more mobile to transport off treated surfaces with rain events. This complication could be accounted for in the future pilot studies being planned by EPA and CPSC. The Panel did not elaborate further on the issue of Cr(VI) in dislodgeable residues, and the rest of the Panel's focus was on valency issues for soil chromium.

Several members of the Panel noted that there is some evidence from two types of studies that Cr(VI) can exist in soils in measurable amounts. The fraction of Cr(VI) in soils is highly dependent on such soil characteristics as moisture content, pH, binding sites for adsorption on mineral and organic components, etc. One line of study entailed experimental evaluation of Cr(VI) formation and stability in soils of differing chemical, moisture, and complexing types (Bartlett, 1991; Bartlett et al., 1983; Bartlett et al., 1979).

A critical factor in formation of Cr(VI) in undisturbed, non-acid soils of typical moisture content is the oxidation of Cr(III) to Cr(VI) by manganese oxide. Bartlett also reported that Cr(VI) can be adsorbed and stabilized to some extent.

A second body of information consists of determination of the fraction of Cr(VI) in soils in Hudson County, NJ, which received alkaline chromite ore processing residues. The fraction of Cr(VI) ranged from 1-50% (Burke et al., 1991). At this site, the amount of Cr(VI) was seldom more than 10%. In situations where the chromium was in solution in surface water, chromium blooms (crystallization) occurred on the soil surface as the soil dried out and contained up to 50% Cr(VI).

The overall discussion by the Panel of what fraction of Cr(VI) in soils should be adopted by EPA in any preliminary risk assessment efforts elicited a range of values and a variety of conclusions as to their significance. This variety of opinions included a desire to wait for the pilot studies being planned nationally before going any further. Some members indicated a range from 5-10% would be conservative. Other Panel members indicated a range of 25 to 50%. One Panel member noted that it was inappropriate to consider the chromite ore residue data in New Jersey.

It was generally the view that it would be unlikely that 100% of total chromium would be present as Cr(VI) in playground and deck areas. Conversely, no Panel member tendered the view that Cr(VI) would never exist in any soils associated with playgrounds and/or decks constructed of CCA-treated wood.

The Panel generally was interested in having the planned studies by EPA and CPSC include as much chemical speciation data as possible -- much more than the agencies had indicated in their draft protocols.

One Panel member, with assent from others, noted that the issue of chromium valency in soils is not subordinated to the subsequent redox transformations that might be assumed to occur in the stomachs of children ingesting soils containing Cr(VI). That is, any transformation of Cr(VI) to Cr(III) in receiving body compartments (lung, GI tract) occurs via uptake of Cr(VI) and

formation of intermediate, bioreactive valencies that may be linked to the mechanism of the toxicity of Cr(VI).

Question 5: Please comment on the Agency's selection of the 0.5 mg/kg/day NOAEL value for use in assessing risks to the general population as well as children from short-term and intermediate-term incidental oral exposures to inorganic chromium as contained in CCA-treated wood. Please provide an explanation and scientific justification for your conclusions as to whether the presented data are adequate or whether other data should be considered for selection of these endpoints.

Recommendation

The Panel expressed concerns regarding the selection of the 0.5 mg/kg/day NOAEL for short-term and intermediate-term incidental oral exposures to inorganic chromium. In general, these concerns involved the appropriateness of the study selected by EPA (Tyl, 1991) to derive this value. It is the Panel's recommendation that the Agency re-review the literature and consider other potentially more relevant studies.

Discussion

The SAP agreed that the most appropriate toxicology data for the development of the NOAEL should involve the same species of chromium as present in CCA-dislodgeable materials and contaminated soils which are the subject of the risk assessment. Given the absence of appropriate data, this decision will ultimately depend on the results of field studies such as the playground studies proposed by EPA/CPSC.

The Panel questioned whether the study proposed for the derivation of the NOAEL (Tyl, 1991) actually demonstrated the purported effect. The Panel was divided on this issue; some thought the study adequate and appropriate to support the proposed NOAEL while others thought the study to be flawed and inappropriate.

- The selected study had the primary purpose of evaluating the reproductive and developmental effects of exposure to Cr(VI). While no developmental effects were observed, maternal effects were noted and were used to derive the NOAEL. Rabbits were given a bolus of chromic acid (CrO_3) diluted in distilled water by gavage for twelve consecutive days. Dosing was at 0, 0.1, 0.5, 2.0, 5.0 mg/kg/day levels; the 5.0 mg/kg/day dose was noted to have a pH of 1.52. Maternal effects observed included mortality in the 2.0 and 5.0 mg/kg/day groups and reduced weight gain, decreased food absorption efficiency, labored breathing, and diarrhea in the 5.0 mg/kg/day group. No pathologic abnormalities were noted in any group.

Several members of the Panel questioned the attribution of the observed effects to the Cr(VI) dosing; they believed that an acid effect could not be ruled out. Others discounted this possibility stating that dietary residues could readily neutralize the acid. Specifically, it was noted that rabbits retain half their ingested diet 24 hours after conventional fasting began

(Carmichael et al., 1945) and this residue would serve to buffer against acid injury from acidic media given after conventional fasting. There was no resolution of this difference in interpretation.

Studies cited by the Agency (MacKenzie, 1958) and Zhang and Li (1987) are generally supportive of the NOAEL value derived from Tyl, but, as noted by OPP, these studies suffer from a lack of definitive exposure information and are of inappropriate duration for use in deriving a short or intermediate measure.

Question 6: Please comment on whether the significant non-systemic dermal effects from dermal exposure to inorganic chromium should form the basis of dermal residential risk assessments, and, if so, how the Agency should establish a dermal endpoint for such an assessment.

Recommendation

The Panel advises that EPA should base risk assessments for noncancer health effects of dermal exposure to hexavalent chromium on direct dermal effects – irritant and allergic contact dermatitis. The Panel was unable to provide EPA with methods for establishing endpoints and determining dose response relationships for these effects.

Discussion

It is unlikely that sufficient chromium could penetrate the skin and enter the circulation to cause systemic effects from dermal exposure. Skin penetration for chromium is estimated to be 1%. It is usually assumed that the contribution to systemic effects from dermal exposure is not likely to be significant relative to oral exposure. Direct dermal effects (irritation and allergenicity) are therefore likely to be the controlling endpoints as far as dermal exposures are concerned. The Panel therefore advises that EPA base its residential risk assessments for the dermal route on these direct dermal effects. In order to make sure this route is inconsequential for systemic effects, one could run a PBPK model and compare the target tissue doses from the oral and dermal routes.

The Panel believes that EPA should consult with the New Jersey Department of Environmental Protection (see Bagdon and Hazen, 1991) concerning establishing dermal endpoints and performing dose response assessments for dermal exposure to chromium using direct skin effect endpoints. The main problem will be determining the appropriate endpoint and obtaining a usable dose estimate from the published literature using data from exposure of workers and other exposed individuals (Bagdon and Hazen, 1991; Burke et al., 1991) or possibly from animal experiments mentioned in the ATSDR document (Mor et al., 1988; Gross et al., 1968; Jansen and Berrens, 1968).

Question 7. Please comment on whether OPP's choices of central tendency and high end values for different parameters should, collectively, produce estimates of the middle and high end of the range of potential exposures. If the Panel thinks that OPP's approach may not estimate the high ends of the exposure range

(because it produces values that are either higher or lower than the upper end of the exposure range), please comment on what specific values should be modified to produce estimates of the high end of potential exposure.

Recommendation

The Panel offers the following recommendations:

- Particularly when using point estimates it is important to do subset analyses for specific regions of the country (for example, the South compared to the North or Midwest) and for age groups (for example, one year olds compared to 5-6 year olds).
- The averaging of exposure over a 75-year lifetime may underestimate risk. More research is needed to understand the uncertainty associated with this form of temporal averaging.
- More research is needed on the amount of soil ingested, as this is still a source of uncertainty.
- For fully evaluating high end exposures it would be necessary to include exposure of children with Pica.
- A probabilistic assessment as discussed in question 8 is recommended.

Discussion

Comments of OPP's choices of central tendency and high-end values for different parameters have been approached in two ways: assessing the quality of the specific values OPP has presented and evaluating whether the point estimates used in the Agency's calculations will provide reasonable estimates of the high-end exposure range.

Specific values

The prototypical three year old behaviorally does not represent either a one year old or a six year old. In addition, the surface area used for fingers, 20 cm^2, while appropriate for a three year old, would be an overestimate for young children, since both the surface area of the hand and the proportion of the surface area which is fingers are different for younger children. This is an argument for either doing subset analyses for smaller age groups, or doing probabilistic evaluations.

Time spent at play outdoors may be an overestimate for the measure of central tendency. Both NHAPS data and that reported by Silvers et al. (1994) suggest that most of the time children are at play outdoors is on grass or paved areas, neither of which represent the types of substrates typically found around CCA wood play structures.

The assumption that the average child spends 130 days playing on these structures is also not a realistic central tendency measure. The National Human Activity Pattern Survey (NHAPS) data for children 1-4 years old suggests that on any day only 50% of children may play outdoors and that, of those, approximately 40% would play on the types of substrates on which play equipment is found. Data presented from Florida suggest that there may be major regional differences in these estimates which would not be treated well with point estimates unless regional subset analyses were done.

The hand to mouth frequencies proposed are based on both indoor and outdoor mouthing periods. Freeman et al. (2001) found that, among children in Minnesota, mouthing rates were significantly higher indoors than outdoors (approximately 3 times higher indoors). At the same time, if residues or soil adheres to hands, the ingestion of that material may not take place outdoors, but occur indoors after the child has played on the equipment. Freeman in her own evaluations has shifted to using the median value of Reed's data (8.5/hr) rather than using the mean of 9.5/hr as a more conservative value for a measure of central tendency. It should be noted that most mouthing behaviors occur indoors during quiet times such as when watching TV. It has been infrequently observed during active outdoor play other than by infants and very young toddlers.

The issue of whether replenishment occurs after mouthing needs to be addressed. Contacts with surfaces and objects are "fast and furious," with the average contact duration of 4 seconds and hundreds occurring per hour. If total replenishment occurs after 4-5 contacts (Rodes et al., 2001), then it is likely that the fingers are fully loaded between mouthing events.

