UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

**Memorandum**

Date: January 10, 2003

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SUBJECT : Statistical Analyses of CCA-Treated Wood Study Phases I and II

# Introduction

The staff of the U.S. Consumer Product Safety Commission (CPSC) is currently addressing a petition to ban the use of chromated copper arsenate (CCA) treated wood in playground equipment. Studies have shown that chronic exposure to arsenic in drinking water may result in an increased risk of cancer.[1] To evaluate this risk to children from exposure to CCA wood, estimates on the level of arsenic (As) transferred to a human hand from contact with CCA-treated wood are needed. CPSC staff has conducted a series of laboratory and field studies to develop test methods to measure the level of arsenic transferred, to produce estimates of the level, and to explore factors that may affect the level.

The studies have consisted of four phases. Phases I and II were exploratory in nature and concentrated on screening experiments and test method development.[2] The primary goal of these two phases was to provide information for the designs and protocols of subsequent studies. This memo presents the results of the statistical analysis of Phases I and II to address that goal. Subsequent studies would consist of field studies that would provide rigorous measurements on actual in-use structures. The field study measurements would be used in the risk assessment of CCA-treated wood playground equipment.

[1] For a review see National Research Council (2001).
[2] The details of the experimental procedures and results of Phases I and II are described in Cobb (2003).

## Phase I Study

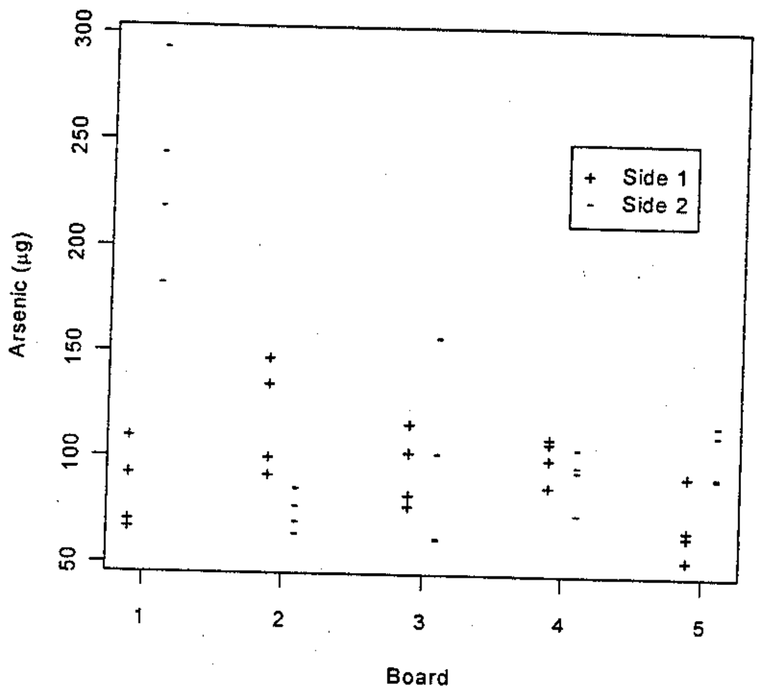
Phase I consisted of a series of exploratory experiments. The initial experiments investigated a test method based on a weighted fabric as a surrogate to the human hand. A surrogate test method has several important advantages over the use of human subjects. It can be more readily applied in large studies and is likely more reproducible. In the fabric surrogate test method, a fabric is attached to a weight and then rubbed over a sample of wood. The fabric is then chemically analyzed for the amount of arsenic. The primary surrogate fabric was a polyester fabric. Factors such as the area of wood rubbed, the number of rubs, the weight applied to the surrogate, and the wetting with saline of the surrogate were examined. In addition, a sampling template that holds and controls the rubbing of the surrogate was developed. The wood used in these experiments was predominately new wood purchased at local retail stores.

In one experiment in this phase, variations in the arsenic level between boards and between multiple locations on a single board were examined. Five boards from a single purchase of new wood were each tested with a wet polyester surrogate. On each board, 4 locations were sampled on each side of the board. Figure 1 displays the results. From the figure, it is apparent that measurements on the same side of a board are consistent with each other. In contrast, measurements on opposites sides of a single board or on two separate boards do not appear consistent with each other.

A variance component model was fit to estimate the three sources of variation: the variation within a side of a board, the variation between sides of a board, and the variation between boards. The variation within a side of a board accounts for both differences along the side of the board and the variation associated with the test method. From the model it was estimated that the correlation of two measurements on a single side of a board was 0.76 and that the correlation of two measurements on opposite sides of a board was estimated to be near zero. Equivalently, measurements on opposite sides of a board or distinct boards may vary considerably.

These findings have implications to the design of experiments to compare methods of measuring the level of arsenic transferred. For example, to compare two methods, each method should optimally be applied on the same side of a board, rather than on separate boards or opposite sides of a board. Such an experimental design is known as a paired design or more generally a block design.

Figure 1: Arsenic per Sample from Wet Polyester Surrogate in Experiment on Board Variations.




The sampling template used to control the surrogate rubbings was designed to perform sampling on surfaces both parallel (horizontal) and perpendicular (vertical) to the ground. To test whether there were differences in the behavior of the template in the two orientations, two boards were each sampled four times in the horizontal and vertical orientation in distinct locations. Table 1 provides the results. The differences were very minor. A model that accounted for the difference in boards was fit to statistically test the difference. The statistical test did not detect a difference (p-value 0.996). However, the large variation in the multiple samples resulted in a low power statistical test.

Table 1: Mean Arsenic per Sample Using Sampling Template by Orientation.

| **Board** | **Orientation** | | | |
|---|---|---|---|---|
| | **Horizontal** | | **Vertical** | |
| | **Mean (µg)** | **Samples** | **Mean (µg)** | **Samples** |
| 1 | 161.9 | 4 | 159.8 | 4 |
| 2 | 96.8 | 4 | 98.9 | 4 |

After the initial experiments, a study was designed to obtain direct measurements using the hands of human subjects and to compare these measurements to those from the surrogate method.[3] The method using the human hands consisted of a human subject rubbing a hand a predefined number of times over a predefined area of wood. The hand was then rinsed and the rinse analyzed for the amount of arsenic.

[3] The study is referred to as Hand Study 1 in Cobb (2003).

The study included samples of new wood and several samples from actual decks. Six adult human subjects were used. On each board, a human subject rubbed a section of wood with a bare dry hand and a section of wood with a polyester-gloved human hand. A third section was used for a weighted wetted polyester fabric. Figure 2 displays an example of the arrangement of the three methods on a board. In the actual experiment, the arrangement was randomized. A total of 20 boards was sampled.

Figure 2: Arrangement of the Three Methods for Hand Study 1.

| | | |
|---|---|---|
| Bare Hand | Gloved Hand | Weighted Polyester |

No correlation was found between the bare hands and the weighted polyester fabric, although later experiments indicated that this was likely due to the incomplete extraction of CCA from the bare hands. However, a strong correlation (0.96, p-value $< 0.001$)[4] was found between the polyester-gloved human hand and the weighted polyester fabric. These results have important implications. First, it established that it is possible to design experiments to examine correlation between test methods. Had the variation in the wood been too large, this would not have been feasible. Second, it showed the lack of correlation between the weighted polyester surrogate test method and the human hand method was not caused by the difference in the morphologies of the contact with the wood surface between the hand and the surrogate methods. The difference might be attributed to the differences in the material properties of the polyester fabric and the human hand surface or the extraction procedures used for the two methods.

A second limited study continued to examine the human hand and the surrogate methods.[5] Adult volunteers extensively rubbed large areas of new wood (2100 $cm^2$) with dry, wet, and oily hands. Two volunteers were used and each volunteer performed the dry, wet, and oily hand sampling twice. The use of the large area was intended to investigate the upper limits of arsenic transferred to the hand and the capacity of the hand to hold arsenic. In addition, procedures for extracting the CCA from the hands after rubbing were investigated. After rubbing, the hand was rinsed with acetic acid and the rinse was saved for analysis. Following the acetic acid rinse, the hand was vigorously wiped with a polyester fabric wetted with acetic acid and the wipe was saved for analysis. Table 2 summarizes the results from the experiment. For wet hands, more arsenic was transferred to the hands than for dry or oily hands. The initial acetic acid rinse only extracted 46% of the total arsenic extracted for dry hands.

[4] Appendix 1 contains a description of the correlation measure and associated significance test used throughout this memo for measuring the relationship between two methods.

[5] The study is referred to as Hand Study 2 in Cobb (2003).

Table 2: Mean Arsenic per Sample for Hand Study 2.

| Hand Condition | Acetic Acid Rinse (μg) | Acetic Acid Wipe (μg) | Total (μg) | Number of Volunteers | Number of Samples per Volunteer |
|---|---|---|---|---|---|
| Dry | 12.9 | 15.5 | 28.3 | 2 | 2 |
| Oily | 8.3 | 19.9 | 28.2 | 2 | 2 |
| Wet | 21.2 | 21.5 | 42.6 | 2 | 2 |

## Phase II Study: Design

Phase II was intended to explore factors that affect the level of arsenic transferred and to further the development of the human hand and surrogate test methods.[6] In particular, the study explored (1) the level of arsenic transferred from a range of woods, (2) the effect of varying the number of hand rubs, (3) the effect of repeated rubbing of a sample of wood, and (4) relationships between the results from the human hand method and results from various surrogates.

Phase II consisted of bringing samples of wood into the laboratory for experimentation. The study made use of 5 classes of wood, 4 adult human subject volunteers, and several surrogate materials. Table 3 describes the 5 wood classes. All the woods were unfinished, i.e., they contained no stains, sealants, or paints. Although an effort was made to find a wide range of woods, choices were constrained by the availability of wood that could be brought into the laboratory. Only the Old Deck class consisted of wood that had actual usage. However, that wood was likely support joists of the deck and therefore would not have had the wear and weathering of the decking planks. Also, the Old Deck wood may have been exposed to leaching of arsenic from the planks.

The surrogate materials included a saline wetted polyester fabric, a dry polyester fabric, and a high-density polyethylene (HDPE) material. Additionally, limited testing was performed with a laboratory tissue paper surrogate. The standard template apparatus was used for the application of surrogates. A series of acetic acid rinses and wipes were used to extract the CCA from the hands.[7]

The study followed the established design of comparing multiple test methods on single sides of boards. For each class of wood, volunteers were each assigned a distinct board. Each board was divided into disjoint segments. Some segments were used for hand rubs and some segments were used for surrogate rubs. Hand rubs consisted of 2, 5, 10 or 20 cycles, in which a cycle is the rubbing of the segment of the board from one side to the other and back. The hand rubs were performed with a dry hand. For example, a single board may include a 10-cycle hand rub, a 20-cycle hand rub, a wet polyester surrogate rub, and a dry polyester surrogate rub. Figure 3 displays an example of the arrangement of the four methods on a board. In the actual experiment, the arrangement was randomized and the run order of the hand rubs was randomized.

[6] The study is referred to as Hand Study 3 in Cobb (2003).
[7] See Cobb (2003).

