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UNITED STATES GOVERNMENT

MEMORANDUM

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

AUG 2 1990

TO : The Commission
Through: Sadye E. Dunn, Secretary
Through: Susan Birenbaum, Acting General Counsel
Through: Thomas W. Murr, Jr., Acting Executive Director
Through: Douglas L. Noble, Director
Office of Program Management and Budget
Through: David W. Thome, Program Manager
Emerging Hazards/Vulnerable Populations, EXPB
FROM : Elaine A. Tyrrell, Project Manager
Vulnerable Population Program, EXPB

SUBJECT: Project on Playground Equipment - Transmittal of Estimate of Risk of Skin Cancer from Dislodgeable Arsenic on Pressure Treated Wood Playground Equipment.

This memorandum is to advise the Commission of the completion and availability of a study by the Directorate for Health Sciences (HS) for assessing the cancer risk to children playing on pressure treated wood playground equipment. (The components of this study, as described below, are available for review by the Commissioners and their staff in the Office of the Secretary.) This study will be used by the Vulnerable Populations Team in the development of the revised Playground Equipment Handbook. The revised Handbook is scheduled to be completed during second quarter of Fiscal Year 1991.

The study consists of four separate reports with a cover memorandum and executive summary. The individual reports are:

- "Report on Leaching, Distribution and Dislodgeable Arsenic and Copper from Pressure-Treated and Untreated Wood."
- "Estimation of Hand-To-Mouth Activity by Children Based on Soil Ingestion for Dislodgeable Arsenic Exposure Assessment."
- "Estimating the Risk of Skin Cancer from Ingested Inorganic Arsenic."
- "Dislodgeable Arsenic on Playground Equipment Wood and the Estimated Risk of Skin Cancer."

These reports have been cleared in accordance with Section 6(b) of the Consumer Product Safety Act and will be released to the public upon request. The reports will be shared with the ASTM Task Groups F15.29 and F15.09 (Playground Equipment for Public Use and Home Playground Equipment, respectively) for their

NOTE: This document has not been reviewed or accepted by the Commission.
Initial _kh_ Date _8/2/90_

use in voluntary standard development activities. The reports will be forwarded to a number of state/federal agencies and lumber/playground equipment manufacturers who have expressed an interest in the study results. If further actions are needed, the staff will submit recommendations to the Commission for approval.

EXECUTIVE SUMMARY

ESTIMATE OF RISK OF SKIN CANCER FROM DISLODGEABLE ARSENIC ON PRESSURE TREATED WOOD PLAYGROUND EQUIPMENT

As part of the 1990 Playground Equipment Handbook project, a study was undertaken by the Health Sciences (HS) staff to estimate the risk of skin cancer from dislodgeable arsenic on pressure treated wood playground equipment.

Arsenic has been associated with human skin cancer when chronically ingested. The wood preservative used in most of the U.S. wood playground equipment is chromated copper arsenate (CCA). Prior to this study, inadequate data and procedures existed for assessing the cancer risk to children playing on pressure treated wood playground equipment as indicated by the Environmental Protection Agency (EPA) (1981, 1984) and the California Department of Health Services (1987).

Under a 1985 agreement with the EPA, the wood preserving industry developed consumer information sheets to provide users of wood preserved with arsenicals, creosote, or pentachlorophenol with important safety information. The sheets contain steps to prevent potentially hazardous exposures to wood preservatives, such as inappropriate uses of preserved wood, handling and woodworking precautions, and proper disposal of wood waste.

Leaching experiments by HS staff demonstrated that arsenic can be released from pressure treated wood. Seven playground equipment wood samples were collected by CPSC field staff from major U.S. manufacturers. One comparison sample of unfinished pressure treated wood was purchased at a retail store. A method was developed by HS for testing dislodgeable arsenic on the eight wood samples.

The estimated risk of skin cancer for the five out of seven samples from manufacturers which were below the detection level of dislodgeable arsenic, was <1 in a million, which is a negligible risk. The estimated risk for the two out of seven samples that had detectable levels was 3-4 in a million. This is a small risk that should be reduced further if it can be practically accomplished.

The estimated risk for the comparison sample was somewhat higher (8-9 in a million). This suggests that a possible hazard might be created when playground equipment is built with unfinished pressure treated wood from retail sources.

Recommendation:

a) Include a statement about the risks from dislodgeable arsenic on playground equipment wood in the revised and updated edition of the CPSC playground equipment handbook.

b) Encourage the wood preservers and playground equipment manufacturers to identify and practice procedures that minimize dislodgeable arsenic on playground equipment wood.

c) Encourage the wood preservers to increase the availability and visibility of their consumer information sheets in the retail stores, since the sheets provide important safety information on the handling and disposal of pressure treated wood.

d) Determine the extent that unfinished pressure treated wood is purchased by the consumer for the construction of playground equipment and other uses which might lead to arsenic exposure. Collect and test samples of pressure treated wood from multiple retail sources for dislodgeable arsenic levels if resources permit. Identify finishing treatments that can be applied by consumers to reduce dislodgeable arsenic levels.

UNITED STATES GOVERNMENT

MEMORANDUM

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

TO : Elaine A. Tyrrell, Vulnerable Populations Project Manager (EX-PM)

Through: Andrew G. Ulsamer, PhD, AED (HS) AGU
Through: Murray S. Cohn, PhD, Director (HSHE) MSC

26 JAN 1990

FROM : Brian C. Lee, PhD (HSHE)

SUBJECT: Summary of Health Sciences memoranda regarding skin cancer risk from dislodgeable arsenic on pressure treated playground equipment wood.

Wood preservatives are used to prevent attack by fungi, termites, or other wood-boring insects that destroy wood. The wood preservative used in most of the US wood playground equipment chromated copper arsenate (CCA). Chronic ingestion of arsenic has been associated with human skin cancer. Since arsenic does not significantly penetrate the skin, ingestion would be the important route of exposure. Inadequate data and assessment procedures existed for assessing the cancer risk to children playing on pressure treated wood playground equipment as indicated by EPA (1981, 1984) and CDHS (1987). Therefore, a study was undertaken by CPSC staff to collect data and develop assessment procedures leading to estimates of skin cancer risk.

The attached four memos report the development and the results of the application of methods and procedures by Health Sciences. In the first memo (from B. Jain), leaching experiments by HSHL staff demonstrate that arsenic can be released from pressure treated. A nylon fabric wipe method was developed for testing dislodgeable arsenic on wood samples collected by Field staff (STI 89-205) from major US playground equipment manufacturers (CPSC, 1989).. Most (5/7) of the samples collected had dislodgeable arsenic levels below the detection limit of 6.3 ug/100 cm^2. The few samples with detectable dislodgeable arsenic had average levels <35 ug/100 cm^2. The application of an oil stain or a water repellant/sealant to the wood by HSHL did not reduce the dislodgeable arsenic levels. The highest average dislodgeable arsenic level of 68 ug/100 cm^2 was found in a comparison sample of unfinished pressure treated lumber (not playground equipment wood).

The second memo (from B. Lee) develops the methodology for the assessment of exposure to dislodgeable arsenic due to hand-to-mouth operations, such as playing on the wood and then eating with unwashed hands or mouthing the hands. Other possible scenarios such as direct mouthing and chewing of the wood are of unknown significance due to the lack of existing data on these behaviors. However, these are felt to be minor compared to the more frequent arsenic exposure by hand-to-mouth operations. Soil ingestion by children is used as the basis for estimating the hand-to-mouth transfer activity of dislodgeable arsenic from the wood. The procedure estimates the age (hand size)-dependent amount of arsenic that might be ingested for a measured level of dislodgeable arsenic on the wood. As an example, it is estimated that a 2 yr old male might have the equivalent daily hand-to-mouth activity resulting in the consumption of 0.42 of the dirt on a hand, or 0.42 of a "handload".