Some Panel members noted that the central value for soil ingestion rates of 100 mg/day is probably an overestimate. Median values reported by both Stanek and Calabrese (1995), and Davis (1990) range from 0-96 and 25-81 mg/day, depending of the tracer used. Other estimates range between 35-70 mg/day and may be more realistic (Sedman, 1989 and 1994; Calabrese, 1995). These values also represent total soil consumption for the day, and not just from the 1-3 hours of play by CCA treated equipment, which would be something less than 100% of daily soil consumption. In addition, the use of 400 mg/day as the high-end value is also an overestimate based on Calabrese and Stanek's work.

In considering high-end exposures, the Agency might consider including an evaluation of children with Pica behaviors. This is an area for which there are little data but may be important for understanding the high end exposures.

Reasonable estimates

The dermal and ingestion models proposed are very simplistic, but there is no harm with trying them and trying a variety of inputs as a first step in understanding exposure and risk. There may be no point trying to agree on a correct set of inputs at this time. Additional data on dermal and ingestion exposure will improve the models and reduce uncertainties. All of the coefficients and parameters seem to be conservatively biased toward overestimating exposure. When inflated "central tendency" values are put into the deterministic exposure calculation, they can be expected to overestimate the expected or "central tendency" exposure. If the distribution of exposure is highly positively skewed, this bias may be considerable. In some cases the arithmetic mean values presented are substantially skewed and should be replaced by median values as a better indicator of central tendency.

Working with the high-end values will be even worse, as the result will correspond to the very rare event of an exposure that is extreme in every aspect and hence will be higher than is ever observed in reality.

Looking at the general variables that the Agency proposes to use for characterizing child exposures through dermal and oral routes, the general conclusion is that using a range of values in a probabilistic evaluation should be the way to approach evaluating child exposures. Issues related to a probabilistic model are discussed in Question 8.

If the deterministic model is used, any parameters that are unnecessarily inflated should be reduced. One value to look at first is the calculation of skin surface area, which could be replaced by the "effective skin surface area." The hours per day of playground activity could also be looked at, the days per year will probably vary regionally.

The models proposed by the Agency for the study of children's acute and chronic CCA metals exposures (ADD-average daily dose and LADD-lifetime average daily dose) from play structures involve the composition (through multiplication and division) of stochastic variables from multiple sources and transitions in the dermal and oral exposure routes. The true composite exposure distribution is expected to be right skewed (e.g., log normal or similar distribution). It is also expected that the distribution is left censored—rarely at zero exposure—but at other exposures not related to playground or play structure use.

Estimates of ADD and LADD distributions, their means, medians, and quantiles, should reflect the distributional parameters (means and variability) of each of the exposure components, the covariance of the exposure components, and, through sensitivity analysis, the uncertainty (variance and bias) of the sample-based or postulated value of these parameters. In addition, the influence of covariates (e.g., region, climate) not explicitly included in the estimation model must be taken into account.

The proposed estimators of ADD and LADD are simple product and/or ratio statistics. In the simple case of a product of two variables, the product of central tendency values is

$$E(X)\,E(Y) = E(XY) - Cov(X, Y)$$

This implies that for positively correlated X, Y the product of means will underestimate the mean of the product.

Furthermore, if these central tendency measures are estimated from sample data, the approximate variance of the product is

$$Var(X\,Y) = Var(X)\,E^2(Y) + Var(Y)\,E^2(X) + 2\,Cov(X, Y)\,E(X)\,E(Y)$$

That is, the variance of the product will be inflated if there is a positive correlation between the variables. For statistics such as the proposed estimators of the ADD or LADD, the properties illustrated here for means of two distributions will be propagated through calculations involving means of more than two variables.

The median of the product X Y may not be the product of the median even if the two distributions are uncorrelated. To illustrate, take two simple discrete uniform distributions, X=(1,

2, 3), Y = (2, 8, 14). Generate all possible (X, Y) pairs and create the distribution of their product (e.g., 1 x 2=2, 1 x 8 = 8, etc.) assuming no correlation. The composite product distribution includes 9 equally likely values X Y=(2, 4, 6, 8, 14, 16, 24, 28, 42) with median = 14, but the product of the medians of the X and Y distributions is 2 x 8 =16.

Likewise, the product of the medians and other distributional quantiles (e.g., Q_{90}, Q_{95}) for X and Y that are positively or negatively correlated will be biased for the quantile of their product distribution. The direction and magnitude of the bias will depend on the size of the correlation and the shape (symmetry and variability about mean) of the distributions of X and Y. The theory here is based on Dirichlet distributions for the products of order statistics.

The alternative to the deterministic approach that is proposed is a probabilistic modeling of the exposure routes. Bayesian methods, possibly with flat priors over the range of measured parameter values, might be considered as the probabilistic approach is developed.

Question 8: Please comment on whether the existing data bases on the variability of the different parameters affecting potential exposure are adequate to support the development of probabilistic estimates of potential exposure. If the Panel regards the data bases as adequate for that purpose, please identify which parameters should be addressed using a distribution of values and which data bases should be used to supply the distribution for particular parameters.

Recommendation

In view of its concerns that the deterministic model reviewed in Question 7 will not correctly estimate the central tendency or percentiles of the exposure distribution, the SAP recommends that the EPA immediately begin to take steps toward the development and progressive refinement of probabilistic models of exposure. The probabilistic models will give high-end values that are interpretable as a percentile of the modeled exposure distribution rather than a biased approximation of the upper limit of exposure. The existing databases on the variability of the different parameters affecting potential exposures of children using CCA-treated playground structures are adequate to begin the development of probabilistic estimates of potential exposure provided the uncertainty associated with these data is reflected in the exposure modeling. As noted above, the Panel views the development of a probabilistic assessment as a process of progressive learning and refinement. New or more detailed data on states and transition factors are needed and will contribute to improvements in the exposure models as they become available.

Discussion

The Monte Carlo risk assessment of CCA metals exposures presented by the Environmental Working Group (EWG), while it contains several deterministic and simplifying assumptions, is a good start and illustrates what can be done with existing data. The use of a probabilistic approach avoids the arbitrariness and artificiality of selecting single values to represent factors that are known to vary considerably across individual exposures. This advantage is of particular

importance for the case of the RME estimates, where it has been demonstrated that the selection of reasonable upper bounds for several distributed parameters used as independent variables in a calculation can result in an estimate of the dependent variable (e.g., exposure) that is unreasonably far out in the tail of the probability distribution for that variable.

EPA guidelines for probabilistic exposure assessment and software programs like SHED, ReX, LifeLine, and Calendex can be used to perform a multi-dimensional analysis (separating, to the extent possible, variability and uncertainty). The LifeLine and Calendex models that have been reviewed by prior SAPs and proposed for studies of cumulative (including residential) exposure to organophosphates provide basic algorithms for beginning probabilistic approaches. One advantage of these programs is that they permit inspection of individual exposure values and the cumulative contribution of individual components to aggregate exposures. In these software systems, varying degrees of deterministic analysis can be forced by simply limiting the variability of the stochastic distributions.

The Panel recognizes that probabilistic exposure assessment is a relatively recent advance in risk assessment methodology. Therefore, a parallel approach is suggested, in which deterministic exposure estimates may be determined quickly and in advance of probabilistic estimates primarily to develop an initial understanding of which parameters have the greatest leverage on the final distribution of exposure outcomes. In addition, it is recommended that a limited variability analysis, similar to that presented by EWG, be performed as well as a full variability/uncertainty analysis. If a probabilistic approach is used, the 50^{th} and appropriate upper percentiles can be used as the central tendency and high-end estimates, respectively. Even if the Agency determines that a probabilistic approach cannot be used for the exposure estimates, the probabilistic results will play an important role in the risk characterization, for characterizing the variability of individual risk, the impact of uncertainty on the risk estimates, and the suitability of the selected central tendency and "high-end" values used in the deterministic calculations.

As mentioned above, a limited variability analysis could be performed in a similar fashion to the analysis presented by EWG. In this case, the Monte Carlo analysis would only vary parameters for which substantial data on variability are available. In the EWG analysis these included daily soil ingestion, dislodgeable arsenic, soil arsenic, and body weight. The approach used by EWG for body weight and surface area, following a child from 12 to 84 months of age with the opportunity for moving, is recommended, since it permits the incorporation of other age-dependent parameters such as mouthing behavior.

The details of the Monte Carlo analysis will need to be determined by considering the presumed nature of the anticipated exposures and the available data. For example, if it is assumed that a child uses a single playset for the entire 6 years, then a single randomly selected data set for dislodgeable arsenic can be associated with each child. If it is assumed that a child would use more than one playset, a more complicated sampling approach would be necessary. Alternatively, a very simple approach would be to repeatedly select at random from the totality of the data for dislodgeable and soil arsenic and use these selected values in the deterministic formulas together with the assumed values for the other parameters. The Panel encourages the

Agency to plan for modeling the exposure risks not only of special scenarios of individual exposures but also exposures in special high-risk populations. Such high-risk populations might include children in day care settings and living in warm climates, where the exposures to CCA treated wood may be more frequent and of longer duration than in the general population at large.

The more complete two-dimensional analysis should include distributions for all of the parameters in the exposure calculations. To the extent possible, separate distributions would be developed to describe variability (inherent variation) and uncertainty (lack of certainty regarding the correct value). The resulting exposure estimates would take the form of a "distribution of distributions" in which the variability around the central estimate would be displayed in one dimension while the uncertainty in the central estimate would be displayed in the second dimension. The multiple curves presented by EWG for different parameter assumptions is a (simpler) example of such a concept. However, instead of just showing the variability results for discrete alternatives of the uncertain parameters, distributions would be presented. The distributions used to describe uncertainty are necessarily much simpler than those informed by variability data. For example, a parameter may be characterized as having a uniform distribution (with equal likelihood of being anywhere in a given range), or by a triangular distribution (with a peak at the best estimate and vertices at the extreme values). The biggest problem with this approach is that there is often considerable uncertainty whether the observed differences in the value of a parameter represent variability or uncertainty or variability compounded by experimental bias (which introduces uncertainty). It is usually valuable to perform an analysis on the probabilistic approach that evaluates the sensitivity of the conclusions to alternative decisions that could be made regarding the variability/uncertainty distributions. As mentioned earlier, even if it is decided that the use of such an analysis for the risk assessment would not be appropriate, the results of the analysis would be very useful for characterizing the potential impact of uncertainty on a risk assessment using a partial probabilistic/deterministic approach.