Figure 3: Example of Arrangement Methods on a Board in the Phase II Study.

| | | | |
|---|---|---|---|
| 10-Cycle Hand Rub | 20-Cycle Hand Rub | Wet Polyester Surrogate | Dry Polyester Surrogate |

Not all surrogates were examined on each board, because of limits in the length of boards. Also, not all volunteers participated in all phases of the study, because of limitations associated with the use of human subjects. The experiment was conducted in three stages, described in Table 4.

Table 3: Wood Classes in Phase II Study.

| Wood Class (Identifier Code) | Description | Number of Boards Used[8] |
|---|---|---|
| New (N) | Wood purchased new. | 6 |
| Lab Aged (A) | Wood purchased new, and then aged outside for 3 months on each side. | 2 |
| Under Deck (U) | Wood purchased new, and then stored under deck for approximately 5 years. | 4 |
| Old Deck (D) | Wood part of deck (probably joists) for approximately 12 years and then stored outside for approximately 10 years. | 2 |
| Weathered (W) | Wood purchased new, then stored outside for approximately 2 years and then stored inside for approximately 2 years. | 2 |

Table 4: Summary of Phase II Study.

| Stage | Volunteers | Wood Classes | Surrogates | Notes |
|---|---|---|---|---|
| 1 | 1,2,3,4 | N | Wet Polyester, Dry Polyester, HDPE, Lab Tissue Paper | Each volunteer was assigned a single board from the wood class. On each board, the volunteers performed 2-, 5-, 10-, and 20-cycle hand rubs. The 5-cycle rub was repeated 4 times. |
| 2 | 2,4 | A, U | Wet Polyester, Dry Polyester, HDPE | Each volunteer was assigned a single board from each of the wood classes. On each board, the volunteers performed 10-, and 20-cycle hand rubs. The 10-cycle hand rub was repeated 3 times. |
| 3 | 1,3 | N, U, D, W | Wet Polyester, Dry Polyester, HDPE | Each volunteer was assigned a single board from each of the wood classes. On each board, the volunteers performed a 10-cycle hand rub. |

[8] In some cases, two sides of one board were used. This is counted in the table as two boards. As noted earlier, experiments in Phase I indicated that there was little correlation between two sides of a single board.

## Phase II Study: Analysis

### Effect of Number of Cycles

For three wood classes, the number of cycles of hand rubs was varied. In particular, for new wood, on each board, volunteers performed hand rubs with 2, 5, 10, and 20 cycles. For the Lab Aged and Under Deck woods, on each board, volunteers performed hand rubs with 10 and 20 cycles. Table 5 summarizes the numerical results and Figures 4 - 6 display the effect of varying the number of cycles.

In the figures, the results of each volunteer are plotted separately. It is clear from the figures that the results for volunteers differ from one another. Since each volunteer was assigned a distinct board, the differences may be due to differences in the boards or to differences in the volunteers. However, for Volunteers 2 and 4, who performed rubs on all three classes of wood, the results for Volunteer 4 are consistently higher than those of Volunteer 2. This would suggest that there are differences in the volunteers.

Although differences exist between the results of the four volunteers, there exist trends that are apparent for all the volunteers. For new wood, a model was fit to estimate the effect of the number of cycles and the combined effect of the differences in volunteers and the differences in boards. The details of the model are described in Appendix 2. The estimated combined volunteer and board effect had a p-value of 0.041, indicating that combined effect is not zero. The estimated effect of the number of cycles was small (0.7%/cycle) and insignificant (p-value 0.577, 95%CI: -1.8 – 3.2 %/cycle). Therefore, for new wood, varying the number of cycles of hand rubs from 2 to 20 does not statistically significantly affect the level of arsenic. However, from inspection of the numeric and graphical summaries in Table 5 and Figure 4, there appears to be some change from 2 to 5 cycles. For the Lab Aged and the Under Deck wood, it is unclear if the number of cycles has an effect, because of the limited amount of data.

It is particularly noteworthy that for new wood, the values for 5, 10, and 20 cycles are near the value of 28.3 µg obtained for the dry hand rub in the study that examined the upper limits of the level of arsenic transferred (see Table 2).

Table 5: Mean Arsenic per Sample from Hand Rubs in Phase II Study by Numbers of Cycles.

| **Wood Class** | **Mean (µg)** | | | | **Number of Samples** |
|---|---|---|---|---|---|
| | **Cycles** | | | | |
| | **2** | **5** | **10** | **20** | |
| New (N) | 17.5 | 27.6 | 32.3 | 24.7 | 4 |
| Lab Aged (A) | - | - | 14.7 | 17.5 | 2 |
| Under Deck (U) | - | - | 12.8 | 27.3 | 2 |

Figure 4: Arsenic per Sample for Hand Rubs by Number of Cycles: New Wood.

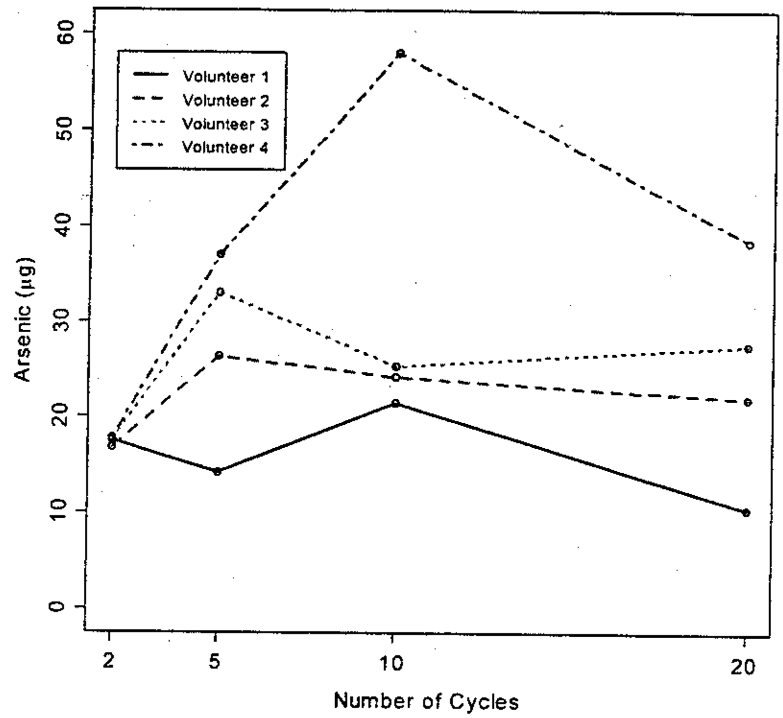



Figure 5: Arsenic per Sample for Hand Rubs by Number of Cycles: Lab Aged Wood.

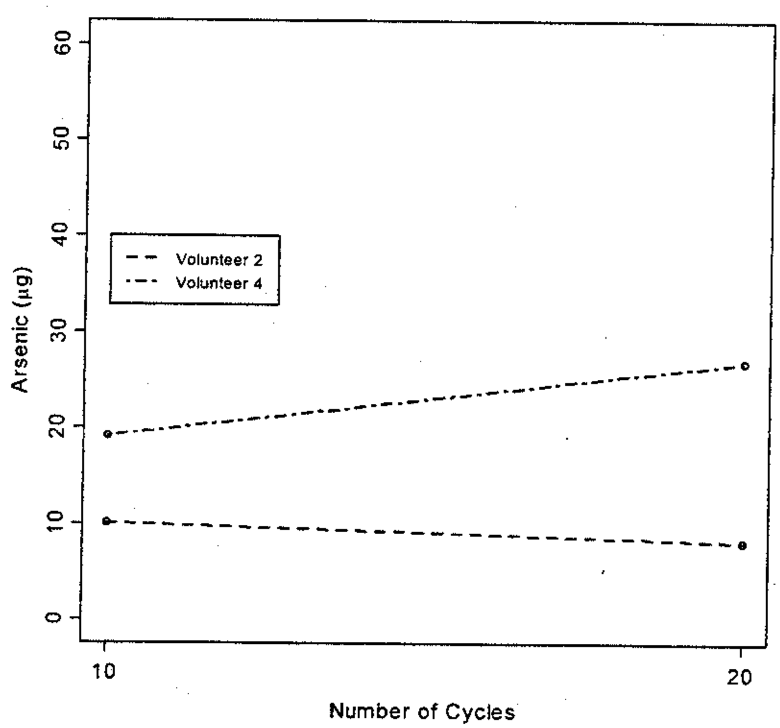
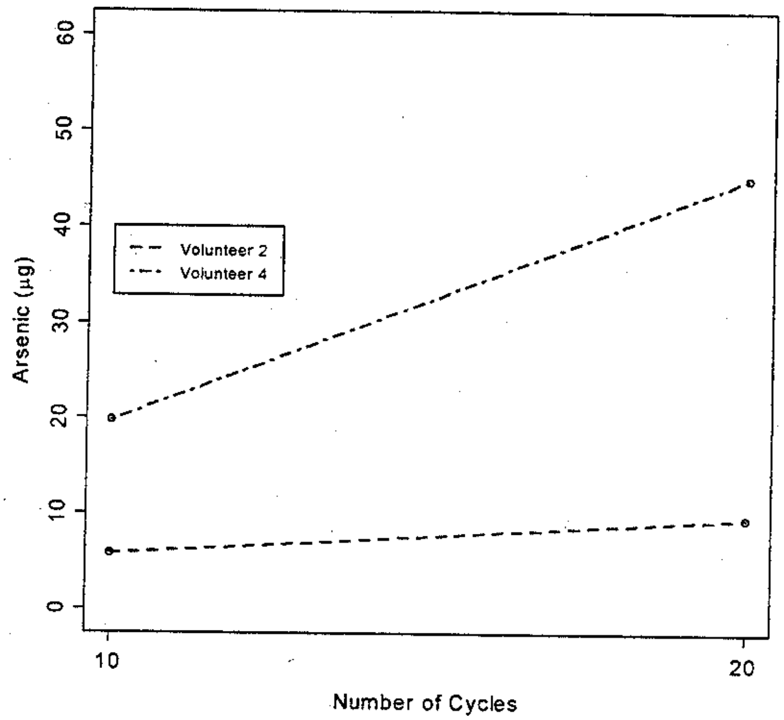


Figure 6: Arsenic per Sample for Hand Rubs by Number of Cycles: Under Deck Wood




**Effect of Repeated Rubbing**

For three classes of wood, the effect of rerubbing the same sample of wood was examined. For new wood, the 5-cycle hand rub was repeated on a segment of each board for a total of 4 times. For the Lab Aged and Under Deck Wood, the 10-cycle hand rub was repeated on a segment of each board for a total of 3 times. Table 6 summarizes the numerical results and Figures 7 - 9 display the effect of the repeated hand rubs.

For the new wood, there is a clear decrease in the arsenic transferred as a function of repetition. For new wood, a model was fit to estimate the effect of rerubbing. The details of the model are described in Appendix 2. The estimated effect was a 20% (p-value 0.001, 95% CI: 12 – 27%) reduction in the level of arsenic for each repeat. For the Lab Aged there appears to be slight effect of repetition and for the Under Deck wood, it is unclear. Recall that neither the Lab Aged nor the Under Deck wood was ever in actual use.