Epidemiological data relating skin cancer incidences and arsenic ingestion levels are modeled in the third memo (from B. Lee) to estimate a unit risk for ingested arsenic. The unit risk is the chance of skin cancer due to the ingestion of 1 ug of arsenic per kg body weight per day for a lifetime. The 4.8×10^{-5} unit risk that is estimated permits the estimation of risk for other arsenic exposure levels, body weights, and time periods.

Results from the application of the exposure (second memo) and unit risk (third memo) assessment procedures to the dislodgeable arsenic levels measured by HSHL (first memo) are reported in the fourth memo (from B. Lee). Additional assumptions in the exposure and risk estimating procedures were made to address the specific situation of children and playground equipment wood. The estimated risk of skin cancer for the majority of the wood samples, which were below the detection level of dislodgeable arsenic, was <1 in a million. The few samples with detectable arsenic generated average risk estimates of 3-4 in a million. If playground equipment wood had levels at the highest average dislodgeable arsenic level measured, which was not in the playground equipment wood collected, the risk would be estimated as 9 per million.

Recommendations based on the information provided by this study and review of the literature include:

a) Determine the extent that unfinished pressure treated wood is purchased by the consumer for the construction of playground equipment and other uses which might lead to possible arsenic exposure. The higher level found on the single sample tested by HSHL suggests that a possible hazard might result if the consumer purchases non-playground equipment pressure treated lumber. Dislodgeable arsenic testing of unfinished pressure treated wood samples from retail outlets should be considered.

b) Encourage the wood preservers and playground equipment manufacturers to continue to identify and practice procedures that minimize dislodgeable arsenic on playground equipment wood. The below detection limit levels of dislodgeable arsenic on most of the tested playground equipment wood samples suggest that the necessary technology and practices may already be available.

c) Include the results of this Health Sciences study in the upcoming update of the CPSC playground equipment handbook. There has been increasing interest in pressure treated wood playground equipment from consumers, industry, and governmental agencies. The wood preservers should also be urged to increase the availability and visibility of their consumer information sheets on pressure treated wood in the retail firms, since the sheets provide important safety information to consumers who may be woodworking their playground equipment.

d) Examine the possible exposure of consumers to arsenic from woodworking operations, such as sanding and sawing, during construction of playground equipment or other uses of pressure treated wood.

References

CDHS (1987)- Evaluation of hazards posed by the use of wood preservatives on playground equipment, report to the Legislature. Ofc Env Health Hazard Assessment. Feb.

CPSC (1989)- Wood preservatives in playground equipment. Memo to BC Lee from TA Karels. 27Mar.

EPA (1981)- Wood Preservative Pesticides: Creosote, Pentachlorophenol, Inorganic Arsenicals. Position Document 2/3. Ofc Pesticides and Toxic Subst, DC 20460. NTIS PB82-229956. Jan.

EPA (1984)- Wood Preservative Pesticides: Creosote, Pentachlorophenol, Inorganic Arsenicals. Position Document 4. Ofc Pesticides and Toxic Subst, DC 20460. July.

EPA (1988a)- Special Report on Ingested Inorganic Arsenic- Skin Cancer; Nutritional Essentiality. Risk Asssessment Forum, Washington, DC. EPA/625/3-87/013, July.

Attached memos

BK Jain- Report on leaching, distribution, and dislodgeable arsenic and copper from pressure-treated and untreated wood.

BC Lee- Estimation of hand-to-mouth activity by children based on soil ingestion for dislodgeable arsenic exposure assessment.

BC Lee- Estimating the risk of skin cancer from ingested inorganic arsenic.

BC Lee- Dislodgeable arsenic on playground equipment wood and the estimated risk of skin cancer.

U.S. GOVERNMENT
MEMORANDUM

U. S. CONSUMER PRODUCT
SAFETY COMMISSION
WASHINGTON DC 20207

JAN 2 6 1990

To : Elaine A. Tyrell, Vulnerable Populations Team Manager (EX-PM)

Through : Andrew G. Ulsamer, PhD, AED (HS) AGU
Through : Warren K. Porter Jr., Director (HSHL) WKP

From : Bhawanji K. Jain (HSHL) BKJ by WKP

Subject : Report on Leaching, Distribution and Dislodgeable Arsenic and Copper from Pressure-treated and untreated Wood.

INTRODUCTION:

Chemical mixtures containing arsenic are commonly used to pressure treat woods to prevent deterioration of wood by bacteria, fungi and other organisms. There is a concern that arsenic treated wood may be hazardous to those having regular contact with the wood. In order to characterize various pressure treated woods and assess possible health hazards of arsenic from treated wood, a study was designed to: (1) measure total arsenic and copper content in treated and untreated woods, (2) measure arsenic and copper levels at various depths of the wood, (3) measure loss of arsenic and copper from the treated wood by leaching with neutral, slightly acidic and 5.6% NaCl solutions, (4) measure arsenic dislodged from samples of treated playground equipment wood collected by the CPSC field office, (5) compare animal skin (chamois) and nylon cloth (Miracle Wipe) for the dislodgeable arsenic, and (6) confirm the efficiency of wood coating in reducing dislodgeable arsenic.

EXPERIMENTAL:

(A) CHARACTERIZATION OF WOOD:

In order to characterize various pressure treated wood, total arsenic and copper content was measured in treated and untreated woods, arsenic and copper were measured at various depths of the wood and loss of arsenic and copper from treated woods was measured by leaching with acidic, neutral and sodium chloride solutions. Six pieces of chromated copper arsenate(CCA) treated lumber A,B,C,X,Y,Z and one piece of untreated wood # 21 were purchased from local lumber yards. Treated woods were southern pine wood with CCA retention of 0.40 lb/cu ft.

Portions of selected blocks from samples A,B,and C were shredded and cut into thin strips. The weight of strips was determined. These scrapings were dried at 100-120 Centigrade for

3 hours to determine the moisture content of the samples. The scrapings were digested with 20-25 ml concentrated nitric acid (HNO3) for 3-4 hours and then diluted to appropriate volumes. Analysis for arsenic and copper was done by the use of an Inductively Coupled Plasma spectrometer. This analysis gave the total arsenic and copper content of the various woods.

In order to determine arsenic and copper content at various depths of the wood, 4 cores (plugs) from different woods were removed. Plugs were sliced into sub-segments from the surface inward. The surface area of each slices was determined. The slices were dried at 110-120 degrees for 3 hours, weighed and digested with 10 ml nitric acid (HNO3) for 3 hours and then diluted to appropriate volume with ultrapure water. Diluted solutions were analyzed for arsenic and copper content using an ICP spectrometer.

For leaching studies scrapings were removed from various parts of the samples of wood. The weight of each sample's scrapings was determined to 0.1 mg. The scrapings from wood(X) were used for leaching studies using neutral and acidic solutions. Scrapings from wood(Z) were used for comparison of arsenic leaching with 0.1N HCl and 0.1N HNO3. Scrapings from wood(Y) were used for leaching studies using different strengths of hydrochloric acid (HCl). In each case 10.0 ml of leaching solution was used. After completion of leaching solutions were analyzed for arsenic content using an ICP spectrometer. The wood samples were subsequently extracted again for a total cumulative time of 78 to 79 days and analyses performed to determine if leachable arsenic decreased frequency of leaching.