Publications and presentations given to the Panel indicate that more data are needed to characterize other sources of variation and that there are more factors that need to be included in the model.

One area of improvement that could be addressed immediately is better representation of age-specific differences in children's body size and behaviors. For modeling population exposures, a first improvement over the current assumption of a fixed age and body weight for exposed children is to draw on data for children that are available from major survey data sets such as the National Health and Nutrition Examination Survey (NHANES). The EWG simulation study presented to the SAP by Dr. Houlihan used this approach. These samples of children provide representative age- and gender-specific data on body weights and heights for U.S. children. Modeling of exposure should adopt the methodology employed in LifeLine and other software that "ages" the child through the exposure window. As the child ages in the probabilistic simulation, the appropriate age-specific activity and exposure factor data are applied to estimate time-dependent contributions to short- and long-term exposures.

Another major source of uncertainty in the current model of exposure is the data on the

distribution of frequency and duration of children's exposures to CCA-treated wood play structures. The deterministic model proposed in the EPA presentation to the SAP makes a very simplifying assumption of constant daily and annual exposure frequency for six years of life. Obtaining precise, nationally representative time and activity data for children in the relevant age ranges would be tremendously costly. However, small local studies and existing small-sample data from the National Human Activity Pattern Survey (NHAPS), the Child Supplement to the Panel Study of Income Dynamics (PSID; http://www.isr.umich.edu/src/child-development/publications.html), and other studies could be used to better approximate the variability in frequency and duration of outdoor play. These data could then be interpolated to approximate time spent on CCA-treated play structures. We need more detailed information on the relative time spent on the structure and in the substrate. These data might be obtained from existing or new observational studies. Activity patterns will very likely depend on the weather, as children may, for example, avoid sand that is too hot or too wet. Data on the correlation between As/Cr in the structure and its substrate will be needed to use this information.

The EPA is planning a new survey of existing playground structures and substrates. These should be executed as one combined survey to look for correlations between existing structures and their substrate. All possible covariates should be recorded in the hope that the "unexplained variation" in As and Cr levels could be reduced from what we have seen in studies to date. Covariates might include the following: evidence of construction debris (sawdust) in the substrate, nature of substrate (clay, sand, etc.), source of wood, age of structure, condition of surface (new, aged, worn to a shine), climate. Initially, the probabilistic modeling could rely on the empirical distributions provided by Townsend, et al. and Stillwell data on soil and surface residue concentrations. The Panel expects that the new survey data will be substituted when they become available. In its response to Question 11, the Panel recommends that data obtained in studies of CCA treated decks not be viewed as representative of dislodgeable residues on CCA treated play structures or in the soils or substrates beneath these structures.

Panel members also identified the transfers of CCA residues from surfaces and soils as a major uncertainty factor in the modeling of exposure. For example, it is possible that wet-weather play and play on damp structures bring increased risk of uptake, but there seems to be no information other than wet-hand/dry-hand wipe studies. The Panel strongly recommends that the EPA explore and evaluate alternatives (by comparison) to the hand loading transfer efficiency in modeling the transfer of CCA metals from surfaces and soils to the child's hands and other skin surfaces. Specifically, the Panel recommends that the EPA conduct direct hand loading measurements in samples of children (preferably) or adults (if human subjects concerns intervene). The best empirical data may actually be collected through sampling of children who are actively involved in playing on CCA treated structures. The Panel also cautions that empirical distributions of arsenic and chromium concentrations measured in these hand loading studies not be used as the concentration values for dermal exposure through non-hand skin surfaces. One Panel member noted that probabilistic exposure models should allow occasional events like splinters and abraded skin to be included in the exposure pathway.

The Panel also noted that the better distributional data on children's outdoor hand-to-mouth frequency and the fraction of residue transfer are needed to improve the probabilistic modeling

of children's exposure. Data from Dr. Natalie Freeman and her colleagues is expected in the Spring of 2002. Preliminary results will be presented at a conference in early November, 2001.

In its response to Question 8, some Panel members noted that there ultimately should be a biomonitoring study that does a reality check on the predictions of the model, perhaps arranging a sample of children to play in a CCA-free environment for several months and comparing some measure of arsenic uptake with the same measure in a matched sample using existing CCA-treated playgrounds. The suggestion was made to collect urine samples from children during the time period after they had actively played on treated and untreated structures. A further comment was made that any analysis of arsenic in urine should examine the speciation of the arsenic. The topic of biomonitoring studies was discussed at length at the conclusion of the question responses. The reader is referred to the general summary of this discussion for a summary of the Panel's recommendations on the need and design issues for biomonitoring studies.

Question 9: OPP is assuming that a one-to-one relationship applies to the transfer of residues from wood to skin. The Panel is asked to address whether this is a reasonable assumption, and if not, to provide guidance on other approaches.

Recommendation

The Panel does not recommend assuming that a one-to-one relationship applies to the transfer of CCA chemical residues from wood to skin as proposed by the Agency. It is the Panel's opinion that the underlying conceptual model is questionable. Sufficient justification for a one-to-one relationship was not provided and the limited available empirical data contradict the validity of the assumed one-to-one relationship.

The Panel strongly recommends that the Agency expand its planned joint study with CPSC to measure dislodgeable CCA chemicals from an appropriate sample of play structures, so as to obtain information of more direct value for exposure assessment. Ideally CCA chemical loadings on the hands (and possibly other skin surfaces) of children using play structures would be measured in addition to corresponding dislodgeable residues. At a minimum, some Panelists would accept gathering of data sufficient to more adequately support implementation of OPP's current conceptual model (e.g., matched adult volunteer hand and cloth wipe samples to better establish the relationship between these two measures as well as the constancy of any relationship as a function of surface area sampled).

The Panel was divided on an interim recommendation for the Agency while it awaits collection of these additional data for the EPA/CPSC study. Some Panel members were willing to endorse interim use of existing hand or fabric wipe data if described probabilistically. One Panel member voiced strong opposition to any use of cloth wipe data until the Agency obtained additional information establishing the validity of the assumption of a constant loading as a function of wiped surface area. At least one Panel member opposed use of a "transfer

efficiency" approach, preferring a "transfer factor" approach which cannot be implemented without further data collection.

Discussion

The Panel was not given any explanation or justification of how OPP's Residential SOP – with its assumption of a one-to-one transfer of pesticide residues from surface to skin – was derived and whether there is general agreement on its principle and use. [Note: The SAP meeting at which the proposed residential SOPs were discussed was held in September of 1999. The reference to April, 2000 is unclear. No source bearing that date was provided as background material or is cited in the background document.]

The Panel noted a number of factors that make an assessment of the appropriateness of a one-to-one transfer relationship difficult. Variables that might influence surface-to-skin transfer include the nature of the initial CCA treatment, type of wood (softwood, hardwood, etc.), condition of wood (age, moisture content, etc.), orientation of wood member (vertical or horizontal), nature of the surface residue (particle-bound, dissolved, crystalline, etc.), condition of skin (moist/dry, intact/broken, clean/dirty), and nature of contact (pressure, duration, static/dynamic, etc.). The Panel discussed the extent to which both published peer reviewed literature and new information presented at the meeting provided empirical data for evaluating the assumed one-to-one transfer of CCA chemicals from wood surfaces. Dr. Stillwell reported transfers of 30 to > 90% when CCA chemicals were applied to a glass surface using his cloth swipe technology. The higher levels of transfer were observed when using damp cloth. Similarly high transfer factors were reported for a study (Rodes et al., 2001) with hand presses to remove household dust. This study showed that the magnitude of transfer was sensitive to surface material (stainless steel > vinyl > carpet) and hand moisture content (wet > damp > dry), although the applicability of this study to dislodgeable CCA wood chemicals was unclear. The Panel was presented with an unpublished study by Scientific Certification Systems (SCS, 2001) that compared loadings of hand swipes versus "KimWipe" tissue swipes of CCA wood. This study reported that transfer efficiencies for damp adult hands were lower than those observed using dry "KimWipe" tissue swipes of CCA wood. Damp hand swipes were reported to be 7.5% of results obtained using "KimWipe" tissue swipes of new CCA wood surfaces that had not been treated with a sealant. The damp hand swipes were 44% of "KimWipe" tissue swipes of aged CCA wood. The Panel noted that these comparisons reflect different surface areas swiped by hand (500 cm^2) versus tissue (100 cm^2), and expressed concern over potential nonlinearity in loading as a function of surface area. Exponent presented an analysis of existing data indicating that hand swipes were on average about 25% of cloth/tissue wipes, but the Panel noted variability and uncertainties related to the size of the surface area sampled, the type of contact and consistency across testers, and humidity of contact surface confounded the interpretation of results.

One Panel member stated that the Agency's proposed model for computing hand loading of CCA chemicals appeared capable of substantially underestimating and overestimating the amount of transfer, based on comparing predicted hand loadings from cloth and tissue swipe data with observed hand loading data. The Panel member strongly urged the Agency to make use of current data with both hand and cloth swipe data (e.g., Lu and Fenske, 1999; California DHS, 1987; SCS, 1998) to validate their conceptual model. It was emphasized that the assumption of

a constant transfer efficiency as a function of surface area wipe had not been established and indeed there were data to argue to the contrary.

It was noted by the Panel that all the transfer studies discussed use the hand only, and the transfer may be different with different body surfaces that may contact the wood. The issue was also raised that there are no studies showing that transfer efficiency is constant across different surface area sizes or types. It should also be noted that Rodes (2000) found that skin loading of dust particles reaches a maximum after typically 4-5 contacts. After that, there may be dislodging of particles from skin.