Table 6: Mean Arsenic per Sample in Phase II Study by Numbers of Repeats.

| **Wood Class** | **Mean (µg)** | | | | **Number of Samples** |
|---|---|---|---|---|---|
| | **Repeat** | | | | |
| | **1** | **2** | **3** | **4** | |
| New (N) | 27.6 | 22.1 | 17.6 | 13.5 | 4 |
| Lab Aged (A) | 14.7 | 11.9 | 4.9 | - | 2 |
| Under Deck (U) | 12.8 | 22.8 | 9.9 | - | 2 |

Figure 7: Arsenic per Sample for Hand Rubs by Repetition Number: New Wood.

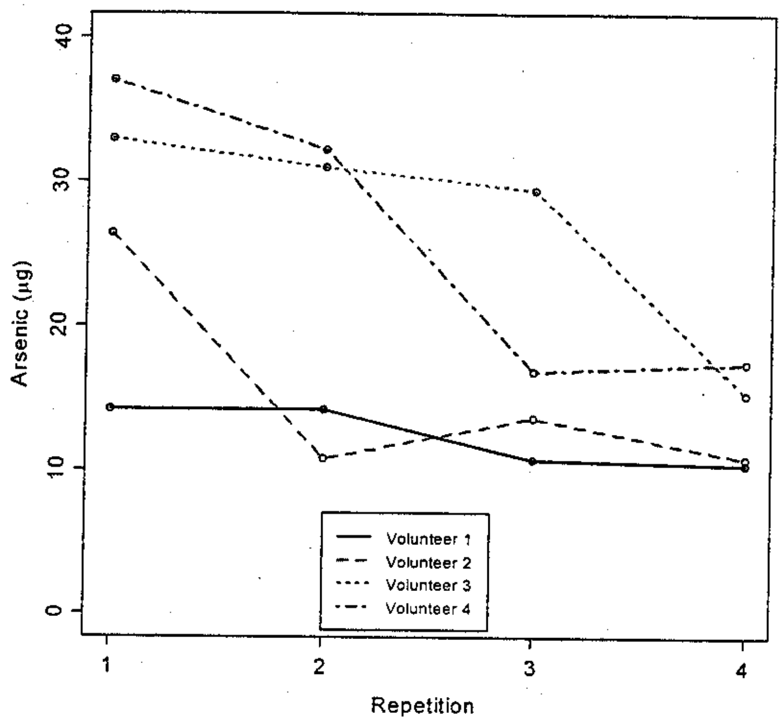



Figure 8: Arsenic per Sample by Repetition Number: Lab Aged Wood.

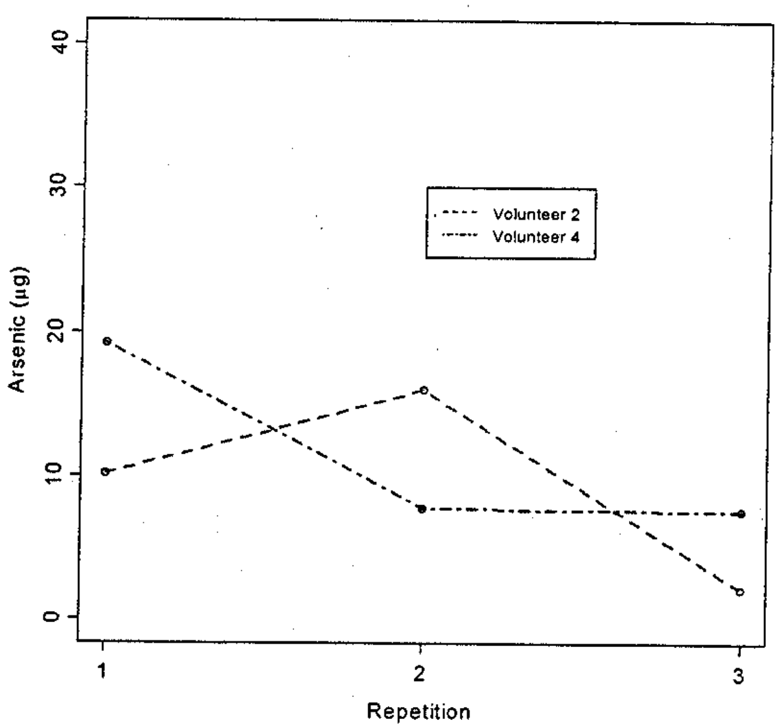
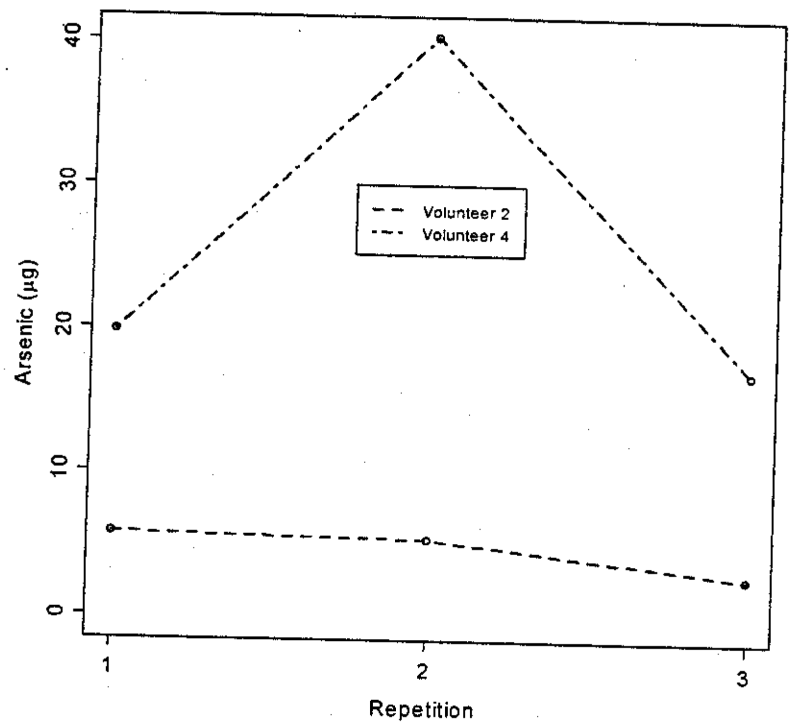


Figure 9: Arsenic per Sample by Repetition Number: Under Deck Wood.




**Surrogates**

The Phase II Study experimented with several surrogates to the human hand test method. The experimentation was exploratory and test of principles in nature. Subsequent studies would provide more definitive results and sensitivity analysis. A good surrogate should have certain mechanic and chemical features that make it feasible for surrogate use. For example, it should not tear when rubbed on wood and should be amenable to chemical preparation and analysis. Notably, the results using the surrogate should relate to those using the human hand method.

On each board, a 10-cycle hand rub and some 10-cycle surrogate rubs were performed. The surrogates included the saline wetted polyester fabric, the dry polyester fabric, and a high-density polyethylene (HDPE) material. Additionally, limited testing was performed using a laboratory tissue paper surrogate. The 10-cycle hand rub values were used for the human hand method values to explore the relationship between the surrogate and human hand results.

The laboratory tissue paper surrogate was used only in Stage 1 of the experiment, because the material tore very easily. For the other three surrogates, regressions of the human hand values on the surrogate values were performed. The regressions were used to estimate conversion factors that relate the surrogate method values to the human hand method values. These conversion factors apply only to the specific hand rub method and the specific surrogate rub method used in the experiment. The specifics include the area rubbed, the number of cycles and the weight applied to the hand and surrogates. Note that the areas rubbed for the hand and surrogate methods differed.[9] Appendix 1 describes the regression model, the correlation measure, and associated tests and confidence intervals.

The numeric summaries, particularly the regression summaries, should be considered preliminary. It was noted above that volunteers produced results that differ in magnitude, although similar in trends. Because the Phase II Study employed a small number of volunteers and limited breadth of wood samples, the numeric summaries may not extrapolate well beyond the four volunteers.

Table 7 provides the statistical summaries for the surrogates. Included in the summaries are the number of samples whose results are used in the regression estimation, the correlation measure of the association between the hand and the surrogate values, the conversion factor relating the surrogate values to the hand values with a 95% confidence interval, the p-value of the test that the conversion factor is zero, and the residual standard deviation from the regression estimation. The p-value on the conversion factor applies to the correlation coefficient as well. The residual standard deviation represents the standard deviation of the portion of the hand values that are not predicted by the surrogate values. A small residual standard deviation indicates that the surrogate has good predictive power. Figures 10 – 12 plot the human hand values versus the surrogate values and include the lines from the regression estimates.

All of the three surrogates have conversion factors that are statistically different from zero. Therefore, all the surrogates correlate with the hand values. Two of the surrogates, the wet and dry polyester, have conversion factors that are statistically less than 1, indicating that they pick up greater amounts of As than the hands.

Table 7: Preliminary Statistical Summary for Surrogates from Phase II Study.

| **Surrogate** | **Number of Samples** | **Correlation** | **Conversion Factor: Hand/Surrogate** (95% CI) | **P-Value** | **Residual Standard Deviation** (μg) |
|---|---|---|---|---|---|
| Wet Polyester | 16 | 0.83 | 0.23 (0.12 – 0.35) | <0.001 | 22.4 |
| Dry Polyester | 12 | 0.86 | 0.54 (0.23 – 0.84) | 0.004 | 21.8 |
| HDPE | 14 | 0.84 | 1.40 (0.59 – 2.20) | 0.003 | 21.5 |

9 The area rubbed for the hand rubs was 700 $cm^2$ and the area rubbed for the surrogate rubs was 400 $cm^2$.

Figure 10: Arsenic per Sample Human Hand Versus Wet Polyester Surrogate Values.

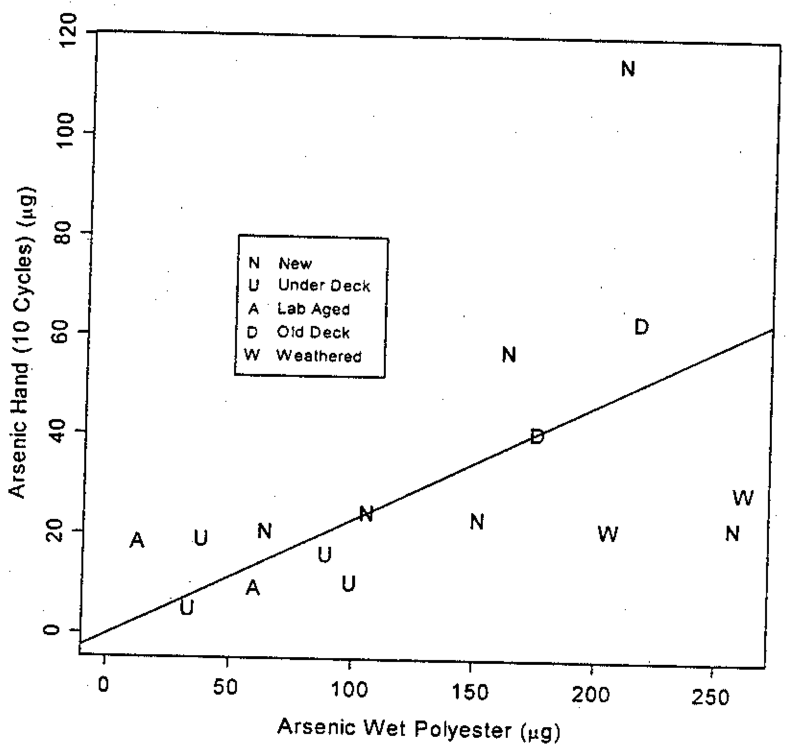



Figure 11: Arsenic per Sample Human Hand Versus Dry Polyester Surrogate Values.