For additional leaching studies, the blocks and surfaces scrapings of wood A,B,C, and 21 were dried at 110-120 degrees for minimum of 3 hours. The weight of each dried block was determined. The samples were immersed in appropriate leaching solutions (ultra-pure water, 0.05N HCL or 5.6% NaCl). Each leaching lasted 14 days. The solutions were filtered into volumetric flasks for determination of arsenic and copper. During leaching, samples were mixed periodically to ensure that all surfaces were immersed in leaching solutions. After leaching period, the solutions were analyzed for arsenic and copper content using an ICP spectrometer.

(B) <u>MEASUREMENT OF DISLODGEABLE ARSENIC</u>:

In order to estimate dislodgeable arsenic, a sampling procedure was developed. The purpose of measuring dislodgeable arsenic was to obtain data, which could be used for exposure and risk assessment.

Nylon cloth, adhesive backed paper and filter paper were studied for their possible use in obtaining dislodgeable arsenic from the surface of the pressure treated wood. Because adhesive backed papers did not withstand the repeated abrasion during wiping on the wood surface and some of the adhesive was lost from the adhesive-backed paper with repetitive cycles of rubbing, it was not used in subsequent studies. Filter paper was also not used in further studies since it failed to pick-up detectable levels of arsenic. The 100% nylon cloth with its tight weave was chosen for sampling dislodgeable arsenic from the surface of the treated wood because it did not snag on imperfections in the wood and withstood repeated wiping without deterioration.

The seven treated playground wood samples and one unfinished treated wood sample were collected by the CPSC staff are described in Table VII. These wood samples had been CCA (chromated copper arsenate) pressure treated with a retention of 0.40 lbs/cu ft.

Five sub samples from each of the eight samples were randomly selected for dislodgeable arsenic measurement. A rectangular shaped area (8 X 50 cm) was marked on the flat surface of each sub-samples. A wood block, which had an 8 X 8 sq cm surface area was cut from the arsenic-free wood. The nylon cloth was attached to one side of the block, with a backing paper between the fabric and carrier block, to prevent cross contamination of the samples. The weight of the block was adjusted to one kilogram with a water filled bottle on top of the block. The wood block was dragged ten times backward and forward over the marked surface, with nylon cloth wipe touching it. The wiping cloth was transferred to 50 ml conical flasks and 25 ml of hydrochloric acid (0.01 N) was added to each flask. Extractions were performed with intermittent mixing for 18 to 24 hours. The extracts were analyzed for arsenic and copper content using an ICP spectrometer.

In order to compare dislodgeable arsenic between chamois leather(animal skin) and nylon cloth, two playground equipment samples having detectable arsenic levels were selected. Three sub-samples from each of the two samples were used for this study. Sampling was done on the areas of the wood surface that had not been previously sampled. The sampling technique as described above, was used for the dislodgeable arsenic measurement.

Reduction in dislodgeable arsenic was studied on two wood samples after treatment with an oil based stain or a water repellant/sealant,which are commonly available to consumers. Treatment was done according to manufacturer's recommendations. Three sub-samples from each sample were used for this study. The treatments were applied on the areas that had not been previously sampled. The coated wood samples were allowed to cure for one week at room temperature in a ventilated wood before testing for dislodgeable arsenic.

RESULTS AND DISCUSSION:

(A) CHARACTERIZATION OF WOOD:

Table I outlines the total arsenic and copper in various treated woods. Total arsenic and copper were fairly consistent among 3 tested samples and the ratio of arsenic/copper in the wood was 1.5 - 1.6. This is the approximate ratio of arsenic/copper in CCA treated wood.

The levels of arsenic and copper at various depths of southern pine wood are summarized in Table II A and II B. Statistical paired t-test values for significance at 95% confidence interval was calculated for the arsenic content between two consecutive layers of wood. Paired t-test values for arsenic content in treated wood(A) were ($t = 1.56$, $df = 2$) and ($t = 1.09$, $df = 2$) respectively between two consecutive layers of wood. Paired t-test values for arsenic content in treated wood(B) were ($t = 0.58$, $df = 2$ and $t = 1.00$, $df = 2$) respectively between two consecutive layers of wood. These findings indicate that the arsenic concentration in treated wood (A) and (B) did not differ significantly from the surface to the interior of the wood.

Table III summarizes arsenic leaching using neutral and acidic solutions. The data indicate that in acidic solutions 2.5 to 4 times the amount of arsenic is leached in comparison to neutral solutions. This may be due to increase solubilization of arsenic by acidic solutions. Figure 1 shows Successive leaching of arsenic in various solutions. The rate of arsenic leaching decreases with time. There was no difference between acidic and neutral leaching from pressure treated wood after two successive leachings.

Comparison of arsenic leaching with 0.1 N HCl and 0.1 N HNO_3 is shown in Table IV. The percentage of arsenic leached with both the acids was similar except aliquot (5Z). This increase in leaching from sample aliquot (5Z) may be due to a high concentration of surface arsenic in that sample aliquot. Total arsenic leached was slightly higher when wood samples were leached for extended periods in both the acid solutions.

Table V summarizes the arsenic leaching using different strengths of hydrochloric acid for two and ten week periods. Total arsenic leached from treated wood increased from 0.25% to 0.41% when using 0.01N to 0.05 N HCl, then leaching stabilized at increased acidity. Total arsenic leached increased about 10-20% with a ten week leaching period compared to a two week leaching period.

Table VI summarizes the leaching of arsenic and copper from the wood by water, 0.05 N HCl and 5.6% NaCl solutions. More arsenic and copper were leached with 0.05 N HCl than with either water or 5.6% NaCl solutions. This is due to increased solubility of the metal compounds in acidic solutions. The sodium ion may exchange with the arsenic and copper, which may have caused the observed increased leaching of arsenic and copper relative to water. The leaching in the untreated wood shows the matrix effect with the ICP.

(B) MEASUREMENT OF DISLODGEABLE ARSENIC:

During method development the sensitivity of measurement of dislodgeable arsenic was evaluated. Standard curves from different analyses indicate that quantitatively arsenic can be detected at 0.5 ug/ml in the solution by extrapolation of the standard curve. However for most of these studies 1.0 ug/ml detection limit was used for arsenic estimation,which corresponds to 6.25 ug per 100 square centimeter surface area of the wood.

Table VIII shows the dislodgeable arsenic levels on the wood. Dislodgable arsenic was not detected in five samples. Two playground wood samples had average dislodgeable arsenic levels in the range of 21.9-32.1 ug/100 sq cm surface area. Average dislodgeable arsenic levels in unfinished treated wood was 68.9 ug/100 sq cm surface area. Dislodgeable arsenic levels varied significantly within the replicates of samples. This may be due to non-uniformity of dislodgeable arsenic on the different surfaces of treated woods.

Comparison of the dislodgeable arsenic levels using chamois leather and nylon cloth is shown in Table IX. The Paired t-test values for dislodgeable arsenic in sample L-830-8638 was not significant between the two wiping medias. This indicates that dislodgeable arsenic does not differ significantly between the wiping media. Paired t-test values for dislodgeable arsenic in sample K-860-6165 was (t = 7.02, df =2) between two media. Overall this indicates that dislodgeable arsenic by nylon cloth sampling is greater or equal to chamois leather sampling. If it is assumed that chamois leather wipes same as human skin, then dislodgeable arsenic sampling by nylon cloth is equal or greater than human skin sampling.

The data on dislodgeable arsenic content of pressure treated wood,which has been treated with oil stain and water sealant is shown in Table X. Statistical paired t-test values for significance at 95% confidence interval was calculated for dislodgeable arsenic between sealers treated and untreated wood samples. The paired t-test values for dislodgeable arsenic from sample L-830-8638 were (t = 0.89, df = 2) and (t = 0.58, df = 2) between (oil stain coated and uncoated wood) and (water sealant coated and uncoated wood) samples respectively. The paired t-test values for dislodgeable arsenic content in the sample K-860-6165 were (t = -0.73, df = 2) and (t = -1.027, df = 2) between (oil stain coated and uncoated wood) and (water sealant coated and uncoated wood) samples respectively. The paired t-test values indicate that these coatings did not significantly reduce dislodgeable arsenic.