Addition of collection of hand wipe samples from children engaged in unstaged activity on play structures has been recommended for the proposed CPSC-EPA field project. Wipe samples should include body parts other than hands, or non-hand surfaces should be removed from the dermal/dislodgeable residue scenario, as loading on body parts other than hands will probably be much lower than loading on hands. If the Agency intends to do these transfer evaluations, it needs to adopt an appropriate standardized sampling protocol for surface collection since that will affect the outcome. Specifically, the Agency needs to include validation of the assumption of constant transfer efficiency as a function of the sampled surface area.

In conclusion, the Panel agrees that a one-to-one relationship for transfer of residues from wood to skin is not justified at this time. The Panel also agrees on the need to collect empirical data that realistically reflect the activities of children on CCA-treated wood play structures and other possible points of contact such as decks and walkways. If a probabilistic risk assessment is to be conducted before new, relevant empirical data are generated, a wide range of possible transfer efficiencies (TEs) should be used in a manner that reflect the uncertainty and variability in the available data.

Question 10: The Panel is asked to comment on whether the proposed Soil Adherence Factor (AF) of 1.45 mg/cm^2 for hand contact with commercial potting soil is a realistic value for use in estimating the transfer of residues from playground soil to skin in this assessment.

Recommendation

Use of an AF of 1.45 mg/cm^2 is not recommended. The proposed AF was derived from an unpublished study of very limited scope. EPA has funded subsequent research to derive more representative values.

Discussion

The proposed AF represents a fairly high hand level and is too high for whole-exposed-body-surface average. Soil loadings on non-hand body parts are typically lower than loadings on hands. The soon-to-be-released RAGS Part E provides an estimate of a surface-area-weighted average soil adherence factor for children. However that number reflects multiple activities on multiple surface types. For purposes of evaluating use of CCA-treated wood in play structures, consideration of media found under play structures is required. Adherence factors relevant to loose media appear most appropriate. A possible alternative to the value recommended in RAGS Part E would be the children-playing data from Kissel et al., 1998. Those data were collected from 8-12 year olds playing in a bed of sandy loam installed in a greenhouse. (The data can be downloaded from http://depts.washington.edu/jkspage/greenpost.html.) Most of the data were collected under wet soil conditions. The wet soil data should be conservative for soil and may be adequate for buffer materials. No data describing adherence of buffering materials (bark, pea gravel, ground tires) to skin are known to exist.

The proposed dermal/soil scenario utilizes an absorption factor derived from 24-hour experiments, implying that the exposure period is also 24 hours. Soil exposures occur intermittently and are interrupted by bathing events. (For instance it is unlikely that soil loadings equivalent to those observed in the greenhouse experiments noted above would be maintained for 24 hours.) A probabilistic approach incorporating temporal description of both exposure and absorption is preferable to the deterministic approach proposed by OPP. To the extent possible, variation with age, season, and geographical region should also be incorporated.

Question 11: OPP will need to calculate intermediate-term, and possibly long-term exposures in this assessment using available wood/soil residue data. The Panel is asked to recommend a credible approach for selecting residue data values for use in OPP's risk assessment, taking into consideration the inherent variability of the data sets. Please advise us on which values are best for representing central tendency and high end exposures. Also, the Panel is asked to discuss the feasibility of combining data from individual data sets.

Recommendation

The proposed USEPA/CPSC study of wood and soil residues associated with CCA-treated playground equipment provides a unique opportunity to generate a substantial data set on the variability of residue levels for the playground scenario using a standardized sampling and analytical methodology. This study should help to resolve uncertainty regarding the relative contribution of true, inherent variability in residues versus variability due to differences in methodology. It is critical, therefore, that the protocol be highly detailed regarding sampling methods, locations, and frequencies and that the protocol be rigidly followed. Basic scientific criteria for acceptance of the final data set should be laid out first and include: standardized collection methods, precision, accuracy, reproducibility, and other measures of QA/QC.

The Agency should not combine data with quite differing levels of precision and conservativeness, and use one set of data to drive other model considerations. The model cannot be fully evaluated without real world (i.e., biomonitoring or soil consumption) data for comparison, and that comparison cannot be made without a representation of both variability and uncertainty in model outputs.

Discussion

There are few studies related to children's playgrounds, and no study contains all of the data that the Panel considers critical to getting an accurate determination of what children are being exposed to on playgrounds and on CCA-treated decks. The Panel believes that separate studies should be conducted (i.e., those looking at residue levels on playgrounds, and those examining home decks and home playgrounds). The residue data should not be combined from decks and playgrounds. Data from piers, walkways in wetlands, and similar structures do not fit the playground scenario and should be ignored. The Panel recommends that the Agency expand the upcoming study to 25 playgrounds and 25 home decks/home playground combinations in each of the three U.S. study areas (e.g., Northeast) in order to determine what children are being exposed to. An extensive sampling regimen must be undertaken.

The critical data required for risk analyses should include the following information and samples:

- Soils selected should mirror those most commonly found in each region;
- History of the playground equipment (e.g., wood type, age, coatings/sealants etc.) must be collected;
- Representative soils should be collected in order to determine speciation and profiles of As, including organic arsenic species and chromium in the soil profile at each site; soils must be collected from throughout the area below and adjacent to the play equipment/deck and analyzed separately to determine the primary sites of residue levels that are unique to each playground/deck studied; adequate control soils must be collected from adjacent areas;
- Soils, including controls should be characterized thoroughly (e.g., clay, sand and silt content, pH, organic matter, moisture, etc.);
- Wood borings from sections of the playground equipment known to have frequent contact by children at play (this can be accomplished by video) for residue analyses should be collected to determine residue levels in wood and relate these to residue levels that have leached to the surface (the treatment process is not uniform due to knots, growth rings, etc., and there probably are "hot spots" of As and Cr) (this is related to Question 9);
- Wipes have been used as a means of determining dislodgeability, but there is no standard technique that provides reliability and uniformity to data collected from various surfaces;

- Consider collecting hand, arm and leg rinses from a representative sampling of children playing on the equipment and tie these to biomonitoring analyses;
- Analyses of buffering materials from play areas including borders should be included in the study (related to Question 14).

Each of the available data sets should be critically evaluated to determine whether they have been obtained 1) from a relevant structure and 2) using acceptable sampling and analysis methodologies.

The following studies present some representative soil data and can be used until additional data are collected:

- Playground equipment: Riedel, D. et al. 1991. Residues of arsenic, chromium and copper on and near playground structures built of wood pressure-treated with "CCA" type preservatives. Draft report to Health and Welfare Canada, 49 pp. (10 playgrounds examined); Malcom Pirnie. 2001. Report results of soil sampling analysis. Chromated copper arsenate treated wood at playground structures. Draft appendices. Prepared for Am. Chem. Council. (4 playgrounds in U.S.)
- Decks: Stillwell, D. E. and K. D. Gorny. 1997. Contamination of soil with copper, chromium and arsenic under decks built from pressure treated wood. Bull. Environ. Contam. Toxicol. 58:22-29 (7 decks); Scientific Certification Systems. 2000. Study of arsenic leaching into soils underneath CCA treated wood decks. Prepared for Osmose, Inc., 47 pp. (10 decks 5-5 to 10 yr and 5-10 to 15 yr old); Townsend, T., H. Solo-Gabriele. 2001. Metal concentrations in soils below decks made of CCA-treated wood. FL Center for Solid and Hazardous Waste Management, Gainesville, FL, 88 pp. (9 structures in FL).

The Agency asked for advice on values for best representing central tendency and high-end exposures. The best measure of the central tendency depends on the shape of the distribution. One Panel Member noted that it has been suggested (Crump, 1998) that the arithmetic mean, as opposed to the geometric mean, is the preferred measure of central tendency for exposure when the concern is for health effects. The best approach for estimating central tendency and high-end exposures and for dealing substantively with the process would be a two-stage probabilistic analysis that evaluates both variability and uncertainty. The use of distributional analyses for CCA exposures should rely on firmly established and transparent criteria that are common to all probabilistic analyses. Many of the same principles that have been incorporated into the assessments of food and residential exposure guidance, for example, should be incorporated into the CCA assessments. In order to do this it is important to develop clear and consistent criteria for both the modeling process and methods for dealing with model uncertainty, model variability, and input uncertainty. All three of these must be addressed systematically throughout the process.

This three-point framework for describing model variability and uncertainty is based on the points outlined in Cullen and Frey (1999), which is a useful guidebook and starting point for addressing the issues raised by this question. Once these principles are clearly articulated and inculcated, decisions based on application of this framework should be easier to justify.

Given the multiple models, data sets, and analyses involved in developing an assessment of CCA, probabilistic methods are the preferred approach for estimating exposures and risks. That said, the use of uniform distributions, which are generally used in cases where data are sparse or inconsistent, are better than point estimates. Fitted distributions should be used when there is

some underlying rationale, such as processes driven by physical parameters where some data exist or in cases where there are fairly good data, such as soil consumption rates. There are several options for combining these data. When appropriate, multiple data sets could simply be combined into a single, "global" data set that could be used as input for a probabilistic exposure assessment. However, this simple approach ignores the "inadvertent" weighting associated with combining data from experiments with different numbers of samples. Appropriate weighting factors could be applied to each data set to correct for this effect.

Alternatively, weightings could be applied on the basis of a judgment concerning the "representative nature" of a particular data set. The specifics of the approach for combining these data should be determined by a qualified statistician in conjunction with scientists familiar with the data. A similar analysis has previously been performed to obtain a "global" distribution for the hair:blood partition coefficient for methylmercury (Clewell et al. 1999).

It is inevitable that dissimilar data will be combined once exposures are aggregated, but uncertainty and variability should be distinguished. The Agency should not combine data with quite differing levels of precision and conservativeness, and use one set of data to drive other model considerations. The model cannot be fully evaluated without real world (i.e., biomonitoring or soil consumption) data for comparison, and that comparison cannot be made without a representation of both variability and uncertainty in model outputs.

In performing a probabilistic analysis the Panel suggests using intervals (i.e., uniform distributions) rather than point estimates when data are sparse/uncertain. This approach reduces the burden of data collection and parameterization and, although it is simpler than second-order Monte Carlo simulations that formally separate variability from uncertainty, it still distinguishes the two. Using intervals in a Monte Carlo simulation avoids creating a mix of partially probabilistic and partially deterministic estimates.