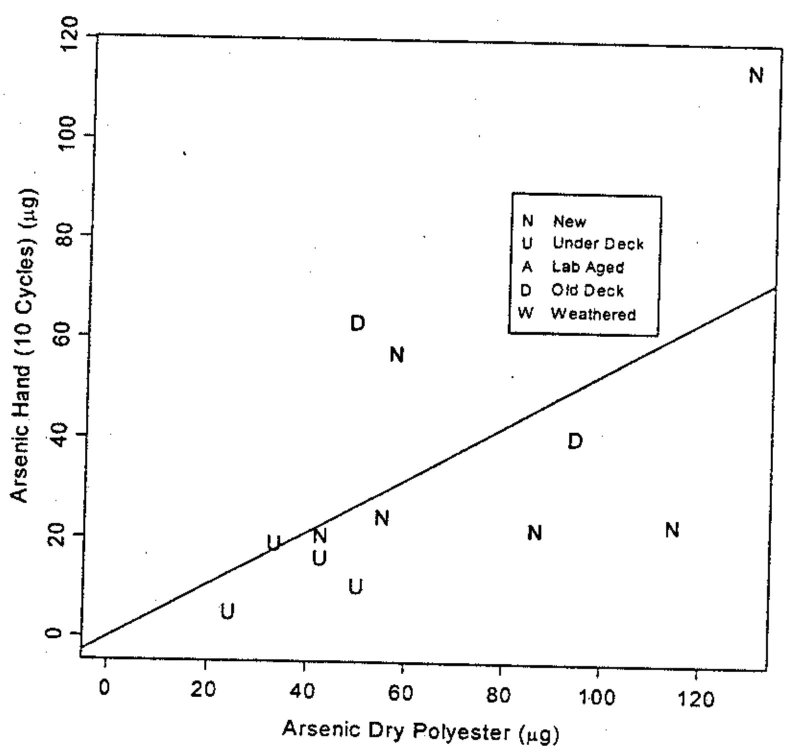
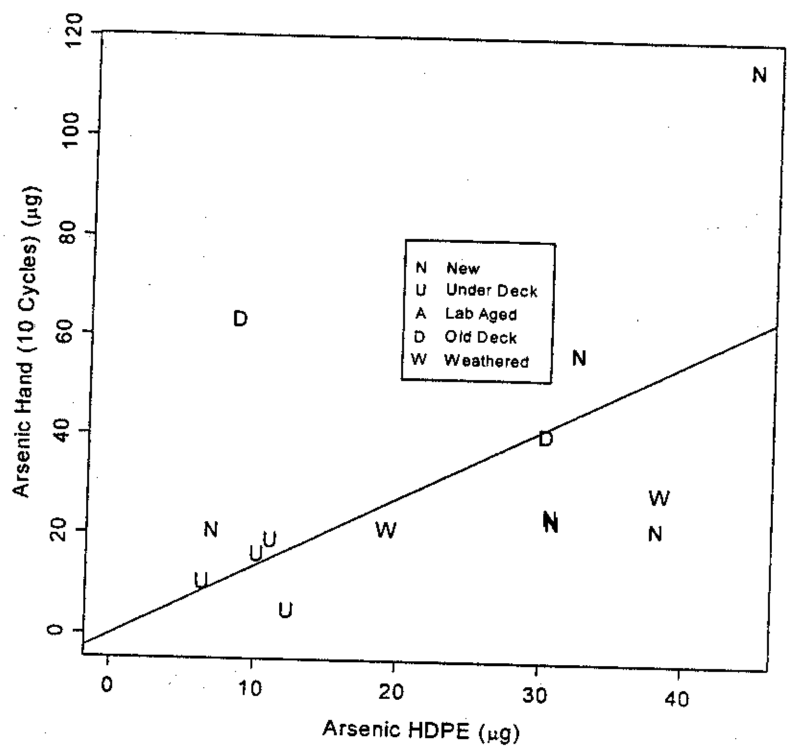


Figure 12: Arsenic per Sample Human Hand Versus HDPE Surrogate Values.




**Preliminary Values**

Based on the available human hand results from the Phase II Study, values of arsenic amounts transferred to the hand are provided in Table 8. These results are preliminary, because of the small number of volunteers used. Additionally, these wood classes may not represent the range of woods in actual use. However, the results do provide rigorous human hand measurements on actual woods. The values for different wood classes include data from different subsets of the volunteers. Therefore, it is difficult to compare wood classes. For reference, the results of the wet polyester surrogate are provided.

Table 8: Preliminary 10-Cycle Hand Values from the Phase II Study.

| Wood Class | Number of Samples | Hand Mean (Range) (µg) | Wet Polyester Mean (Range) (µg) | Comments |
|---|---|---|---|---|
| New | 6 | 44.6 (21.6 - 115.6) | 157.8 (63.6 - 256.5) | Results from volunteers 1 - 4, volunteers 1 and 3 provided two results each |
| Lab Aged | 2 | 14.7 (10.2 - 19.2) | 35.9 (12.0 - 59.8) | Results from volunteers 2 and 4 |
| Under Deck | 4 | 13.5 (5.8 - 19.8) | 64.4 (32.6 - 98.6) | Results from volunteers 1 - 4 |
| Old Deck | 2 | 52.9 (41.6 - 64.2) | 196.5 (175.5 - 217.5) | Results from volunteers 1 and 3 |
| Weathered | 2 | 26.1 (22.2 - 30.0) | 233.3 (205.5 - 261.0) | Results from volunteers 1 and 3 |

## Conclusions

The laboratory experiments produced several important results.

- Boards from a batch of new wood were found to be statistically different from one another based on a surrogate test method. Moreover, surrogate results from locations near one another on a board were positively correlated.
- An experimental design approach was established to compare methods of measuring CCA transfer. The approach uses blocking to reduce the effect of variation among boards.
- Protocols were developed for both the human hand and surrogate methods. This included the refinement of the procedure to extract CCA from the hand for analysis and the fabrication of a sampling template for the surrogate method.
- For new wood, it appears that the hand reaches a plateau in its arsenic level, possibly by 5 cycles. Also, for new wood, there appears to be a reduction in the amount of CCA transferred when a sample is rubbed repeatedly.
- Over a limited sample of woods examined, the measured level of arsenic transferred to the hand ranged from 13.5 µg to 52.9 µg.
- Surrogate materials were examined and several were found to correlate with the human hand method. Regressions were used to estimate conversion factors that relate the two methods mathematically.

## Appendix 1: Measures of Association Between Sampling Methods.

There were several experiments in which the results from hand rubs were compared to those of surrogate rubs. In the typical experiment, multiple human subjects were used with each subject rubbing multiple boards. This is known in the field of statistics as a *repeated measures problem*, which requires special analysis. Additionally, based on sensible considerations, the relationship between the hand and surrogate results should be constrained to pass through the origin.

Two primary statistical summaries were used in the analysis of these experiments. The first summary was a correlation measure that summarized the association between the hand and surrogate results. The second summary was a conversion factor that mathematically relates the surrogate values to the human hand values.

The basic correlation measure used was related to the Pearson product moment measure. However, the measure is modified to constrain the relationship to pass through the origin. The correlation measure between $X$ and $Y$ used is given in Equation (A1). Like the ordinary correlation measure, the one in Equation (A1) is bounded between -1 and 1. It is equal to –1 or 1 if $Y=bX$.

$$\frac{\sum_{i=1}^{n} X_i Y_i}{\sqrt{\sum_{i=1}^{n} X_i^2 \sum_{i=1}^{n} Y_i^2}} \qquad \text{(A1)}$$

The conversion factors between the hand and the surrogate results were estimated using a linear mixed model.[10] The model is given in Equation (A2).

Hand Result = (Surrogate Result)(Conversion Factor + Volunteer Effect) + Measurement Error (A2)

The model relates the hand results to a linear function of the surrogate results. The Conversion Factor is the slope parameter of the linear model. The Volunteer Effect is a parameter for each volunteer that represents the deviation from the common slope for the volunteer. The Volunteer Effect is modeled as a random effect, which implies it is fixed for each volunteer but random over volunteers. The inclusion of the Volunteer Effect accounts for the repeated measures problem. The reported conversion factors in Table 7 estimates the mean conversion factor over the population of volunteers.

The model does not include an intercept, ensuring the relationship goes through the origin. For models without an intercept, the correlation measure given in Equation (A1) parallels the ordinary correlation for models with an intercept.

The model was fit using Restricted Maximum Likelihood (REML) using the *lme* routine in the statistical package R.[11] Estimates, hypothesis tests, and confidence intervals are based on normal

[10] See McCulloch and Searle (2001) for a review of mixed models.

theory for mixed models. The hypothesis test that the conversion factor is zero is equivalent to the test that the correlation measure given in Equation (A1) is zero. Thus, the p-value for the conversion factor applies to the correlation factor as well.

## Appendix 2: Modeling of Arsenic Levels

In the analyses of the Phase II Study, the effect of varying the numbers of cycles and the effect of repeating the sampling were analyzed. For these experiments, each volunteer rubbed a single board. Therefore, differences among the volunteers and differences between the boards are confounded. The analysis followed a common approach of using mixed models similar to those described in Appendix 1. The models given in Equations (A3) and (A4) were used to estimate these effects. The Number of Cycles and Repetition Number are continuous covariates. The associated slope coefficients, the Cycle Coefficient and Repetition Coefficient, formed the basis of the analysis of the cycle and repetition effects. The Volunteer/Board Effect, the combined effect of the volunteer and board, was treated as a random effect. The logarithm transform of the arsenic level improved the satisfaction of the modeling assumptions, in particular the linearity of the model and the constant variance of the residuals.

log(Arsenic Level) =
Intercept + (Number of Cycles)(Cycle Coefficient)+ Volunteer/Board Effect + Measurement Error (A3)

log(Arsenic Level) =
Intercept + (Repetition Number)(Repetition Coefficient)+ Volunteer/Board Effect + Measurement Error (A4)

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[11] See R Project (2002) for a description of the R package and routines.