CONCLUSIONS:

This study has shown that 2.5 to 4 times as much arsenic leaches from pressure treated wood exposed to acidic solutions in comparison to neutral solutions during first two successive leaching. After two successive leaching the rate of arsenic leaching remains same in acidic and neutral solutions.There is a slight increase in arsenic leaching with sodium chloride (NaCl) solution compared to water but it is not significant. Surface leaching of arsenic from treated wood decreases considerably after initial leaching.Whether this is due to a rapid removal of surface layer salts on the wood surface or to rapid extraction of the arsenic in the top layers of the wood followed by diffusion limited leaching from the interior of the wood can not be assured from these data.

Total arsenic and copper content and the ratio of arsenic/copper content are fairly consistent among the tested samples. The levels of arsenic and copper at different depths of treated wood are not significantly different in the samples tested (none of the samples exceeded 1 1/2 inches in the minimum dimension, i.e., 2 x 4s).

Studies on rubbing media show that nylon cloth is more suitable for obtaining dislodgeable arsenic compare than various paper media. Chamois leather works fairly well as rubbing media. Chamois leather dislodgeable arsenic sampling is significantly different from cloth media.

The two types of coatings applied to the playground equipment wood samples did not significantly reduce the dislodgeable arsenic. Possible for differences to CDHS results may be related to the type of oil stain used, higher initial levels of dislodgeable arsenic in the CDHS results, and the type of wood and pressure treatment process.

TABLE I

TOTAL ARSENIC AND COPPER IN VARIOUS TREATED WOODS

SAMPLE DESCRIPTION	ug/mg ARSENIC IN WOOD	ug/mg COPPER IN WOOD
Treated Southern Yellow Pine (A)	3.28 ± 0.59	1.99 ± 0.31
Treated Southern Yellow Pine (B)	3.06 ± 0.15	1.98 ± 0.12
Treated Southern Yellow Pine (C)	3.89 ± 0.63	2.43 ± 0.33

TABLE II A

ARSENIC LEVEL AT VARIOUS DEPTHS IN SOUTHERN PINE WOOD (SUMMARY)

SAMPLE DESCRIPTION	ug/cm2 of ARSENIC ON SURFACE			ug/mg OF ARSENIC IN WOOD		
	Near Surface	Next To Surface	Inside Wood	Near Surface	Next To Surface	Inside Wood
Untreated Wood # 21	2.64	3.14	2.51	0.34	0.07	0.02
Treated wood (A)	172.66 ± 40.36	222.92 ± 38.47	284.82 ± 90.09	2.44 ± 0.73	2.47 ± 0.20	2.17 ± 0.97
Treated wood (B)	161.75 ± 84.91	230.77 ± 186.03	114.50 ± 74.44	2.49 ± 1.45	1.85 ± 1.45	1.04 ± 0.42

TABLE II B

COPPER LEVEL AT VARIOUS DEPTHS IN SOUTHERN PINE WOOD (SUMMARY)

SAMPLE DESCRIPTION	ug/cm2 of COPPER ON SURFACE			ug/mg OF COPPER IN WOOD		
	Near Surface	Next To Surface	Inside Wood	Near Surface	Next To Surface	Inside Wood
Untreated Wood # 21	1.37	0.12	0.30	0.17	0.00	0.00
Treated wood (A)	120.31 ± 20.02	138.77 ± 20.60	183.34 ± 70.72	1.67 ± 0.13	1.54 ± 0.16	1.40 ± 0.72
Treated wood (B)	98.188 ± 53.55	134.68 ± 111.85	50.23 ± 28.97	1.51 ± 0.91	1.07 ± 0.88	0.47 ± 0.13

TABLE III

ARSENIC LEACHING STUDIES USING NEUTRAL & ACIDIC SOLUTIONS

SAMPLE ALIQUOT	WEIGHT OF WOOD (mg)	LEACHING SOLUTION	LEACH TIME (DAYS)	SUCCESSIVE ug LEACHED	% As LEACHED FROM SAMPLE
1X	35.11	TAP WATER	5	038.60	0.11
			17	014.05	0.04
			31	*006.58	0.02
			79	005.51	0.02
2X	33.20	DIST. WATER	4	055.15	0.17
			16	016.70	0.05
			30	009.19	0.03
			78	007.23	0.02
3X	34.30	0.1N HNO3	4	146.50	0.43
			16	032.60	0.09
			30	009.85	0.03
			78	004.54	0.01
4X	32.80	0.1N HCl	4	146.00	0.44
			16	030.50	0.09
			30	010.80	0.03
			78	006.00	0.02

TABLE IV

COMPARISON OF ARSENIC LEACHING WITH 0.1 N HCl & 0.1 N HNO3

SAMPLE ALIQUOT	WEIGHT OF WOOD (mg)	LEACHING SOLUTION	LEACH TIME (DAYS)	SUCCESSIVE ug LEACHED	% As LEACHED FROM SAMPLE
2Z	71.2	0.1N HCl	18	134.30	0.19
			69	016.90	0.02
3Z	44.4	0.1N HCl	18	070.40	0.17
			69	008.00	0.01
4Z	59.5	0.1N HCl	18	099.20	0.17
			69	014.90	0.02
5Z	41.4	0.1N HNO3	17	128.50	0.31
			69	009.00	0.02
6Z	57.4	0.1N HNO3	17	112.10	0.20
			69	015.40	0.02
7Z	55.0	0.1N HNO3	17	104.40	0.18
			68	013.70	0.02

TABLE V

ARSENIC LEACHING STUDIES USING DIFFERENT STRENGTH OF HCl

SAMPLE ALIQUOT	WEIGHT OF WOOD (mg)	LEACHING SOLUTION	LEACH TIME (DAYS)	SUCCESSIVE ug LEACHED	% As LEACHED FROM SAMPLE
1Y	36.3	0.01N HCl	14	092.25	0.25
			70	036.40	0.10
2Y	44.7	0.05N HCl	14	183.50	0.41
			70	029.50	0.06
3Y	49.3	0.10N HCl	14	187.00	0.38
			70	043.90	0.08
4Y	38.4	0.25N HCl	14	198.50	0.52
			70	018.80	0.04
5Y	47.9	0.50N HCl	14	230.00	0.48
			70	022.20	0.04

TABLE VI

LEACHING OF ARSENIC AND COPPER FROM THE SOUTHERN PINE WOOD (SUMMARY)

SAMPLE DESCRIPTION	ug/mg ARSENIC LEACHING FROM WOOD			ug/mg COPPER LEACHING FROM WOOD		
	WATER	0.05N HCl	5.6 % NaCl	WATER	0.05N HCl	5.6 % NaCl
Untreated Wood # 21	0.010 ± 0.000	0.012 ± 0.000	0.016 ± 0.000	0.002 ± 0.002	0.004 ± 0.003	0.000 ± 0.000
Treated wood (A)	0.148 ± 0.000	0.986 ± 0.009	0.174 ± 0.012	0.028 ± 0.017	1.582 ± 0.236	0.353 ± 0.087
Treated wood (B)	0.147 ± 0.019	0.870 ± 0.378	0.202 ± 0.058	0.048 ± 0.046	0.998 ± 0.471	0.210 ± 0.093
Treated Wood (C)	0.096	2.453	0.195	0.012	2.181	0.282
Treated Wood (C) Surface Scraping	1.368 ± 0.378	5.089 ± 1.376	2.462 ± 0.809	0.492 ± 0.048	3.399 ± 0.303	1.544 ± 0.468