Question 12: Does the Panel have any recommendations for combining the four scenarios (oral/wood, dermal/wood, oral/soil, dermal/soil) such that a realistic aggregate of these exposure routes may be estimated?

The Panel offers the following recommendations:

- The Panel encourages the Agency to aggregate exposure estimates across all potential sources. This should occur in a way that makes the contribution of various sources of exposure transparent and tracks separate species of arsenic and chromium. Although data at present are limited, it is possible that the different species of arsenic encountered from distinct exposure scenarios may differ with respect to their hazard. For example, arsenic in the form of a complex of copper chromated arsenate ingested from direct contact with freshly treated wood might be metabolized and excreted differently than arsenate leached from weathered wood and ingested incidentally in soil.

- The suggested scenarios *(oral/wood, dermal/wood, oral/soil, dermal/soil)* capture the exposures that may occur on playscapes and decks. Inhalation exposure may be a route

that should be included, however at this point in time, data are insufficient to estimate the distribution of possible inhalation exposures. Refer to the response to question 13 for further analysis.

- However, in terms of the aggregate exposure assessment, the proposed scenarios do not capture sources of exposure that appear to be significant. The Panel suggests that the Agency broaden its inquiry to consider the diversity of possible exposures to arsenic, chromium and copper. Some Panel members felt that the Agency should expand its formal analyses of exposure to include other media under the jurisdiction of other EPA offices—drinking water, air, and waste—to avoid a fragmented and incremental approach to risk assessment and management of arsenic, chromium and copper species.

- Probabilistic methods should be used to estimate exposure and risk. This demands selection of best available data sets to construct distributions. This must be done with considerable care. The EWG approach seems conceptually reasonable; however, their method combines point estimates with distributions, and this may introduce bias into the estimates. The Lifeline method is especially well adapted to aggregate exposures across diverse routes, while preserving estimates at the level of the individual. The Agency should be encouraged to develop this model in the immediate future while closing data gaps.

- Uncertainty should be carefully characterized, distributions characterized, and clear criteria applied to judge the quality of available data for each parameter included in the assessment. The Agency should further develop Table 4 in the EPA support document *Children's Exposure to CCA Treated Wood Playground Equipment and CCA Contaminated Soil*. Table 8 in the Gradient Corporation submission provides a similar model that attempts to identify ranges of factors potentially affecting exposure, tracks the sources of data, and provides a preliminary characterization of uncertainty.

- Regarding uncertainty and default assumptions the Agency should confront two questions directly: When are data of sufficient quality to include in a modeling effort? What should be done until data are adequate? The SAP provided the Agency with clear criteria to judge data quality in 1999, and these were recognized in support documents provided to this panel. Under conditions of moderate or high uncertainty (absence of sufficient data to fully capture the variability in exposure from these sources), the Agency should develop clear default assumptions to be employed until sufficient data are secured. These assumptions should err on the side of overestimation of exposure, or factors that contribute to exposure, and reduced if and when credible data are presented.

- The Agency should develop methods that aggregate exposure and risk estimates for individuals. These may then be aggregated by various demographic characteristics—age, income, ethnicity, and location (north/south; urban/rural), or specific behavioral characteristics.

- The literature on childhood behavior and activity patterns that may be associated with CCA exposures is quite young. It provides only a limited basis for understanding the associations between behavior and exposure. The Panel recommends that the Agency undertake studies of childhood behavior and activity patterns to clarify these possible associations, as children move through their daily life. These studies would be useful in EPA assessment of exposures to many different hazardous substances. The Agency's efforts in developing the Exposure Factors Handbook and the more recent Children's Exposure Factors Handbook are very positive and important contributions that support data based, behavioral scenario-building.

- The Panel anticipates considerable year-to-year variability in exposure among children ages 1-6. Toddlers between 1 and 2 years of age play, behave, eat and dress very differently than 6 year olds, and these are likely to affect contact with contaminated media.

- Residential, educational, day-care, recreational, and occupational environments all offer the possibility of childhood exposures to CCA. Specific locations where CCA is in common use include decks, playscapes, railings, docks, piers, pilings, fencing, and exposed untreated interiors of structures, especially those close to the ground such as sills. Picnic tables, mulch, and contact with wood scraps, smoke from intentional and unintentional fires, and ashes from burned construction debris could all be sources of exposure.

- CCA-treated wood is increasingly being used for interior construction, and if unfinished and left exposed, may be an additional source of childhood exposure. It would be helpful for the Agency to estimate the extent of these uses.

- The Panel encourages the Agency to consider possible high exposure scenarios defined by overlapping risk factors. For example, a toddler living in the Southwest, may experience high drinking water concentrations of arsenic. At the same time the warm climate encourages extended periods of outdoor recreation. If this child is enrolled in a day care facility with decks and play structures made from CCA-treated wood, the aggregate exposure may be high. The identification of populations that are both physiologically susceptible and highly exposed would provide a logical basis for strategic risk management.

Question 13: Can the Panel comment on whether OPP should conduct a child playground inhalation exposure assessment, taking into consideration the hazard profile for chromium (VI) as an irritant to mucous membranes? If so, can the Panel comment on whether the endpoint described above is appropriate for assessing the risk to children from such an exposure?

Recommendation

The Panel notes that both the trivalent and hexavalent forms of chromium are of concern in the inhalation route of exposure and that arsenic should also be considered in the inhalation route of exposure.

However, the Panel agrees that calculations of probable exposure concentrations suggest that the Agency should not consider the inhalation route of exposure to inhaled metals in their risk assessment. The SAP strongly suggests, however, that exposure concentrations be monitored via personal and area sampling to validate such a conclusion.

Discussion

The contribution of inhaled metals to the risk for children using playground equipment constructed of CCA wood is dependent on the airborne level of metals. Unfortunately, there are no data on the ambient concentrations of metals in the vicinity of CCA-wood play structures. There is a need for determination of the range of background ambient exposure levels to chromium and arsenic and to compare these values to potential exposure levels for a 15-kg child during a 1-3 hours of play.

Soil in the immediate vicinity of play structures is frequently disturbed during child play and inhalable particles can be resuspended and re-entrained in air. Although the question posed to the SAP referred to the volatility of the inhaled metals, the primary concern is a resuspended dirt scenario, and not the volatility of chromium and arsenic, which should be considered. The questions posed to the Panel also referred to respirable particles. Most mechanically generated particles are very large. Thus, inhalable (particles which can be inhaled into the nasal or oral passages; generally less than 100 μm in aerodynamic size) and not respirable (particles which reach the gas exchange region of the lung; generally less than 3 or 4 μm) particles are of concern in terms of the nasal effects of chromium. These particles deposit in the nasal cavity, are cleared towards the back of the throat, and swallowed, thus ultimately resulting in an oral delivery.

It is likely that the assumption of 100% hexavalent chromium is an overestimate of its proportion in the soil and dislodgeable residue. In addition, there are very sparse published data on hexavalent vs. trivalent chromium in CCA-treated wood and none (except for what was presented by Drs. Stillwell and Townsend) for soil. Such a data set regarding the valence state of chromium in soil needs to be developed.

Because no data have been developed for airborne metals in the vicinity of playgrounds built with CCA-treated wood, one must use surrogate values to calculate a potential risk. The Panel members introduced three arguments against the need for an inhalation examination of the potential effects of playground exposure to chromium and arsenic. First, workers are exposed to

much higher concentrations of CCA-treated wood dust in occupational settings (Decker et al., 2001) and the occupational exposure limit for chromium is not exceeded. It must be considered, of course, that an occupational exposure limit (OEL) is set for a healthy adult worker over an 8-hour period.

Second, using the NOAEL given in the EPA document for adverse nasal effects in workers, one can calculate relative inhalable concentrations of chromium for a child. Using a rough assumption of the volume of air inhaled by a child, the level of exposure to inhalable chromium is insignificant:

- Using the following rough assumptions, one can calculate that a 15 kg child inhales approximately 5.4 m^3 in a 24 hour period:

  0.25 l/breath x 15 breaths/min x 60 min/hr x 24 hour/day = 5.4 m^3.

- Assumption of a NOAEL of 2.4 x 10^{-4} mg/m^3 (noted in the EPA document) yields:

  0.086 µg/kg-day for 24 hr (0.000086 mg/kg-day for 24 hr exposure) for a 15 kg child
  or
  0.0036 µg/kg-day for 1hr (i.e., 0.000036 mg/kg-day for 1 hour exposure).

Therefore, in comparison to the LOAEL of 0.05 mg/kg-day (or 50 µg/kg-day) considered in Question 1, this exposure level is below that of concern.

Of course, an assumption of 2.4 x 10^{-4} mg/m^3 as a NOAEL for hexavalent chromium could be high, but as noted previously, it is unknown what the exposure levels are for airborne particles in playground areas.

Third, one can calculate a worst-case scenario for inhaled resuspended soil and compare it to the central tendency value for the oral ingestion of soil. If one uses a central tendency value of 100 mg soil ingested/day for a child (as suggested by EPA), this can be compared with the potential concentration of airborne soil particles which would need to be inhaled to equal this amount of soil delivered via the oral route. Using a rough assumption of 5 m^3 for the volume of air inhaled in a day suggests that a child would have to be exposed to an airborne concentration of 20 mg/m^3.

100 mg/day / 5 m^3/day = 20 mg/m^3

This value of 20 mg/m^3 for inhalable particles is exceedingly high and is very unlikely in a playground setting. It was noted by Panel members that the soil, sand, or buffering material below the playground structure may influence the degree of resuspension of dislodgeable CCA or soil.

Thus, it appears to be unlikely that an inhalation pathway needs to be considered in the EPA risk assessment of the use of CCA-treated wood in playground settings. However, the Panel feels it

would be prudent to develop a data set for airborne/reentrained soil particles to validate this recommendation. It is suggested that personal or area monitoring be added to the proposed EPA-CPSC playground study. In addition, this data set should include airborne arsenic as there is no justification to exclude it in an inhalable CCA-treated wood risk assessment.