## References

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**Memorandum**

Date: January 13, 2003

TO : Patricia Bittner, M.S.
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Division of Hazard Analysis

SUBJECT : Statistical Analysis of CCA-Treated Wood Study Phase III

# Introduction

The staff of the U.S. Consumer Product Safety Commission (CPSC) is currently addressing a petition to ban the use of chromated copper arsenate (CCA) treated wood in playground equipment. Studies have shown that chronic exposure to arsenic in drinking water may result in an increased risk of cancer.[1] To evaluate this risk to children from exposure to CCA wood, estimates of the level of arsenic (As) transferred to a human hand from contact with CCA-treated wood are needed.

CPSC staff has conducted a series of laboratory and field studies to develop test methods for measuring the level of arsenic transferred, to produce estimates of the level, and to explore factors that may affect the level. The studies have consisted of four phases. The first two phases consisted of screening experiments and test method development.[2] The results from the first two phases were to be used in the design of the subsequent studies. The purpose of the Phase III study was to obtain reliable hand measurements from a variety of in-use CCA-wood structures and derive a mathematical relationship between test methods based on human hands and those based on surrogates. The study made use of residential decks. The use of decks offered large regular surfaces to obtain controlled, paired measurements with the hand and surrogate test methods. A subsequent study, Phase IV, would make use of the relationship between the hand

[1] For a review see Arsenic in Drinking Water, National Research Council (2001).
[2] The studies are described in Cobb (2003) and the statistical analysis is given in Levenson (2003).

and surrogate test methods, established in Phase III, to obtain measurements on in-use play structures using surrogate test methods. This memo reviews the Phase III study and statistically analyzes the results.

The specific objectives of the Phase III study were to:

(1) Quantify the level of arsenic transferred over a range of in-use wood structures using a human hand test method.
(2) Examine differences in the level of arsenic transferred from varying hand contact with the wood structures.
(3) Establish the relationships between surrogate test methods and the human hand test method.

The remainder of this memo is organized in three parts. The first part presents the design of the Phase III study. The second part analyzes the results of the study. The analysis is organized by the objectives of the study. The third part reviews the conclusions of the analyses. An appendix provides the data from the study. The details of the study protocol and the analytic methods are available in laboratory reports.[3]

## Study Design

The Phase III study consisted of visiting 8 decks in the Washington, D.C. metropolitan area. An attempt was made to represent a variety of in-use structures in terms of age, usage, and finish treatment. The large uninterrupted wood surfaces available on decks permitted the design of an extensive experiment designed to address the overall objectives of the Phase III study. Table 1 summarizes the 8 wood structures.

Two test methods were employed to measure the level of arsenic transferred to a human hand. Both methods were examined in Phases I and II of the CCA studies. The primary method makes use of human subjects. Briefly, a subject rubs a hand over a predefined area of a sample of wood for a predefined number of times. The hand is then repeatedly rinsed and wiped with acetic acid, and the rinses and wipes are chemically analyzed for the amount of arsenic. The second method uses surrogate materials, such as a polyester fabric. Using a sampling template, a weight is applied to the surrogate and the surrogate is rubbed over a predefined area of a sample of wood for a predefined number of times. The surrogate material is then chemically analyzed for the amount of arsenic. Protocols for both methods were developed in Phases I and II of the CPSC CCA studies.

[3] See Cobb and Davis (2003).

Table 1: Summary Wood Structures in Phase III Study.

| ID | Age | Finish and Cleaning | Description |
|---|---|---|---|
| 1 | Approx. 15 years. | No finish. Cleaned 1 or 2 times w/chlorine bleach and water. | Deck near ground. Southern exposure. Large shade tree nearby. Spots with algae or moss. Slightly warped boards. Well weathered. Even wear. Brown appearance. |
| 2 | Approx. 5 months. | No finish. | Second level deck. Southern exposure. No Trees. Yellow and green tint. |
| 3 | Approx. 14 years. | No finish. | Deck near ground. Western exposure. No shade trees. Well weathered. Brown appearance. |
| 4 | 2 days on deck. Several months in stack outside. | No Finish. Pressure treated with water repellant. | Deck raised off ground. Northern exposure. Shade from house. No wear or weathering. Varying green tint. |
| 5 | Approx. 12 - 14 years. | Finish applied several times. Last finish was penetrating oil finish, applied with brush 2 or 3 years ago. | Deck raised off ground. Northern exposure. Shade from house. No wear or weathering. Slightly evenly worn. Red color from stain. |
| 6 | Approx. 15 - 18 years. | Water seal (initial sealer). Stain (6 – 7 years ago), Sealer (2 years ago). Cleaned with sodium hypochlorite (2 years ago). | Deck raised off ground. Northern exposure. Shade from house and trees. Cracks and splinters. |
| 7 | Approx .5 years. | Worn or no finish. | Deck raised off ground. Southeast exposure. Some shade from trees. Gray/brown tint. Smooth surface. |
| 8 | Approx. 8 months. | No Finish. Pressure treated with water repellant. | Deck raised off ground. Southern exposure. No trees. No wear. Gray/brown tint. Weathered surface. |

Eight volunteers were used in the experiment. The 8 volunteers were assigned to 4 pairs. Each pair visited 2 decks. At each deck, the 2 volunteers each sampled 2 boards. Each board was divided into 5 equally sized segments. Two of the segments were used for hand rubs and 3 of the segments were used for surrogate rubs. The two hand rubs consisted of 10- and 20-cycles of back and forth rubbing of the segment with a dry hand. The three surrogates consisted of a saline-wetted polyester fabric, a dry polyester fabric, and a high-density polyethylene (HDPE) material. The surrogate rubbings consisted of 10 cycles. Figure 1 displays an example of the arrangement of the 5 sampling methods on a board. In the actual experiment, the assignment of the 5 methods to the 5 segments was randomized for each board. Additionally, the run order of the 2 hand rubs and the run order of the 3 surrogate procedures were each randomized. Table 2 summarizes the experimental factors.

Figure 1: Example of Arrangement Methods on a Board in Phase III Study.

| | | | | |
|---|---|---|---|---|
| 10-Cycle Hand Rub | 20-Cycle Hand Rub | Wet Polyester Surrogate | Dry Polyester Surrogate | HDPE Surrogate |

Table 2: Summary of Experimental Factors in Phase III Study.

| Structures | Number Visited | Volunteers per Structure | Boards per Structure | Sampling Methods on Each Board |
|---|---|---|---|---|
| Decks | 8 | 2 | 4 | 10- and 20-cycle hand rubs, wet polyester, dry polyester, and HDPE surrogate rubs. |

## Statistical Analysis

The statistical analysis is organized by the three research objectives stated in the introduction. Each objective is restated, the findings are summarized, and the supporting statistical analysis is provided.

**Objective (1): Quantify the level of arsenic transferred over a range of in-use wood structures using a human hand test method.**

Findings

The arsenic levels based on the 10-cycle hand method for the 8 decks ranged from 1.0 μg to 20.9 μg with a mean value of 7.7 μg and a median value of 4.8 μg. The values are derived from a model that accounts for differences in volunteers and the skewed distribution of the measurements. The model uses all 32 of the 10-cycle hand method results. The arsenic levels transferred for the 8 decks were statistically different from one another (p-value: $<0.001$)

Table 3 provides the estimates for the 8 deck structures based on the 10-cycle hand method. Included with the deck estimates are the 95% confidence intervals of the estimates and the p-values for the one-sided test that the arsenic levels are greater than 1 μg. For comparison purposes, the table also includes the simple arithmetic mean value of the measurements for each structure. For 7 of the 8 deck structures, the arsenic levels are statistically greater than 1 μg using a one-sided test at a significance level of 0.05.

There was some variation among the 4 boards sampled within each deck (p-value 0.094).

Table 3: Arsenic Estimates for the Deck Structures in Phase III Study.

| Structure | 10-Cycle Hand Method Arsenic Level (µg) | | | | P-Value Arsenic Level > 1 µg |
|---|---|---|---|---|---|
| | Mean Value | Estimate | 95% Confidence Interval | | |
| | | | Lower Endpoint | Upper Endpoint | |
| 1 | 2.2 | 2.0 | 1.0 | 4.0 | 0.019 |
| 2 | 7.6 | 6.7 | 3.4 | 13.1 | <0.001 |
| 3 | 3.1 | 3.0 | 1.5 | 5.8 | 0.002 |
| 4 | 24.7 | 20.9 | 10.7 | 40.8 | <0.001 |
| 5 | 3.3 | 2.4 | 1.2 | 4.7 | 0.007 |
| 6 | 1.1 | 1.0 | 0.5 | 2.0 | 0.456 |
| 7 | 12.0 | 11.8 | 6.0 | 23.0 | <0.001 |
| 8 | 14.6 | 13.9 | 7.1 | 27.1 | <0.001 |

Statistical Analysis

Figure 2 displays the results of the 10-cycle hand method for the 4 boards on each of the 8 deck structures. The logarithm scale is used to compare structures in which the arsenic levels vary significantly. From the figure it is apparent that structures vary from one another in arsenic levels. Also, it is apparent that volunteers differ from one another in arsenic levels. For example, for structures 3 and 8, volunteer 8 always produced higher values than volunteer 3. Similar patterns exist for other volunteers. Because volunteers differ from one another, it is important that the effect of the volunteers be accounted for in the estimation of the arsenic levels for the decks.

The arsenic levels for the decks were estimated using a linear mixed model.[4] The model is given in Equation (1). Each arsenic result from the 10-cycle hand method for a particular structure and volunteer is modeled with three terms. The terms are the Structure Mean, the Volunteer Effect, and the Measurement Error. The Structure Mean is the population mean arsenic level of the structure. It conceptually represents the mean of a large number of measurements by a large number of volunteers. The Volunteer Effect is the deviation from the Structure Mean arising from differences associated with a volunteer. For example, a particular volunteer may have more hand contact with the wood than average resulting in the higher arsenic levels. The effect is modeled as a random effect, which means that each volunteer has a fixed effect on the arsenic level, but the effects are random across the volunteers. The Measurement Error includes the potential effects of the variation of the boards within each deck and the measurement error associated with the hand test method.

$$\log(\text{Arsenic Level}) = \text{Structure Mean} + \text{Volunteer Effect} + \text{Measurement Error} \quad (1)$$

The model was fit using Restricted Maximum Likelihood (REML) using the *lme* routine in the statistical package R.[5] Estimates, hypothesis tests, and confidence intervals are based on normal

[4] See McCulloch and Searle (2001) for a review of mixed models.
[5] See R Project (2002) for a description of the R package and routines.

theory for mixed models. Applying the inverse logarithm functions gives the results in terms of the original scale.

The logarithm transform of the arsenic level was used to improve the satisfaction of the modeling assumptions, in particular the linearity of the model and the normality and constant variance of the Measurement Error. Additionally, the use of the transform implied that the Volunteer Effect had a multiplicative effect on the untransformed arsenic level. This means that a given volunteer's results on the average deviates from any Structure Mean by a constant multiple.