TABLE VII

DESCRIPTION OF THE WOOD SAMPLES USED FOR DISLODGEABLE ARSENIC STUDY

SAMPLE #	DESCRIPTION
K-800-9941	Southern pine wood, which is chromated copper arsenate (CCA) treated with retention of 0.4 lb/cu ft. Surface was treated with a semi-transparent stain.
K-800-9942	Southern yellow pine wood, which is 2 x 4 x 88 inches in size. Lumber is chromated copper arsenate (CCA) treated with retention of 0.4 lb/cu ft. Lumber was sanded and molded.
K-800-9943	Southern pine wood, which had been molded and sanded. Surface was treated with a brown colored semi-transparent stain. Lumber is chromated copper arsenate (CCA) treated with retention of 0.4 lb/cu ft.
K-800-9944	Southern yellow pine wood, which had been molded and sanded. Lumber is chromated copper arsenate (CCA) treated with retention of 0.4 lb/cu ft.
K-830-0584	Southern yellow pine wood, which is 2 x 4 x 88 inches in size. Surface was treated with the oil base stain. Lumber is chromated copper arsenate (CCA) with retention of 0.4 lb/cu. ft.
K-860-6165	Lodge Pole Pine construction logs, which are chromated copper arsenate (CCA) treated with retention of 0.4 lb/cu ft. The Surface was treated with stain.
L-830-8638	Pine wood, which is 6 x 6 x 36 inches in size. Lumber is chromated copper arsenate (CCA) with retention of 0.4 lb/cu ft. The surface was sanded.
L-400-6961	Southern yellow pine wood, which is chromated copper arsenate (CCA) treated with retention of 0.4 lb/cu ft. The wood is unfinished. It is not a playground equipment wood.

TABLE VIII

DISLODGEABLE ARSENIC CONTENT OF VARIOUS TREATED WOOD SAMPLES

SAMPLE #	ug/100 sq cm ARSENIC
K-800-9941	< 6.25
K-800-9942	< 6.25
K-800-9943	< 6.25
K-800-9944	< 6.25
K-830-0584	< 6.25
K-860-6165	32.10 ± 22.38
L-830-8638	21.88 ± 22.47
L-400-6961	68.84 ± 50.65

TABLE IX

DISLODGEABLE ARSENIC MEASUREMENT IN TREATED WOOD WITH CHAMOIS LEATHER AND NYLON CLOTH

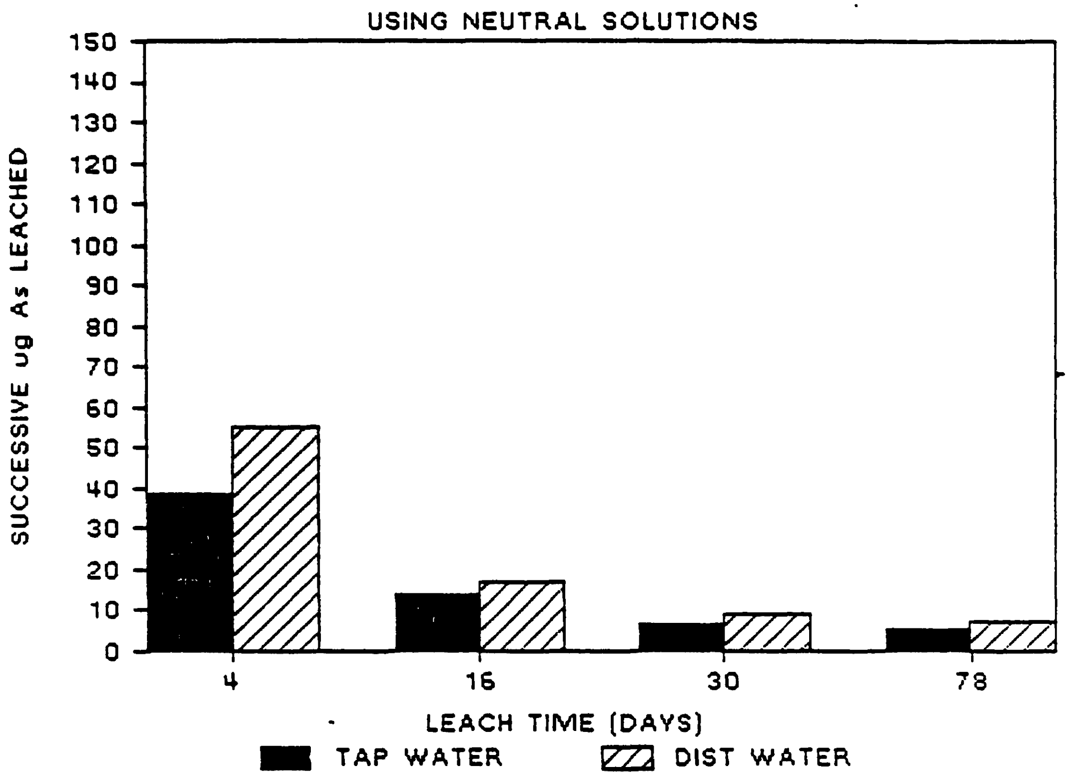
	ug ARSENIC / 100 SQ CM SURFACE AREA	
SAMPLE #	CHAMOIS LEATHER	NYLON CLOTH
K-860-6165	22.45 ± 3.44	38.78 ± 2.11
L-830-8638	25.52 ± 27.83	33.78 ± 43.84