Question 14: Data on the effectiveness of reducing exposure by using buffering materials are limited. Does the Panel have recommendations as to whether additional studies to obtain this information are warranted? Does the Panel have suggestions on how OPP can best evaluate child exposures attributed to contact with CCA-contaminated buffering materials?

Recommendation

The consensus of the Panel is that additional studies are warranted to obtain information needed to assess the exposures associated with using buffering materials.

Buffering materials do not appear to provide a means to reduce exposures to CCA leached from play structures. Rather, buffering materials can present important risk scenarios that differ from the four scenarios currently proposed for analysis by the Agency. These additional scenarios include: 1) exposure to buffer materials that become contaminated with metals from CCA leached from play structures and 2) exposure to buffer materials that contain CCA because they consist of recycled construction/demolition debris which contains CCA-treated wood.

Exposure to buffer materials that become contaminated with metals from CCA needs to be examined. This effort should be aided by the generation of data describing the amount and nature of exposure in young children who play on or with these materials. It may also be possible to generate bounding estimates of exposure from these materials for the purpose of screening the relative importance of this scenario compared to other play structure-related scenarios.

Exposure to buffer materials that contain CCA-bearing mulch will likely result in a sufficient hazard potential to warrant a modification of the recycling practices that lead to the introduction of this mulch into children's play environments.

Discussion

Buffering materials refer to those materials that are placed below a play set to minimize injury in the event of a fall. Examples of buffering materials include sand, pea gravel, wood mulch, and tire chips.

There are two sets of issues imbedded in the concern over buffering materials. The first is the potential that the materials can become contaminated due to their close proximity and contact with CCA-treated wood play structures as CCA leached from the play structures coats the buffers. The second issue is the potential presence of CCA-containing wood in construction debris that is recycled into wood mulch used as buffering material. Both of these issues are of

particular concern because children may be attracted to the buffering materials due to their unusual textures, colors, and ready availability. Therefore, where there is CCA contamination of buffering materials, exposure potential to young children may be particularly high.

Regarding buffer materials that become contaminated by CCA leached from the play structure, the following assumptions can be used to help conceptualize the issue:

- Leached CCA forms a surface coating that is dislodgeable and thus available to children who handle these materials. This implies that the proper way to analyze these materials for the purposes of risk assessment is to find out how much dislodgeable residue is present on the buffer material surfaces in ug/cm2 surface area as has been done with play structure surfaces, rather than analyzing the entire material to get a ppm readout of arsenic or chromium on a mass unit basis. Expressing the contamination as metal concentration per surface area has the advantage of direct applicability to risk assessment equations since children can be modeled to take up some or all of the dislodgeable residue through mouthing behavior (putting entire chip or stone in mouth for brief period) or via chip-to-hand transfer followed by hand-to-mouth behavior. However, it is unlikely that children will actually ingest an entire chip and so the ppm type measurement would be less relevant. The Panel noted that the Alachua County, Florida data presented to the Panel, while limited in number of samples, suggested similar ppm contamination of buffer material (shredded rubber in this case) as neighboring soil. However, since buffers will not be ingested on a mg/day basis, the exposure implications of ppm in soil and ppm in buffer are not the same.

The recommendation that comes from these considerations is that buffering materials that are passive recipients of CCA leached from play structures should be chemically analyzed by finding out how much dislodgeable metal is available per square centimeter surface area. A suggestion for how to conduct this analysis is to put a representative number of chips/stones into dilute acid solution to extract the metals, analyze the metal content in the extract (e.g., ICP) and then calculate the dislodgeable residue by dividing the total metal extracted by the surface area of the chips/stones placed into the dilute acid solution. This would result in an estimate of the maximum metal loading concentration that children may dislodge onto hands or extract in their mouth.

The Panel is not aware of any survey or videotaping data of children's behaviors with respect to buffer materials. Therefore, exposure assessment in this area will be uncertain and data collection is important. The most direct and empirical form of data collection may be the sampling of children's hands and other exposed dermal surfaces at the end of a play event to find out how much of the dislodgeable material (measured by analyzing the buffer materials as described above, from various portions of the playground) is transferred onto children's hands. This may allow for an estimation of buffer-to-hand (or skin) transfer efficiency. Given that this transfer will be highly age and behavior dependent (types of interactions with the buffer materials and location on playground where child interacts with buffer), there will be much variability in the data. Therefore, a sizable dataset would be needed to obtain a representative distribution of dermal loading per play event. The value of such distributions obtained in this

way is that they could be suitable inputs to probabilistic (Monte Carlo style) exposure calculations.

Another option for data collection pertinent to this exposure scenario is obtaining observational (e.g., videotape) data on children's play activities to compile information on the frequency of contact with the buffer materials and classification of contact into categories such as superficial (brief touches) vs. intimate (handling/playing with the chips) vs. mouthing of chips. This information could then be combined with study data on how much CCA is dislodged from the chips from superficial vs. intimate vs. mouthing of chips in studies involving children or adult volunteers performing these types of activities. Of course, the mouthing of chips would not be performed but would have to be simulated in some way or assumptions used regarding percent extraction of residues from chip/stone residence for brief periods in the mouth.

Actual empirical data are most desirable for input into this or any other human health risk assessment. However, to evaluate the need to collect field data and perform a refined analysis for this particular scenario, the Agency may want to consider performing bounding, screening level calculations. Given that without the types of empirical data described above there will be greater uncertainty in exposure estimates, the defaults used should necessarily be high-end bounding assumptions. Such assumptions may look like the following:

- The dislodgeable residue loading on wood/rubber/gravel buffers is equal to the dislodgeable residue on the wood play structure. This may tend to be a reasonable upper bound on the relationship between wood structure to recipient buffer material loading since the buffer material will not only receive leached CCA but will also have such residues washed off in rain events, and so some equilibrium (probably no higher than what is on the donor wood) would be established on the buffer materials.

- The chip-to-hand transfer efficiency is 1:1, that is, whatever surface loading that is assumed to be on the chips will also exist on the hands. This assumption implies intimate contact with the chips such that the hands would be in equilibrium with the chips. Lower levels of loading are also possible from less intimate contact but would not represent an upper bound default. Higher levels of loading in which the hand actually accumulates dislodgeable residue might also theoretically occur, but empirical data would be needed to find out the circumstances under which this might be possible.

- Mouthing of chips/gravel would extract all the dislodgeable residue from that buffer material; the amount of residue available is based upon the surface area of the chip (empirical measurements for different buffering materials should be used) and the loading on the chip (as discussed above).

- The Panel did not have an opportunity to explore what might be reasonable bounding assumptions on frequency of mouthing behavior, time spent playing in chips relative to time spent on play structure itself, hand-to-mouth frequency, etc. (This might be based upon the same videotaping studies used for the hand-to-mouth assumptions for children on play structures.)

In summary, the Panel recommends that empirical data be gathered with respect to children's exposures to dislodgeable residues of CCA from buffer materials via actual children's play studies or from observational data on children's play behavior combined with data describing the range of chip-to-hand transfer for different degrees of contact. An additional study design mentioned during Panel deliberations was to have a single playscape underlain with differing buffering materials including no buffer (native soil) around different portions of the play structure. After a period of environmental loading and equilibration of buffer material, then children could be instructed to play on one of the buffer types to allow a comparison of exposure potential across the range of different materials.

Whatever study data are generated, they should be of sufficient diversity and robustness to characterize the distribution of behaviors and residue transfer efficiencies. However, if appropriate empirical datasets are not available for probabilistic assessments, EPA may consider the option of screening level deterministic assessments using reasonable upper bound defaults based upon available empirical data.

The possibility that these buffers might lead to a decrease in exposure to CCA relative to native soils does not look promising, based upon the evidence that leached CCA can lead to elevated arsenic concentrations near CCA-treated wood structures (Alachua County data). However, additional studies along these lines or as described above may better answer this question.

Unfortunately, when construction debris is recycled into mulch, a percentage of the wood may contain CCA. Data are available (Tolaymat et al., 2000, Townsend et al. 2001, and Solo-Gabriele 1998, 1999) that indicate that CCA-treated wood is found in mulches produced from construction and demolition facilities within Florida. During 1996, the mulch from 12 different construction and demolition facilities was found to contain 6% CCA-treated wood by weight, on average. A study at 3 facilities during 1999 found that concentrations of CCA-treated wood in mulch varied between 9 and 30%. Mulch samples collected from retail establishments showed evidence of CCA as observed by arsenic leaching tests.

If CCA-wood bearing mulches are used as buffering material under play structures, then there could a higher exposure potential from children's hand contact and mouthing of CCA wood mulch. As the wood degrades into smaller pieces and dust, there might be a higher opportunity for bulk ingestion of material containing high concentrations of metals both from direct mouthing of small objects and from hand to mouth transfer. Additionally, the dust generated from playing with the mulch might become an inhalation risk issue, particularly with respect to the Cr(VI) that may be present in the dust particles.

Rather than conduct a risk assessment on this portion of the scenario, the Panel recommends survey, intervention, and education activities on the part of the Agency, perhaps coordinated with other agencies, to prevent this exposure pathway to the extent possible. The survey would be of the wood mulch marketplace to determine to what degree CCA-treated wood enters the playscape environment, including practices at the municipal and homeowner/residential levels. This survey information should be followed with focused intervention and education/warnings to

prevent or modify the practices that lead to this type of wood entering children's play environments.

Question 15: The Panel is asked to comment as to whether stains, sealants and other coating materials should be recommended as a mitigation measure to reduce exposure to arsenic and chromium compounds from CCA treated wood. If so, can the Panel comment on the most appropriate way for the Agency to recommend effective coating materials when the current data on long-term performance are limited and sometimes inconsistent, and should the Agency specify a time interval for the re-application of these selected coating materials? Can the Panel make recommendations for additional studies?