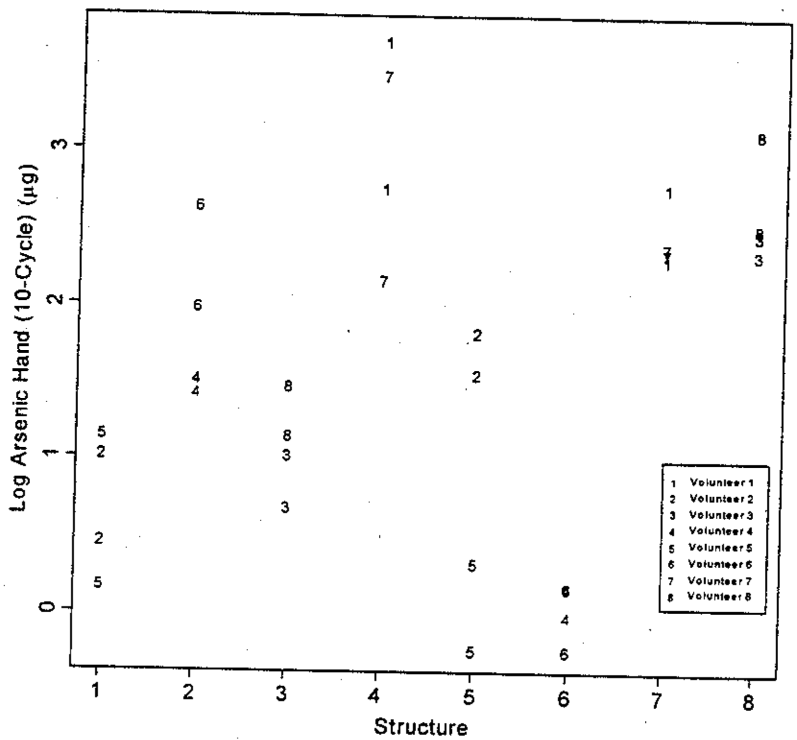
Differences in hand surface areas among the volunteers might produce such a multiplicative effect. The Volunteer Effect in Equation (1) was marginally significant (p-value 0.073). When the arsenic levels are normalized by the hand size of the volunteer, the Volunteer Effect diminishes (p-value 0.135). It appears that although hand surface area may account for some of the differences in the results of the volunteers, it does not appear to account for all of the differences. Other factors such as variations in contact pressure and hand surfaces may account for some of the differences. Note that the detection of a statistically significant volunteer effect was limited by the narrow range of hand surface areas among the volunteers.

The mean value for each structure is the arithmetic mean of the 4 measurements from the structure. The differences between the mean values and the model estimates arise because the mean values are calculated on the original scale and the model estimates are calculated on the logarithm scale and transformed to the original scale. The use of the logarithm transformation reduces the effect of the skewed distribution of the measurements.

A linear mixed model, given in Equation (2), was used to test for variation among boards within deck structures. The model is similar to that given in Equation (1), but includes an additional term, the Board Effect. The Board Effect represents the deviation of the arsenic level of a board from the Structure Mean. For the analysis, both the 10- and 20-cycle hand method results from each board were used and were treated as repetitions. The implication of this approach is that the measurement error variation was potentially overestimated, resulting in a conservative test of the board effect.

$$\text{log(Arsenic Level)} = \text{Structure Mean} + \text{Board Effect} + \text{Volunteer Effect} + \text{Measurement Error} \qquad (2)$$

Figure 2: Arsenic per Sample 10-Cycle Hand Rub Method by Structure.



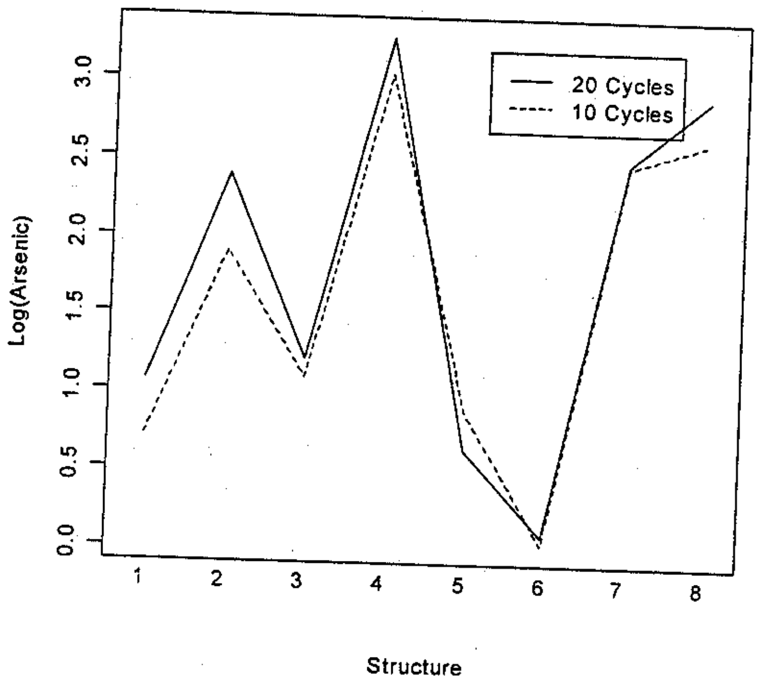

log(Arsenic Level) = Age Class Level + Volunteer Effect + Measurement Error (3)

**Objective (2): Examine differences in the level of arsenic transferred from varying hand contact with the wood structures.**

<u>Findings</u>

The difference between the levels of arsenic transferred between the 10- and 20-cycle hand rubs provides information on the effect of varying hand contact on the amount of arsenic transferred. Figure 3 displays the means of the logarithm of the 10- and 20-cycle hand rub values for the 8 deck structures. The 20-cycle hand rub was found to produce values 18% greater than the 10-cycle hand rub. This percentage was not statistically different from zero (p-value: 0.129, 95% CI: -5% – 45%). The statistical power to detect a 10% difference in the levels between the 10- and 20-cycle hand rubs was 34%.

Figure 3: Mean Logarithm Arsenic per Sample for 10- and 20-Cycle Hand Rubs.




Statistical Analysis

For each board the difference in the logarithm of the 10- and 20-cycle hand rub measurements was calculated. Based on the assumption that the structure, volunteer, and board effects are additive on the logarithm scale, the differences for each board are independent across the volunteers and structures. The hypothesis test that the difference is 0 and the confidence interval on the difference were based on the one sample t-statistic of the differences. Applying the inverse logarithm functions gives the results in terms of the percentage difference between the 10- and 20-cycle hand-rub measurements. The power calculation was based on the non-central t-distribution using the observed standard deviation of the difference. A sample size of 100 boards would have been required to obtain 80% power.

**Objective (3): Examine the relationship between surrogate test methods and the human hand test method.**

Findings

Three materials were examined for use as surrogates to human subject hand rubs. They were a dry polyester fabric, a saline-wetted polyester fabric, and a high-density polyethylene (HDPE) material. On each board sampled for the deck structures, all three surrogates and the 10- and 20-cycle hand rubs were performed. The results from the surrogates and the 10-cycle hand rub were compared to evaluate the form and strength of the relationships between the surrogate and the hand rub values.

Regressions of the hand rub values on the surrogate values were performed. The regressions were used to estimate conversion factors that relate the surrogate method values to the human subject method values. These conversion factors apply only to the specific hand rub method and the specific surrogate rub method used in the experiment. The specifics include the area rubbed, the number of cycles and the weight applied to the hand and surrogates. Note that the areas rubbed for the hand and surrogate methods differed.[6]

Figures 4–6 display plots of the 10-cycle hand rub values versus the three sets of surrogate values. The solid lines in the figures represent the regression estimates of the linear fit of the hand values on the surrogate values. For the dry and wet polyester surrogates, the relationship appeared to be linear and to pass through the origin. However, for the HDPE surrogate, the relationship appeared non-linear. Among the three surrogates, the dry polyester surrogate was the most clearly related to the hand rubs.

For all three surrogates, the conversion factors were statistically different from zero indicating that there exist statistically significant relationships between the surrogate and hand rub values. For the wet and dry polyester surrogates, the conversion factors were statistically less than one indicating that these surrogates have higher values than the hand rubs.

Table 5 provides the statistical summaries for the surrogates. Included in the summaries are the number of boards available in the regression estimation, the correlation measure of the association between the hand and the surrogate values, the conversion factor relating the surrogate values to the hand values with a 95% confidence interval, the p-value of the test that the conversion factor is zero, and the residual standard deviation from the regression estimation. The p-value on the conversion factor applies to the correlation coefficient as well. The residual standard deviation represents the standard deviation of the portion of the hand values that are not predicted by the surrogate values. A small residual standard deviation would indicate that the surrogate has good predictive power.

In the Phase II study, conversion factors were calculated as well.[7] The conversion factors from the Phase II Study were numerically higher than those calculated based on the Phase III study. The differences are likely due to differences in the hand rub results. The Phase III employed more volunteers and a more rigorous protocol on the hand rubs. Additionally, Phase III consisted of a more diverse sample of wood than Phase II. Therefore, the conversion factors from the Phase III study are recommended.

[6] The area rubbed for the hand rubs was 700 $cm^2$ and the area rubbed for the surrogate rubs was 400 $cm^2$.
[7] See Levenson (2003).

Table 4: Statistical Summary for Surrogates.

| **Surrogate** | **Number of Boards** | **Correlation** | **Conversion Factor: Hand/Surrogate** (95% CI) | **P-Value** | **Residual Standard Deviation** (µg) |
|---|---|---|---|---|---|
| Dry Polyester | 32 | 0.91 | 0.20 (0.16 – 0.24) | <0.001 | 5.3 |
| Wet Polyester | 32 | 0.79 | 0.076 (0.031 – 0.12) | 0.002 | 6.4 |
| HDPE | 32 | 0.88 | 0.96 (0.47 – 1.5) | <0.001 | 5.1 |

Figure 4: Arsenic per Sample Hand Rub Versus Dry Polyester Surrogate Arsenic Values.

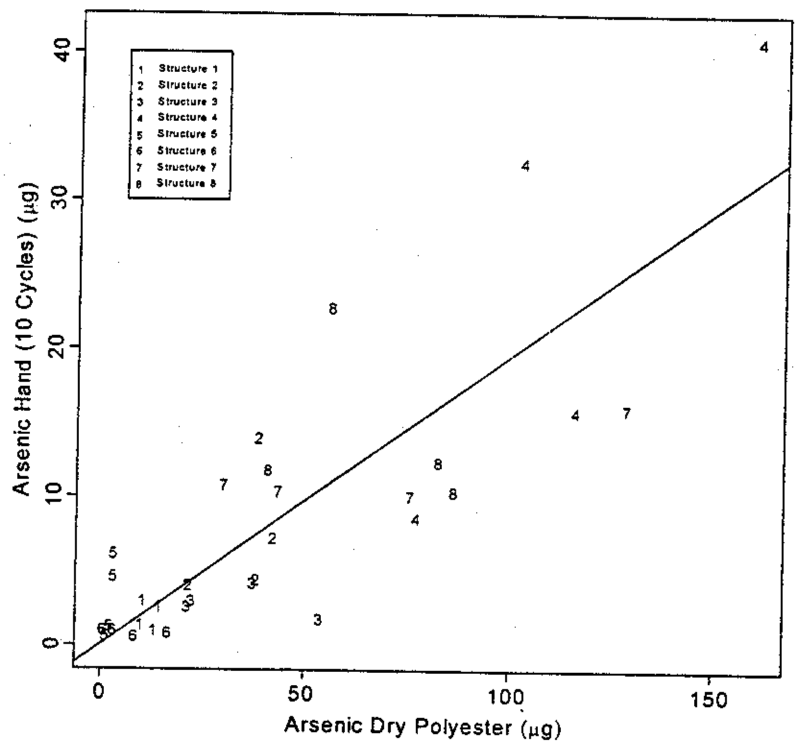


Figure 5: Arsenic per Sample Hand Rub Versus Wet Polyester Surrogate Values.