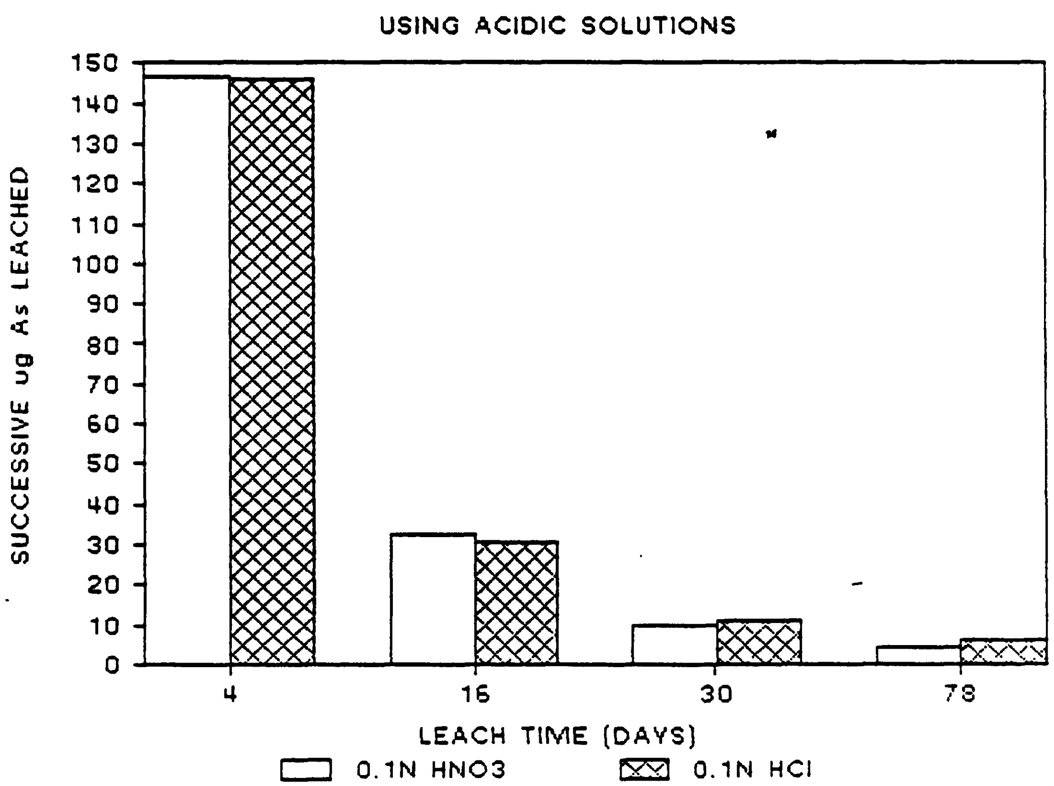
TABLE X

DISLODGEABLE ARSENIC MEASUREMENT IN CCA TREATED WOOD, COATED WITH OIL STAIN OR WATER REPELLANT/SEALANT

	ug ARSENIC / 100 SQ CM SURFACE AREA		
SAMPLE #	OIL STAIN	WATER REPELLANT/ SEALANT	BEFORE COATING
K-860-6165	50.02 ± 36.58	52.50 ± 26.39	32.06 ± 22.16
L-830-8638	9.72 ± 2.97	14.02 ± 6.74	21.88 ± 22.47

ARSENIC LEACHING STUDIES





UNITED STATES GOVERNMENT

MEMORANDUM

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

TO : Elaine A. Tyrrell, Vulnerable Populations Project Manager (EX-PM)

Through: Andrew G. Ulsamer, PhD, AED (HS) AGU

JAN 26 1990

Through: Murray S. Cohn, PhD, Director (HSHE) MSC

FROM : Brian C. Lee, PhD (HSHE)

SUBJECT: Estimation of hand-to-mouth activity by children based on soil ingestion for dislodgeable arsenic exposure assessment.

I. Introduction

When a play surface contains arsenic that may easily be removed by casual contact with the surface (dislodgeable arsenic), oral exposure of children could occur by touching the surface with the hands and then inadvertently transferring the arsenic to the mouth by eating with unwashed hands or mouthing the hands. Assessing the risk of toxicity to the children requires data or estimates of the amount of arsenic that the children might receive. Since arsenic is poorly absorbed through the skin, the oral route of exposure is of concern. No data currently exist on the amount of arsenic on a play surface that is transferred to the mouth via the hands. Therefore, this document will develop a procedure to estimate exposure based on soil ingestion.

EPA has assumed that young children normally ingest 100 mg (EPA, 1986b) or 200 mg (EPA, 1988a) of soil per day. The California Dept. of Health Services (CDHS, 1987) has proposed scenarios of children ingesting 50% and 100% of the soil on the hands. CDC has assumed that age-specific soil ingestion mimics the amount of soil deposited on the skin so that 1.5-3.5 yr olds ingest 10 g (10,000 mg) per day and 3.5-5 yr olds consume 1 g/day (Kimbrough, 1984). However, as Paustenbach (1986) relates in a critical review of the CDC assumptions, a more strongly scientifically supported basis is needed to estimate the amount of soil ingested by children for the assessment of exposure resulting from the hand-to-mouth transfer of substances into the mouth.

In the present memo, the risk is not from toxicants within the soil, but rather, dislodgeable arsenic from playground equipment wood. Thus, rare individuals who routinely consume handfuls of soil do not constitute a sensitive subpopulation. Data from these individuals will be excluded so as not to induce error into the estimates of the equivalent number of hands with soil consumed daily by "average" children.

I.A. General approach

Two types of data will be employed to estimate exposure. The first type of data is used to estimate the amount of soil ingested per day using poorly absorbed trace elements in the soil as markers (Al, Si, Ti, Y). The source of the ingested soil is presumably from hand-to-mouth operations such as eating with unwashed hands and mouthing or chewing of inedible substances. The second type of data is used to estimate the amount of soil on the hands by correlating the concentration of an elemental marker (Pb) on the hands with the concentration in the soil where the child has played.

Linking these two types of information will allow the ingestion of dislodgeable arsenic from a play surface to be estimated. Daily soil ingestion resulting from hand-to-mouth activity can then be expressed in terms of handloads per day. A "handload" is equivalent to an age-specific size hand loaded with an average amount of soil on the palmar side. Assuming the same hand-to-mouth activity that leads to soil ingestion will result in parallel exposure to dislodgeable arsenic, the handloads per day estimate can then be used in conjunction with the dislodgeable arsenic levels on the wood to estimate the exposure by ingestion.

Exposure to dislodgeable arsenic from a play surface is assumed to occur by contacting the surface with the hands and then mouthing the hands or eating with unwashed hands. Exposure might possibly also occur by directly mouthing the surface. It could be assumed that the behavior which leads to soil ingestion from direct mouthing of the soil or non-hand objects might also lead to arsenic ingestion from direct mouthing of the wood. However, no data exists concerning the proportion of soil or arsenic that is ingested by directly mouthing soil, soil-contaminated objects, or wood compared to the proportion ingested by hand-to-mouth operations. Therefore, the present exposure procedure will treat soil and arsenic ingestions as being due to hand-to-mouth operations, even though some of the ingestions may possibly be due to direct mouthing.

I.B. Mouthing and pica behaviors

Approximately 80% of 1-2 yr olds exhibited mouthing and chewing of the hands and other nonedible objects in a study of 780 children in Washington, DC (Millican, 1962). The prevalence of this behavior declines to about 30% at age 6. From ages 1-6 yr, the overall prevalence was 53% for black and 33% for white children.

Pica is the abnormal craving and ingestion of substances not usually considered food. Soil may be ingested as well as objects such as paper, clothing material, ashes, paint, plaster, or buttons (Barltrop, 1966). Pica has been associated with mineral deficiencies and certain psychological factors, but may appear to be fairly common among young children, depending on how "pica" is defined.

It is not known whether the pica incidences reported by Barltrop (1966) and Millican (1962) were representative of the national population. However, Barltrop (1966) reported that from interviews of 185 families representing 439 Boston area children, about 40% of 1 yr olds engage in pica, which declines to about 20% at age 6. Racial differences [uncorrected for socioeconomic factors] were noted in a study of 780 Washington, DC children (Millican, 1962). At age 1-2 yr, 57% of the black and 28% of the white children engaged in pica, 39% and 20% respectively at 2-3 yr, and about 20% and 5% from 3-6. Pica and mouthing behaviors can be major factors in lead (Pb) poisoning of young children (Lepow, 1975; EPA, 1986a) and can contribute to the exposure to other substances as well.

II. Review of studies and assessments of soil ingestion

Several studies and assessments have estimated the amount of soil ingestion by children. Hallmarks of better studies were the use of poorly absorbable markers, verification of the lack of absorption of the markers, and control and analyses of markers in the diet. A chronological progression of major studies and assessments is reviewed.

Problems in the use of markers which are more than slightly (>5-10%) absorbable are that the apparent absorption can be highly variable according to age, diet, and environment. For example, the absorption of Pb is 42-53% for 0-2 yr olds, 30-40% for 2-6 yrs, and 18-20% for 6-7 yrs (EPA, 1988b). Pb absorption is also inversely related to calcium intake and iron status (Mahaffey, 1989). Pb intake from the air is decreasing due to the reduction of tetraethyl Pb in gasoline (EPA, 1988b), causing other sources such as Pb paint dust and Pb in water to become more significant to human exposure.

Therefore, if a moderately absorbable marker element, such as Pb, is used for soil ingestion studies, then the children's ages should fall into a tight range, controls should be applied to the diet and environment should be controlled and analyzed, and the absorption should be measured.