Recommendation

The Panel offers the following conclusions and recommendations:

- The Panel recommends that the EPA inform the public of the ability of certain coatings to substantially reduce leachable and dislodgeable CCA chemicals and thus reduce potential exposure to arsenic and chromium. While the Panel makes recommendations below regarding the need for additional studies in this area, it feels that the current evidence is sufficient to begin advising the public about the use of coatings now.
- The weight-of-evidence from available studies indicates that certain coatings can substantially reduce dislodgeable and leachable CCA chemicals.
- Reductions of 70 to 95% in dislodgeable arsenic were seen in all studies that subjected CCA wood to natural weathering.
- There is no evidence that water repellents added directly to the CCA treatment solution are effective in reducing leachable/dislodgeable CCA chemicals;
- Current data are not adequate for identifying a particular coating as being clearly superior or inferior to reducing leachable/dislodgeable CCA chemicals.
- Confidence is highest for polyurethane as this coating has been shown to result in substantial 70 to >95% reduction in dislodgeable arsenic in a well controlled field study, a "real-world" application allowing for effects of use, and a short-term controlled laboratory study.
- Current data support a treatment frequency of once per year, although for some products this may be too frequent (e.g., possibly polyurethane where one study noted up to 95% reduction in dislodgeable arsenic out to 2 years). This is an area in need of additional study.
- More studies are needed to evaluate the performance / efficacy of different types and brands of coatings.

Discussion

Important definitions when evaluating coating data include the differences between treated and untreated wood. Treated wood typically implies that the wood is CCA treated. Untreated wood refers to virgin wood without the addition of CCA wood treatment chemicals. Both treated and untreated wood can be either coated or uncoated. Coatings or sealants refer to paints, stains, varnishes, and polyurethane resins applied to wood surfaces. For years the manufacturers of CCA wood have recommended the use of surface coatings to reduce the checking and cracking of wood resulting from effects of weather, such as rain, temperature, humidity, solar radiation (http://www.preservedwood.com/faqs/faqs.html). Intuitively, reductions in leachable and dislodgeable CCA chemicals should be expected to the extent that coatings establish a barrier to moisture contacting and entering wood and as a barrier to direct hand contact with the wood surface. Likewise, the surface area available for leaching, including access to deeper wood layers which are less depleted of CCA chemicals, should be reduced given that such coatings reduce checking and cracking of CCA wood.

Evaluation of Coating Data

Sealant studies evaluated were separated into three groups: Studies that evaluated the impacts of coatings on dislodgeable arsenic, impacts on leaching of arsenic, and related studies.

Studies available to the Panel that evaluated the impact of coatings on dislodgeable arsenic included: Stilwell 1998, Scientific Certification Systems 1998, California Department of Health Services 1987, and the Consumer Products Safety Commission 1990. Stilwell, 1998, evaluated boards with four different coatings (polyurethane, latex/acrylic, oil stain, and spar varnish). His results indicate that these coatings remained very effective in reducing dislodgeable CCA chemicals for at least one year after they are applied. This study did not evaluate the performance of sealants beyond one year. The boards were subjected to natural weathering processes but the study did not include the effects of wear from human use. Also, the experimental design would have benefited with the inclusion of a temporal control.

The SCS 1998 study evaluated the impacts of two post-treatment coatings (Superset stain, 3M clear sealer/polyurethane -) and one coating incorporated into the CCA-treatment process (Osmose water repellent). The other two coatings were applied after the wood was CCA-treated. The SCS study was a laboratory-based study using a series of boards. It is assumed that the measurements of the dislodgeable arsenic were taken shortly after the coatings were applied. Wear and tear from human use was not simulated, nor was rainfall or other weather related effects taken into consideration. Results from this study were variable indicating that the 3M polyurethane sealant was effective at reducing dislodgeable arsenic whereas the Superdec stain and the Osmoses water repellent were not effective. Results from this work suggest that there is variability in the reduction of dislodgeable arsenic by different types and brands of coatings.

The California Department of Health Services 1987 study was the only study that evaluated structures (a fishing pier treated with polyurethane and a playset treated with an oil-based stain) that were in current use and therefore included the effects of wear and tear upon the efficacy of the coatings. Results of this study suggest that coatings provide a considerable reduction in the amount of dislodgeable arsenic and, in the case of polyurethane, out to two years post-treatment.

One drawback of the study is the lack of an uncoated temporal control. However, the decrease in dislodgeable arsenic was very large that even in the absence of such a control, the data are considered to be meaningful.

The last study, sponsored by the Consumer Products Safety Commission in 1990, evaluated an oil-based stain and a water repellent in a laboratory setting. The results of this study were variable which is reflected in the high standard deviation observed in the uncoated CCA-treated control. This variability confounds the ability to interpret the data and therefore the results are considered inconclusive.

Only one study, Cooper et al. 1997, evaluated the ability of coatings to reduce the leachability of arsenic from CCA-treated wood. This study evaluated the ability of Thompson's water seal (applied after CCA treatment) to reduce leaching of CCA from fences. The efficacy of water repellents applied as part of the CCA treatment chemical were evaluated for fences and decks. Results show that Thompson's water seal (applied after CCA treatment) significantly reduced the quantity of arsenic for a period of two years after the application of the water seal. The water repellents applied as part of the CCA treatment chemical were not effective at reducing leachable arsenic concentrations.

Related studies cited as part of the EPA review include Riedel et al. 1991 and Lebow and Evans, 1999. Riedel et al., 1991, focused on collecting dislodgeable arsenic data from 10 CCA-treated playsets. Some playsets were coated with sealants and some were uncoated. This study is useful in providing a range of dislodgeable arsenic variables from playsets. However, there are many confounding factors when comparing the coated set of playsets with the uncoated sets. These confounding factors include differences in retention levels between one playset and another, wear and tear, locations sampled, and absence of any information on time elapsed from when a coating was last applied. Given these confounding factors it is difficult to conclude whether or not coatings reduce the quantities of dislodgeable arsenic.

Lebow and Evans et al., 1999, evaluated the use of an innovative pre-stain (water soluble acrylic polymer with an iron oxide) which was applied prior to treatment with CCA. Results from this study found that the pre-stain was able to reduce the release of arsenic by 25 to 30%. This was a laboratory study that simulated natural rainfall over a 17-week period.

Conclusions from studies

Table 1 summarizes design features of the various studies and results in terms of percent reduction in dislodgeable or leachable arsenic. Results of these studies as a whole support that surface coatings (applied after CCA treatment) are effective at reducing the quantities of dislodgeable and leachable arsenic. Reductions of 70 to 90% in dislodgeable arsenic were observed across the studies as CCA-treated wood was subjected to natural weathering. Conflicting results were obtained from the laboratory studies. It is noted that no studies looked at both dislodgeable and leachable arsenic fractions. The current data are not sufficient to identify a superior coating. The evidence is strongest for polyurethane, based on results from Stilwell 1998, California DHS 1987, and SCS 1998. Future experiments should evaluate the efficacy of different types of brands of coatings on both the quantities of dislodgeable and leachable arsenic. Such studies should include a validated and consistent measure of dislodgeable (e.g., Stilwell, 1998) and leachable CCA chemicals and should evaluate performance over at least a 2-year and preferably a 3-year period. Furthermore, studies should also focus on the durability of the coatings when subjected to wear and tear and include natural weathering conditions.

The Panel recommends that the Agency inform the public of the potential benefits associated with coatings in reducing leachable and dislodgeable CCA chemicals. Polyurethane should be recommended for the time being. It should be also mentioned that other coatings show some promise including acrylic/latex, oil-based stains, and some consumer applied water sealants, although data are more limited. Furthermore, recommendations should mention that some coatings will change the surface properties of the wood making it necessary for additional traction on floors and deck portions of playsets. It is recommended that the decks be sealed at least once per year. More definitive information concerning the use of coatings should be provided to the public once additional data are available.

One Panel member recommended that the coating applied be clearly visible so that the effects of wear can be easily observed. The Panel member indicated this is especially important in light of the fact that there are limited data on the durability of the coatings against wear. In areas of heavy wear, the coating should be applied more frequently than once per year if the coating is visibly removed from these high-wear areas.

Another Panel member, who supported the use of coatings, voiced the concern that the CCA chemical may accumulate below the coatings which if pealed and ingested could result in an elevated risk to children. This comment emphasizes the need to periodically inspect the coatings to minimize this potential exposure route.

It is important to keep in mind that none of the studies cited in this review have been published in peer-reviewed journals. The strength of the overall conclusions made through this review relies on the relative consistency between the results observed between some studies.

Table 1

Study	Design	Weathering	Sampling	Treatments	Results	Comments
Stilwell, 1998 (CT)	Purchased boards, placed outside, 4 coatings, 4 replicates, 5 time points out to 1 year	Outside, natural weathering, no human use	Standardized wipe method. Repeat rubbing of same surface under controlled pressure	Polyurethane, acrylic latex, Spar varnish, Oil-based stain. Brush applied, 2 coats.	> 95% reduction for polyurethane, acrylic resin, and varnish at all time points as compared to pretreatment. 80-97% reduction for oil stain.	Does not account for wear. Lacks temporal control. Aesthetic problems after 1 yr for spar varnish.
California DHS, 1987 (CA)	Fishing pier, 1 coating, 4 replicates, 2 time points out to 2 year	Outside, natural weathering, in use	Gauze wipe, 100 cm^2 with repeat rubbing to same surface	Polyurethane, no information on application methods	> 95% reduction at 2 years as compared to pretreatment levels.	Considers wear. Lacks temporal control. Limited sample sizes and coatings.
California DHS, 1987 (CA)	Single playground, 1 coating, ? replicates, 3 time points, out to 2 years	Outside, natural weathering, in use	Gauze wipe, 100 cm^2, with repeat rubbing of same surface	Oil-based stain, no information on application methods.	> 95% reduction at 6 months as compared to pretreatment levels. 70% reduction at 2 years.	Considers wear. Lacks temporal control. Limited sample sizes and coatings.
SCS, 1998 (lab)	Purchased boards, used in laboratory, 3 coatings, 5 replicates, 1 time point apparently soon after coating applied.	Inside, no weathering, not subject to human use.	Kimwipes,100 cm^2, damp. Hand wipes, 500 cm^2, repeat rubbing of same surface	3M sealant, Superdec stain, no information on application methods, Osmose water repellant	60% - 80% reduction for 3M sealant as compared to pretreatment. No reduction for stain or water repellent.	Variable within type of coating. Does not account for wear. Not subject to natural aging and weathering. Short-term evaluation.
Cooper et al., 1997 (New Brunswick, CAN)	Laboratory prepared wood, fence & deck structures, placed outside, 1 coating, ? replicates, 2 time points, 4 mo, 2 yrs	Laboratory simulated aging, plus outside, natural weathering, no human use.	Collection of natural rain water contacting wood surface	Thompson's Water Seal (fence only) & Water Repellent in CCA treatment soln (fence & deck).	70% reduction at 4 months and 80% reduction at 2 years for Thompson's. No reduction for water repellent added into treatment solution.	Does not account for wear. Includes temporal control.
Riedel et al., 1991 (Ontario, CAN)	10 playgrounds, 2 to 10 years old. Some stained / painted, others not. 4 sampling points per structure.	Outside, natural weathering, in use	Gauze wipe, 250 or 500 cm^2 with repeat rubbing of same surface.	Oil based stain on some though not all structures.	4 structures treated with stain had on average 74% lower levels of dislodgeable As than average of 3 structures without any coating.[a]	Cross-sectional study with no site specific controls. Limited information on past application of coatings. Sampling locations vary across sites.
CPSC, 1990 (lab)	Purchased boards, used in laboratory, 2 treatments, 3 replicates, 2 wood types.	Inside, no weathering, not in use, no aging	Nylon cloth wipe, 400 cm^2	Oil-based stain, water repellant, applied per manufacturer's label.	No clear evidence of reductions.	Considerable variability in the controls, short-term study with no weathering.
Lebow and	Laboratory prepared wood	Laboratory	Collection of	Water soluble acrylic	25-30% reduction in total As	Coating applied pre-CCA