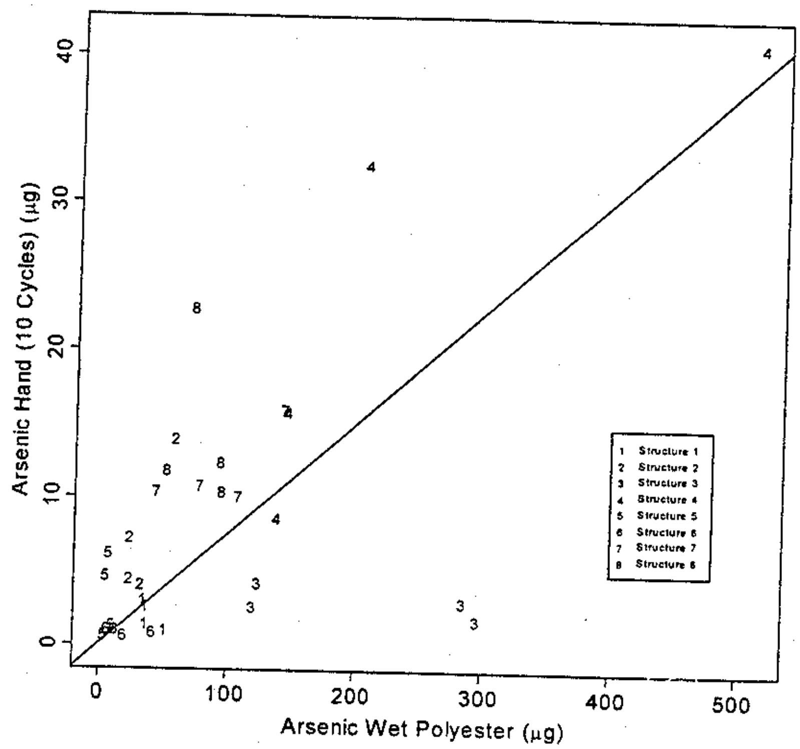
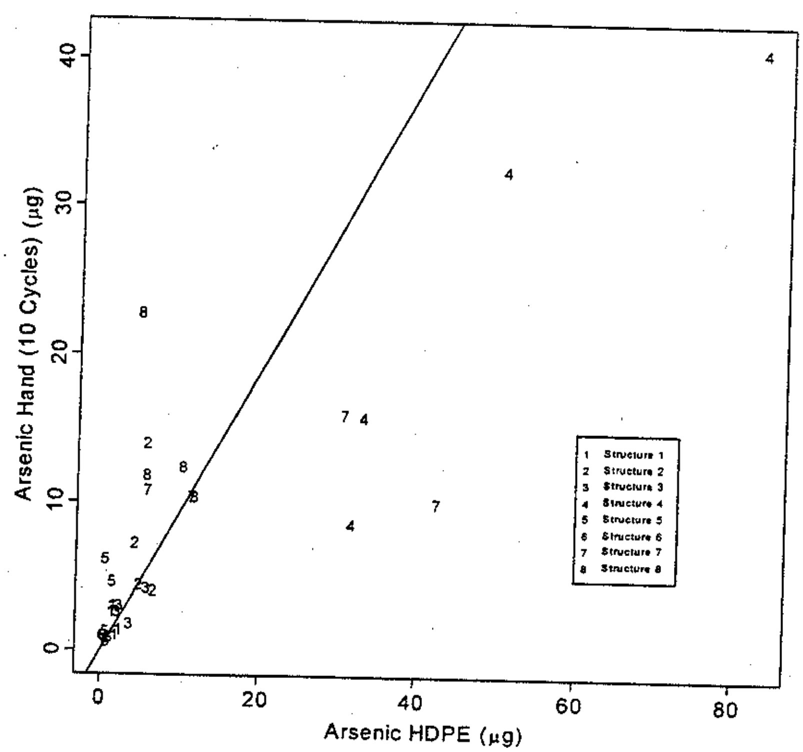



Figure 6: Arsenic per Sample Hand Rub Versus HDPE Surrogate Arsenic Values.



Statistical Analysis

The relationships between the hand values and the surrogate values were modeled on the original scale as a straight line without an intercept. A linear, mixed model was used that accounted for differences in the volunteers by including a random effect term associated with volunteers. The model is given in Equation (4). The reported conversion factors in Table 4 represent the mean conversion factor over the population of volunteers.

$$\text{Hand Result} = (\text{Surrogate Result})(\text{Conversion Factor} + \text{Volunteer Effect}) + \text{Measurement Error} \quad (4)$$

Because the model does not include an intercept, an alternative correlation measure was used. The correlation measure used is given Equation (5). For a straight-line model without an intercept, the correlation measure given in Equation (5) parallels the Pearson product moment correlation for models with an intercept.

$$\frac{\sum_{i=1}^{n} X_i Y_i}{\sqrt{\sum_{i=1}^{n} X_i^2 \sum_{i=1}^{n} Y_i^2}} \quad (5)$$

The hypothesis test that the conversion factor is zero is equivalent to the test that the correlation measure is zero. Thus, the p-value for the conversion factor applies to the correlation factor as well.

Several additional analyses were performed to examine the sensitivity of the results to the modeling assumptions. The additional analyses include (1) the use of a model with an intercept and the corresponding ordinary Pearson product moment correlation, (2) the removal of an influential measurement in the fitting of the models, and (3) the examination of the residuals from the fitted models.

The model with an intercept is given in Equation (6). The model differs from that given in Equation (4) by the inclusion of a fixed intercept and a random intercept term associated with volunteers. Table 5 gives the estimates of the intercepts, conversion factors, and the Pearson product moment correlation for the three surrogates.

$$\begin{aligned}\text{Hand Result} &= \text{Intercept} + \text{Volunteer Effect} + \\ &(\text{Surrogate Result})(\text{Conversion Factor} + \text{Volunteer Effect}) + \text{Measurement Error}\end{aligned} \quad (6)$$

For the dry polyester surrogate, the estimated intercept is small and not statistically different from 0 at the 0.05 level. The conversion factor is very close to that derived from the model without an intercept. The situation for the wet polyester surrogate is similar, except the conversion factor is more affected by the inclusion of the intercept. For the HDPE surrogate, the intercept is small, but statistically different from 0 at the 0.05 level. As mentioned above, from examination of Figure 6, it appears that a linear relationship is not suitable for the HDPE surrogate. Because of this the intercept for HDPE surrogate can be expected to be nonzero.

Table 5: Statistical Summary of Surrogates with Intercept Model.

| Surrogate | Correlation | Intercept (95% CI) (μg) | Conversion Factor: Hand/Surrogate (95% CI) | Residual Standard Deviation (μg) |
|---|---|---|---|---|
| Dry Polyester | 0.82 | 0.61 (-2.3 – 3.5) | 0.19 (0.13 – 0.24) | 5.3 |
| Wet Polyester | 0.63 | 4.7 (-0.22 – 9.6) | 0.063 (0.0044 – 0.12) | 4.6 |
| HDPE | 0.83 | 3.7 (1.4 – 6.0) | 0.42 (0.31 – 0.53) | 5.2 |

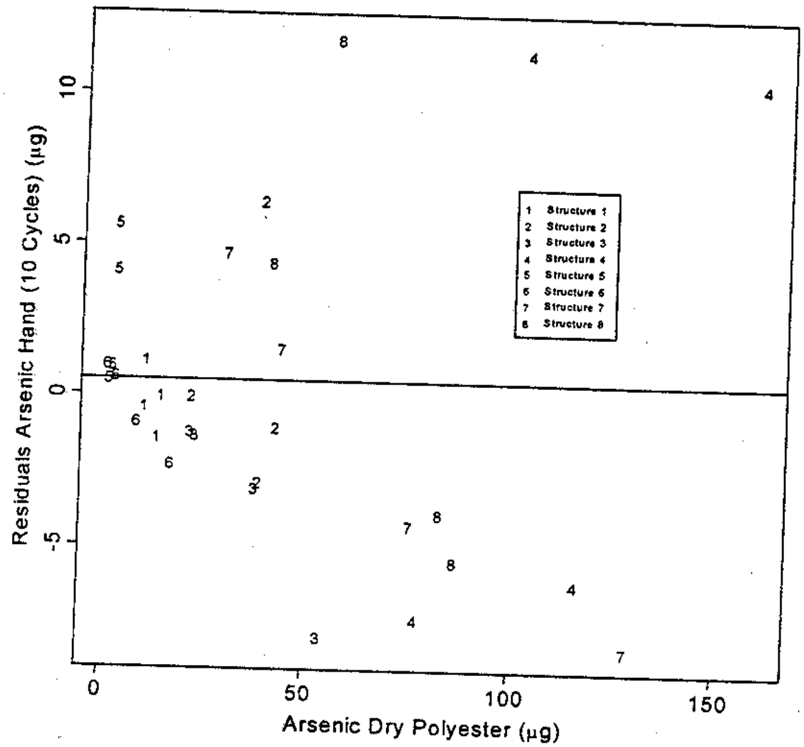
The estimates from the model without an intercept may be heavily influenced by the single large hand rub value of 41.0 μg, which is prominent in Figures 4–6. To examine this influence, the model was fit without this measurement. The results are given in Table 6. Comparing the results in Table 6 to those of Table 4, the large hand rub value does not appear to have much influence on the estimates.

Table 6: Statistical Summary for Surrogates without Influential Point.

| Surrogate | Number of Boards | Correlation | Conversion Factor: Hand/Surrogate (95% CI) | P-Value | Residual Standard Deviation (μg) |
|---|---|---|---|---|---|
| Dry Polyester | 31 | 0.88 | 0.18 (0.13 – 0.24) | <0.001 | 4.4 |
| Wet Polyester | 31 | 0.67 | 0.081 (0.032 – 0.13) | 0.002 | 6.4 |
| HDPE | 31 | 0.81 | 0.96 (0.45 – 1.5) | <0.001 | 5.1 |

In all the analyses, other than the analysis of the surrogates, the logarithm transform was used on the measurements. For the surrogate analysis, the measurements were analyzed on the original scales. This produced a superior fit to that of using the logarithm transformation. However, the residuals did display some non-constant variance. Figure 7 displays the residuals for the dry polyester surrogate. It appears that the residuals have low variance for low levels of arsenic. This could be corrected by using several techniques, for example weighting. However, the non-constant variance was judged to be acceptable.