II.A. Hawley (1985)

Hawley assessed soil ingestion without using direct measures of soil ingestion. Some of the assumptions that were made appear to be unrealistic. For example, it was assumed that a child ingested dirt equivalent to half the soil on the fingers of both hands, and that the hand surface area of 2.5 and 6 yr olds were 300 and 400 cm^2 [should be about 200 and 280 (CPSC, 1975)]. Hawley also attempted to distinguish between ingestions of dust (indoors) and soil (outdoors) although it was recognized that most of the dust might have come from the soil. The Hawley data were not used to develop the method of estimating soil ingestion in the present document.

Using estimates presented in the article, 90 mg/day of "soil" was ingested by 2.5 yr olds and 21 mg/day by 6 yr olds. Corresponding "soil"+"dust" ingestions would be 150 and 24 mg/day for the 2.5 and 6 yr olds. Despite having no actual soil ingestion data for comparison at that time, the estimate for 2.5 yr olds is in agreement with Clausing (1987) (section II.C) and the estimate for 6 yr olds in agreement with Calabrese (1989) (section II.E).

II.B. Binder (1986)

A frequently cited average of 180-184 mg soil ingested per day (121-136 median) was estimated from fecal aluminum and silicon in 59 1-3 yr olds (Binder, 1986). This was the first study which measured elemental markers of soil ingestion. However, its popularity in the scientific literature should not be taken as its continued accuracy. The author felt that the 7.5 g/day dry fecal weights were too small due to the possible loss of feces during collection. So, the weights were assumed to be 15 g/day. No evidence was found indicating fecal material was being lost in the diaper material, and in retrospect the need for assuming 15 g/day fecal weights was not appropriate (S. Binder, personal communication). Without the 15 g fecal weight assumption, the average soil ingestion would have been estimated as 90-92 mg/day (65-68 median).

Proper controls were not applied to the diets of the children. Samples of food that was consumed were not analyzed for aluminum and silicon. It was assumed that the amounts of markers in the feces were only from the ingestion of soil. However, error could possibly have been induced by the consumption of common substances such as vegetables grown in soils of different mineral contents, bread raised with aluminum baking powder, and medicines and powders containing silicon desiccants and flowing agents. Due to the assumptions and the lack of controls, the Binder data was not used to develop the method of estimating soil ingestion in the present document.

II.C. Clausing (1987)

A 10 g/day fecal weight was assumed for 18 nursery school and 6 hospitalized 2-4 yr olds (Clausing, 1987). The weight was close to the 12.6 g/day measured by Calabrese (1989). Aluminum, titanium, and the "acid insoluble residue" in feces and in the top 5 cm of soil from play areas outside the nursery school were sampled. Percent recoveries of the 3 markers from soil were determined by analyses, but the recovery of aluminum and titanium from feces were assumed to be 95% and 90%, respectively.

Several assumptions were made by Clausing due to the lack of proper controls or analyses. Since controls were not applied to the dietary intake of the children and the analyses of the three markers were not done in samples of consumed food, it was assumed that the hospitalized children had food similar to those at the nursery school. It was further assumed that the hospitalized children had no soil exposure. Ingestion of marker elements in dust was not considered. The nursery school children's intake of markers (representing food+soil) was decreased by the hospitalized children's intake (representing food only) to produce an estimated soil intake of 56 mg/day.

Substantial inaccuracies in the Clausing (1987) study could have been induced by the method used in calculating the average soil intake from the fecal data. Instead of separating the data by marker, the maximum soil ingestion for each individual was used irrespective of the marker. Acid insoluble residue has not been accepted as a soil marker since the amount of "ash" varies widely in foods. Soil ingestion calculated from titanium only indicated that the hospitalized children had an average of over 3 times the soil ingestion of the children from the nursery school. It is possible that the titanium intake of the hospitalized children was higher due to ingestion of medicines containing titanium as a white coloring agent.

The data from Clausing was not used to develop the method of estimating soil ingestion in the present document. However, if the Clausing data derived from the aluminum marker is recalculated, then the nursery school children's intake from soil+food minus the hospitalized children's intake from food was 232 - 56 = 188 mg soil /day. This value is the same as from Binder (1986) and has been used to confirm Binder's results. However, it is twice the mean ingestion value when Binder is recalculated (see section II.B).

II.D. Sedman (1989)

Sedman incorporated studies using trace element markers (aluminum, lead, silicon, titanium) which ranged from practically unabsorbable to moderately absorbable by correcting the amount in the feces by the fraction of the marker that was absorbed. The 15 g fecal wt assumption of Binder (1986) (section II.B) was used in the calculations and data on lead (Pb), silicon, aluminum, and titanium were collected. (Clarification note- the formula for

Sedman's (1989) mass-balance approach should read: [(Fc x F / EF) - DI] / Sc = soil ingestion, where Fc is the fecal concentration of the marker element, F is the daily fecal weight, EF is the fraction of the daily intake of marker element excreted into the feces, DI is the daily intake of the marker element, and Sc is the soil concentration of the marker element.)

The use of moderately absorbable marker elements for soil ingestion presents so many complications that unless strictly designed and controlled studies are conducted, the results may be highly inaccurate (see beginning of section II). Thus, the estimate of soil ingestion by Sedman (1989) based on Pb was not used. Furthermore, the intake of titanium was not controlled or measured in the Sedman study. Since the results with titanium in another uncontrolled intake study (Clausing, 1987) were unacceptable, the soil ingestion estimate made by Sedman and based on titanium was also not used.

Dietary intakes of the marker elements were not measured by Sedman (1989). Instead, the typical diet according to the elemental composition of the FDA commodities lists and other published sources were used to estimate the daily intake of marker elements (Sedman, 1989). However, the "typical" diet does not necessarily represent the actual diet particularly since young children tend to be "finicky" eaters who will avoid specific foods or even classes of foods and wide variation may occur due to regional and cultural differences. Furthermore, the trace element content of foods can be widely variable depending on mineral content of the soil that plants were grown in, mineral intake of the food animals, and food processing.

Finally, Sedman (1989) decided to average all of the estimates derived from the various element markers which cover a 40-640 mg soil/day range to produce a mean value of 330 mg/day (sd=260 mg/day). An average should not have been made because the overly wide range should have suggested that a more critical examination of the data and calculations was needed.

II.E. Calabrese (1989)

A comprehensive and well-controlled study of 65 1-4 yr old children from day care centers and non-randomly selected volunteers at the Univ. of Massachusetts examined 8 potential elemental markers of soil ingestion (aluminum, barium, manganese, silicon, titanium, vanadium, yttrium, and zirconium) in fecal material (Calabrese, 1989). Diets were controlled, sampled, and analyzed for the markers so that the intake of each element could be measured. The fecal collection period was 8 days. In addition, sterilized samples of a soil standard were ingested by adult volunteers to validate the use of each element as a marker by determining recovery of the elements in fecal material. It was assumed that the potential markers would be handled similarly in the 1-4 yr old children as in the adults.

The average outdoor time for the children was 1.5 hr/day (sd=1.6 hr). The upper 3" of soil from play areas of the nursery school or home yard and dust from inside the schools and homes were collected and analyzed for the potential elemental markers. Special care was taken to prevent contamination of the fecal samples, such as collection and handling samples for the parents and nursery school attendants and providing a specific lot of diapers which had been analyzed for the elements of interest.

Aluminum, silicon, and yttrium were felt by Calabrese to be the most representative markers since the respective recoveries were nearest 100% (92%, 95%, and 88%) when 1.5 g of soil standard was ingested. When 0.3 g of soil standard was ingested, 7 of the recoveries for the 8 potential markers were substantially greater than 100%. This suggests that a non-dietary source of the potential markers, such as dust in the lungs, was contributing elements at a low level. [Note-- Table 32 of Calabrese (1989) is incorrect due to the inclusion of nonpositive recoveries listed as "0%" when the averages were calculated. This did not affect the values estimated for soil ingestions.]