Evans, 1990	1 treatment, ? replicates, 1 time point at 17 weeks	simulated rainfall for 17 weeks.	natural rain water contacting wood surface	polymer applied pre-CCA treatment.	leached in artificial rainfall.	treatment, so of limited relevance to post-treatment coatings.

Estimate of 77% reduction based on comparing mean or the means for playgrounds designated A, B, and H (reported as no prior treatment with stain or paint) to mean of means for playgrounds designated as D, E, G, I and J (identified as having a stain applied). Playgrounds C and F not included because of ambiguity about application of stains. 50-60% reduction in leachable arsenic suggested from comparison of data on soil samples.

ADDITIONAL PANEL RECOMMENDATIONS

A. Biomonitoring study

Recommendation

The Panel recommends that a biomonitoring study of children normally exposed to CCA-treated play equipment and decks be conducted. This study should be designed according to well-accepted epidemiological principles, with adequate sample size, to resolve the issue of whether there is substantive exposure of children to arsenic (and possibly chromium) residues. The study should include urinary arsenic measurements as a biomarker of exposure. If practicable, skin wipe samples should be collected in the same study. It would be used to provide exposure information that could be used directly in the risk assessment and also to validate the proposed exposure models.

Planning and study design should begin immediately, as there is a need for such information, irrespective of the final form of the proposed exposure models.

Discussion

In the course of its deliberations the Panel noted two particular things: Firstly, the high degree of uncertainty inherent in the assumptions and default measures proposed for use in the exposure assessment pathway. The cumulative uncertainty in the resulting exposure assessment (and, therefore, the risk assessment) was likely to be substantial. Secondly, the Panel noted the absence of data on exposure of children to arsenic and chromium residues from playing on CCA-treated playground equipment and decks.

There was general consensus that there was an urgent need to obtain biomonitoring data for two main purposes: to obtain data that could be directly used in risk assessments and to validate the exposure assessment models.

The ultimate risk assessments that would employ the exposure data would be of two kinds: risk assessments involving acute or short-term toxicity endpoints and assessments of chronic toxicity endpoints, particularly carcinogenicity. The former would involve relatively large differences in exposure between children exposed and unexposed to CCA-treated timber structures. These differences could be detected in studies using smaller numbers of children than would be necessary for assessments of carcinogenic risk, when smaller incremental exposures might be important.

Concerns about the potential difficulties of carrying out epidemiological studies of this nature were raised. These included the possibility of confounding by other sources of arsenic exposure and whether it would be possible to obtain a representative sample of children.

In response, it was pointed out that other exposures to arsenic would only cause confounding if they were correlated with exposures to arsenic from CCA. *A priori*, this seemed unlikely.

Provided a sufficient sample size was used and data on any potential confounding factors were collected, confounding would not necessarily be a problem and, if necessary, could be adjusted for in the statistical analysis.

In regard to whether a representative sample was necessary, it was agreed that such a sample should not be necessary in the first instance, as the primary issue was one of causal inference – whether there was evidence that children were substantially exposed to arsenic and chromium from CCA-treated timber. A first study could be done in a potentially "worst case" situation. If such a study provided evidence of minimal exposure then it would be likely that children actually did not receive substantial exposure to residues from CCA-treated timber. On the other hand, if such a study did show evidence of exposure then further studies in other settings would be appropriate for refinement of the exposure assessments.

Ideally, the proposed study would include collection of skin (particularly hand) wipe data from the children. This could lead to an improved understanding of the relationship between skin exposure and actual absorption. However, it is important that collection of such wipe samples does not lead to underestimates of the amount of arsenic absorbed and that the collection process does not alter the normal play activities of the children.

It was generally agreed that such studies, involving children, are inherently difficult and need to be designed and carried out very carefully. Because of the potentially long lead time for such studies, it is advisable to begin the planning process for such a study as soon as possible. At the same time, the risk assessment process should not be delayed pending final results of the biomonitoring study.

B. Effects of Metal-Metal Interactions on Toxicokinetics of Arsenic from CCA-Contaminated Materials and Environmental Media (Soil, Dislodgeable Material)

Recommendation

Detailed information must be provided about total composition of metals and metalloids that are introduced into CCA-treated wood and that are present in contaminated soil and dislodgeable materials. Information about known interactions between arsenic, chromium, and copper should be included into the risk assessment related to CCA-treated wood. Additional studies are needed to obtain more data about chemical and biological interactions of arsenic, chromium, copper, and other metal (metalloid) contaminants found in CCA-treated (contaminated) materials.

Discussion

Exposures to CCA-treated wood components or to CCA-contaminated environmental media represent in fact combined exposures to three metals (metalloids), arsenic, chromium, and copper. It is generally recognized that biological effects associated with a co-exposure to a mixture of metals may significantly differ from effects caused by an exposure to each metal separately. The presence of chromium and copper may affect toxicokinetics (e.g., absorption, tissue distribution/retention, biotransformation, biliary and urinary excretion) of arsenic and *vice*

versa. Because bulk chemical agents are used for the CCA treatment, other minor chemical contaminants are also of concern in their effect on the subsequent disposition of arsenic with co-ingestion by exposed children.

Metabolic and toxicological interactions between the three major metallic components of the CCA mixture have previously been reported:

- Co-exposures to arsenic are known to cause a profound accumulation of copper by the kidney cortex (Ademuyiwa, et al., 1996). Although, copper is a relatively nontoxic metal, possible adverse consequences associated with its accumulation in the kidney should be considered under these exposure conditions.
- Co-exposures to arsenic affect tissue levels of chromium in laboratory animals with no significant effects on hypoglycemic properties of inorganic chromium (Aguilar et al., 1997).
- Combined acute exposure to Cr(VI), arsenate, and copper causes a marked decreased in fetal weight and increased incidence of fetal resorption and abnormality formation in rats, while none of the metals is teratogenic when administered (i.p.) separately (Mason et al., 1989).

One concern is the extent to which impurities would affect the process of biliary excretion of arsenic. Any effect on biliary excretion, for example, would complicate easy comparisons and computational adjustments for biliary excretion when doing relative bioavailability studies. That is, these substances would affect arsenic in dislodgeable residues or receiving soils but obviously would not affect any toxicokinetics of the reference, soluble As(V) or As(III) dosing solution. This creates a miscomparison. For example, inorganic selenium is known to modify excretion of arsenic in bile. It has previously been shown that the biliary excretion of arsenic is strongly dependent on glutathione levels in hepatic tissue (Gyurasics et al., 1991). Co-exposures to selenite dramatically increase levels of arsenic in bile in rats (Gregus et al., 1998). Metabolic interactions between arsenic, selenium, and glutathione are responsible for this effect. A complex, seleno-bis(*S*-glutathionyl) arsinium ion, has recently been identified in the bile of rabbits injected with selenite and arsenite (Gailert et al., 2000). Similar biliary interactions have also been reported for other metalloids (Gregus et al., 1998). Although effects of copper and/or chromium on biliary excretion of arsenic are unknown, a report of Peoples et al., (1979) provided to the Panel indicate that they exist. Here, dogs were fed with food containing sawdust from CCA and ACA treated wood. The first dog received 6 mg As in CCA sawdust; the second dog received 13.2 mg As in ACA sawdust (ACA does not contain chromium). Based on urinary excretion, about 40% of the arsenic dose was absorbed in the first dog over 8 days. In contrast, about 60-70% was absorbed in the second dog, indicating that the presence of chromium in CCA sawdust may decrease absorption and/or urinary excretion of arsenic. The fact that these are one-animal and one-dose data prevents more extensive evaluation of these results.

Other interactions with arsenic that are of concern are those that may potentially affect uptake of arsenic in various media as a function of nutritional status. As noted in responses to Question 2, the arsenic pathway interacts with the phosphorus pathway in biological systems so that a child's

nutritional status with respect to phosphorus deficiency or adequacy could possibly affect the parameter of arsenic uptake.

C. Bioavailability of Dislodgeable CCA Residues

The Panel agreed with the Agency's decision to assume on an interim basis 100% relative bioavailability of ingested dislodgeable CCA residue. During the public comment period, results of an unpublished study were presented in which the absolute oral bioavailability of dislodged material from CCA-treated wood was measured in hamsters. The Panel recommended not using this information in the risk assessment at this time because the material dosed has not been characterized and concerns about the animal model. However, the Panel recognizes that oral absorption is a critical variable in the assessment of dose from oral exposure to CCA residues and encourages further research to characterize it.

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