The average of the soil ingestion estimates that had been corrected for diet and based on soil and dust combined levels of elemental markers according to the 3 markers was 209 mg/day. Calabrese felt that the median values more accurately represented the data than geometric or arithmetic means, or means excluding the outliers, such as an individual who had eaten 5-8 g of soil during the study. The average of the median values for the 3 markers was 30 mg/day. The Calabrese data was used to develop the method of estimating soil ingestion in the present document.

II.F. Beck (1989)

Beck based a 100 mg/day soil ingestion value for 1-6 yr olds in a risk assessment for arsenic in soil on conservative median estimates from elemental marker studies (Calabrese, 1989). Since the median soil ingestion rates ranged from 9-96 mg/day corrected for diet and based on soil concentrations of marker elements, the maximal value of 96 (rounded to 100) was selected. However, values based on soil and dust combined were 11-123 mg/day, the most conservative value rounding to 125 mg/day. Whether or not corrected for dust, the maximal values were derived from the vanadium marker, which was not representative of soil ingestion due to its recovery of 1.5 times the expected amount. Therefore, that data was not used to develop the method of estimating soil ingestion in the present document.

III. Estimation of equivalent hand-to-mouth activity based on soil ingestion

III.A. Soil ingestion

Estimation of the soil ingested by children will be based on the data but not necessarily the results of Calabrese (1989). Calabrese (1989) considered aluminum, silicon, and yttrium to be the most representative elemental markers of soil ingestion based on recoveries from experimental doses of soil (section II.E). However, when one outlying datapoint was discarded from the data, titanium (adjusted recovery =138%) could also be considered a representative marker. Average recovery for aluminum, silicon, yttrium, and titanium would then be 103%, which suggests that soil ingestion estimates derived from these 4 markers taken together may be more representative than the 3 identified by Calabrese. This study had the proper controls and analyses of markers, so that the use of titanium would not be invalidated, such as with Clausing (1987) and Sedman (1989) (see sections II.C and II.D).

Adding titanium as a marker had little effect on the means and no effect on the medians estimated for soil ingestion. The mean soil ingestion corrected for diet, and based on soil and dust combined was 218 mg/day (sd=1286, sd range 620-3105, n= 62-64) with 90% of the children <268 and 95% <587. The median was 30 mg/day. If only the 3 elemental markers recommended by Calabrese (1989) were used, then the mean was 234 mg/day (sd=1484, sd range and n same) with 90% <209 and 95% <430. The median, using the 3 elements, was also 30 mg/day.

The mean soil ingestions of 209 or 218 mg/day appear to be near the 150 mg/day of Hawley (1985) (section II.A) and 188 mg/day from a recalculation of Clausing (1987) (section II.C). However, as mentioned in section II.E, Calabrese (1989) felt that the outliers had skewed the mean and that the median was more representative of the data. The large standard deviations are the result of the outlier data. No raw data were available to enable recalculations after omitting the outliers. Therefore, the median soil ingestion of 30 mg/day will be used as the first type of data needed to estimate exposure (section I.A).

III.B. Estimating soil on the hands

The second type of data needed was the typical amount of soil found on the hands. Equivalent number of handloads represented by the 30 mg of soil ingested per day can be estimated for specific ages by determining the soil on the hands and the corresponding surface area. Roels (1980) measured the amount of Pb in the soil of play yards at rural, urban, locations and 1.0 and 2.5 km from a smelter and associated it with the Pb washed from the hands of 11 yr old children who played in those areas. It was then assumed that the Pb on the hands was from the soil and not other sources, such as paint. From this data the amount of soil adhering to one hand was calculated (Table 1). Males had considerably more soil on the hand than females (range 133-178 mg, avg 158 vs. range 43-111, avg 88). There was no relationship between the location of the play area and the soil on the hand. Calculations were made separately for males and females due to the differences in soil on the hand.

III.C. Linking soil ingestion and soil on the hands to estimate hand-to-mouth activity

If it is assumed that the soil adheres to an area equivalent to the palmar side of the hand and the palmar side surface area of the hand for an 11 yr old is 107.8 cm^2 (CPSC, 1975), then the soil per unit of hand surface area is 158/107.8 = 1.47 mg/cm^2 for males and 88/107.8 = 0.82 for females. A 2 yr old boy with 48 cm^2 palmar side surface area per hand (CPSC, 1975) could have an estimated 71 mg of soil per handload. Thus, one handload for a 2 yr old boy represents 71 mg of soil. From the recalculation of Calabrese's (1989) data, a child ingests a median of 30 mg/day which is equivalent to 30/71 = 0.42 of a handload. Estimated handloads of soil ingested for 2 and 5 yr olds are listed in Table 2 based on mean, median, 90th percentile, and 95th percentile soil ingestions recalculated from Calabrese. Values for 12 yr olds are included but might possibly be overestimates since older children have less mouthing behavior and could be expected to ingest less soil.

The handload values for females are greater than males because more handloads of soil from "cleaner" female hands would be needed to accumulate the daily amout of soil ingested. The handload value is not the actual number of times child puts a hand in his mouth and consumes all the dirt from the hand. It represents the equivalent hand-to-mouth activity resulting in the amount of soil that is estimated to be ingested daily. Lepow (1975) observed ten 2-6 yr old children and estimated a conservative mouthing frequency (of hands and other inedible objects) of 10 times per day. If this estimate of mouthing frequency is correct, then the amount of soil consumed from 10 mouthings by a 2 yr old boy would be equivalent to the median soil amount in less than half of a handload (Table 1).

If it is assumed that the same hand-to-mouth activity occurs with a substance from a play surface, such as dislodgeable arsenic from playground equipment wood, then the handload value may be applied to estimate exposure as an average maximum amount which might be ingested.

IV. Example application of handloads of soil ingestion estimates to exposure assessments

Suppose 2 yr old boys played on a surface having dislodgeable arsenic and the level on their hands was 100 ug/cm^2. The amount of arsenic on each hand would be 100 ug/cm^2 x 48 cm^2 per hand = 4800 ug per handload. Since 2 yr olds ingest the equivalent of 0.42 handloads per day (section III.C), the average maximum amount of chemical ingested would be estimated as 4800 ug/handload x 0.42 handloads/day = 2016 ug/day.

Table 1

Soil on 11 yr old Childrens' Hands
(calculated from Roels, 1980)

area	soil Pb	Pb in hand		soil on hand	
		male	female	male	female
rural	112 ug/g	17.0 ug	11.4 ug	151 mg	102 mg
urban	114	20.4	12.7	178	111
2.5 km from smelter	466	62.2	20.0	133	43
1.0 km from	2560	436	244	170	95
				---	---
			mean	158 mg	88 mg

Table 2

Soil Ingestion by Children
in terms of handloads

age	hand area	soil on hand	
		male	female
2 yr	48 cm^2	71 mg	39 mg
5	65	96	53
12	115	169	94

Hand area from CPSC (1975)
Soil on hand at 1.47 mg/cm^2 for males and 0.82 for females (section III).

Males

age	mean	median	90th	95th
2 yr	3.07 hnlds/day	0.42	3.77	8.27
5	2.27	0.31	2.79	6.11
12	1.29	0.18	1.59	3.47

Females

age	mean	median	90th	95th
2 yr	5.59 hnlds/day	0.76	6.87	15.05
5	4.11	0.56	5.06	11.08
12	2.32	0.31	2.85	6.24

Soil ingestion mean of 218 mg/day, 90th percentile = 268, 95th percentile = 587, median = 30; section III.

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