Figure 7: Residuals of Dry Polyester Conversion Factor Model (No Intercept).




Comparing the conversion factors from the Phase II and Phase III studies showed that the ratios of the conversion factors for the dry and wet polyester surrogates were close, 2.3 for the Phase II study and 2.6 for the Phase III study. The ratios remove the effect of the hand rub results. Therefore, the differences in conversion factors between the two studies are likely attributed to differences in the hand rub results.

## Conclusion

The Phase III study examined a variety of CCA treated decks structures to address several objectives. It produces several significant findings.

- The levels of arsenic transferred to a human hand ranged from 1.0 μg to 20.9 μg among the 8 decks sampled with a mean value of 7.7 μg and a median value of 4.8 μg.
- There were significant differences in the arsenic levels among the 8 decks. There was some variation in the levels among boards sampled within each deck.
- Varying the hand contact by increasing the number of hand cycles from 10 to 20 increased the arsenic level by 18%. However, the increase was not statistically significant.
- Results using three surrogate materials correlated well with human hand results. Conversion factors that relate the surrogate method results to the hand method results were estimated. The best surrogate for human hand rubbing of those tested was the dry polyester fabric.

# Appendix: Phase III Data

Table A1: Phase III Study Data.

| | | | Hand (µg) | | Surrogate (µg) | | |
|---|---|---|---|---|---|---|---|
| Structure | Board | Volunteer | 10 Cycle | 20 Cycle | Wet Polyester | Dry Polyester | HDPE |
| 1 | 1 | 2 | 2.8 | 3.6 | 35.7 | 14.1 | 1.4 |
| 1 | 2 | 5 | 1.2 | 2.2 | 50.7 | 13.1 | 1.8 |
| 1 | 3 | 2 | 1.6 | 3.0 | 36.3 | 9.8 | 2.3 |
| 1 | 4 | 5 | 3.2 | 3.0 | 34.4 | 10.2 | 1.5 |
| 2 | 1 | 4 | 4.2 | 5.4 | 32.7 | 21.5 | 6.6 |
| 2 | 2 | 6 | 7.4 | 13.0 | 22.7 | 42.2 | 4.2 |
| 2 | 3 | 4 | 4.6 | 11.0 | 23.0 | 38.3 | 4.7 |
| 2 | 4 | 6 | 14.2 | 18.6 | 57.9 | 38.6 | 5.6 |
| 3 | 1 | 3 | 2.0 | 3.6 | 297.0 | 53.6 | 3.6 |
| 3 | 2 | 8 | 3.2 | 5.8 | 285.8 | 22.4 | 2.3 |
| 3 | 3 | 3 | 2.8 | 1.6 | 119.6 | 21.3 | 2.0 |
| 3 | 4 | 8 | 4.4 | 3.8 | 123.5 | 37.2 | 5.7 |
| 4 | 1 | 1 | 16.0 | 28.4 | 145.4 | 116.1 | 32.9 |
| 4 | 2 | 7 | 8.8 | 13.4 | 137.6 | 77.3 | 31.5 |
| 4 | 3 | 1 | 41.0 | 63.4 | 515.3 | 160.5 | 83.4 |
| 4 | 4 | 7 | 32.8 | 20.2 | 205.5 | 102.6 | 50.6 |
| 5 | 1 | 2 | 4.8 | 3.6 | 5.3 | 3.0 | 1.4 |
| 5 | 2 | 5 | 1.4 | 1.6 | 9.5 | 2.0 | 0.6 |
| 5 | 3 | 2 | 6.3 | 1.4 | 7.2 | 2.9 | 0.5 |
| 5 | 4 | 5 | 0.8 | 1.6 | 3.9 | 1.2 | 0.8 |
| 6 | 1 | 4 | 1.0 | 1.2 | 41.7 | 16.5 | 1.1 |
| 6 | 2 | 6 | 1.2 | 1.0 | 7.2 | 0.8 | 0.3 |
| 6 | 3 | 4 | 1.2 | 0.4 | 12.6 | 2.9 | 0.5 |
| 6 | 4 | 6 | 0.8 | 3.0 | 19.2 | 8.3 | 0.8 |
| 7 | 1 | 1 | 10.2 | 6.0 | 107.6 | 75.6 | 42.6 |
| 7 | 2 | 7 | 10.6 | 12.4 | 43.8 | 43.4 | 11.3 |
| 7 | 3 | 1 | 16.2 | 31.4 | 143.3 | 128.7 | 30.5 |
| 7 | 4 | 7 | 11.0 | 8.8 | 77.4 | 29.9 | 5.7 |
| 8 | 1 | 3 | 10.6 | 13.2 | 94.2 | 86.3 | 11.6 |
| 8 | 2 | 8 | 12.6 | 28.1 | 93.6 | 82.5 | 10.1 |
| 8 | 3 | 3 | 12.0 | 17.8 | 50.9 | 40.7 | 5.6 |
| 8 | 4 | 8 | 23.0 | 16.4 | 70.7 | 56.1 | 4.5 |

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**UNITED STATES**
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**Memorandum**

Date: January 24, 2003

TO : Patricia Bittner, M.S.
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THROUGH: Susan Ahmed, Ph.D. RR for JA
Associate Executive Director, Directorate for Epidemiology

Russell Roegner, Ph.D. RR
Director, Division of Hazard Analysis

FROM : Mark S. Levenson, Ph.D. ML
Division of Hazard Analysis

SUBJECT : Statistical Analysis of CCA-Treated Wood Study Phase IV

# Introduction

The staff of the U.S. Consumer Product Safety Commission (CPSC) is currently addressing a petition to ban the use of chromated copper arsenate (CCA) treated wood in playground equipment. Studies have shown that chronic exposure to arsenic in drinking water may result in an increased risk of cancer.[1] To evaluate this risk to children from exposure to CCA-treated wood, estimates of the level of arsenic (As) transferred to a human hand from contact with the wood are needed.

CPSC staff has conducted a series of laboratory and field studies to develop test methods for measuring the level of arsenic transferred, to produce estimates of the level, and to explore factors that may affect the level. The studies consisted of four phases. The first two phases consisted of screening experiments and test method development.[2] The results from the first two phases were used in the design of the subsequent studies. The purpose of the Phase III study was to obtain reliable hand measurements from a variety of in-use CCA-treated wood structures and derive a mathematical relationship between test methods based on human hands and those based on surrogates.[3] The Phase III study sampled residential decks. The use of decks offered large

[1] For a review see Arsenic in Drinking Water, National Research Council (2001).
[2] The studies are described in Cobb (2003) and the statistical analysis is given in Levenson (2003a).
[3] The study is described in Cobb and Davies (2003) and the statistical analysis is given in Levenson (2003b).

regular surfaces to obtain controlled, paired measurements with the hand and surrogate test methods.

The Phase IV study sampled in-use playground equipment using surrogate test methods. This memo presents estimates of the level of arsenic transferred to a human hand from contact with CCA-treated wood playground equipment.

## Analysis

Phase IV consisted of sampling 15 wooden playgrounds in the Washington, DC metropolitan regions.[4] Twelve of the playgrounds were constructed of CCA-treated wood. The remaining three playgrounds were used as controls. The sampling was performed using the dry and wet polyester surrogate methods developed in Phases I to III.

Table 1 presents summary information on the 12 CCA-treated wood playgrounds and the hand method estimates.[5] Each hand method estimate is equal to the median of the dry polyester surrogate methods values multiplied by a conversion factor of 0.20. The conversion factor, derived in Phase III, converts the dry polyester surrogate method values to the hand method values.[6] Table 2 presents the number, the median value, and the mean value of the measurements for each playground.

Table 1: Phase IV Playground Summary.

| Structure | Age | Playground Manufacturer Supplied Lumber | Sealer Treatment | Time Since Sealed | Hand Method Estimate (μg) |
|---|---|---|---|---|---|
| 9 | 10 years | Yes | Yes | Approx. 10 years | 33.7 |
| 10 | 5 months | No | No | | 3.7 |
| 11 | Approx. 8 years | No | Yes | 7 years | 0.8 |
| 12 | Over 6 years | No | Unknown* | | 3.1 |
| 13 | Unknown | No | Unknown* | | 8.0 |
| 14 | 11 years | Yes | Unknown* | | 0.9 |
| 15 | 18 years | Unknown | Unknown | | 15.4 |
| 16 | 6 months | Yes | Yes | 6 months | 1.0 |
| 17 | 5 years | Unknown | Yes | 1 year | 0.3 |
| 18 | 7 years | No | Unknown* | | 9.1 |
| 19 | Approx 7 years | Yes | Yes | 1 to 2 years | 2.2 |
| 21 | 9 months | No | No | | 12.1 |

*: No appearance of sealer.

The overall estimate of the hand method for the playgrounds was 7.6 μg. This value is the mean of the 12 playground estimates.

4 The experimental details and data are provided in Cobb and Davies (2003).
5 See Cobb and Davies (2003) for further details on the playgrounds.
6 See Levenson (2003b).

The effects of age and sealer treatment appear to be complex. There are old structures with relatively high levels (structures 9 and 15) and with relatively low levels (structures 11 and 14). Structure 9 has the highest estimated level. The structure had been sealed, but not for some time.

Table 2: Phase IV Dry Polyester Surrogate Method Results

| **Structure** | **Number of Samples** | **Median (µg)** | **Mean (µg)** |
|---|---|---|---|
| 9 | 2 | 168.5 | 168.5 |
| 10 | 2 | 18.6 | 18.6 |
| 11 | 2 | 4.2 | 4.2 |
| 12 | 2 | 15.4 | 15.4 |
| 13 | 1 | 40.2 | 40.2 |
| 14 | 5 | 4.4 | 10.1 |
| 15 | 2 | 77.1 | 77.1 |
| 16 | 4 | 5.0 | 5.8 |
| 17 | 4 | 1.6 | 2.8 |
| 18 | 2 | 45.6 | 45.6 |
| 19 | 4 | 11.2 | 16.1 |
| 21 | 4 | 60.6 | 60.8 |

## References


Cobb D. (2003) Chromated Copper Arsenate (CCA) Pressure-Treated Wood Analysis Exploratory Studies Phase I and Laboratory Study Phase II, US Consumer Product Safety Commission.

Cobb D. and Davis D. (2003) Chromated Copper Arsenate (CCA) Treated Wood Field Study – Phases III and IV, US Consumer Product Safety Commission.

Levenson M. (2003a) Statistical Analyses of CCA-Treated Wood Studies Phases I and II, US Consumer Product Safety Commission.

Levenson M. (2003b) Statistical Analyses of CCA-Treated Wood Studies Phase III, US Consumer Product Safety Commission.

National Research Council (2001) *Arsenic in Drinking Water: 2001 Update*, National Academy Press, Washington, DC.

United States
**CONSUMER PRODUCT SAFETY COMMISSION**
**Washington, D.C. 20207**

**MEMORANDUM**

**DATE:** January 2003

**TO** : Patricia Bittner, M.S., Project Manager for CCA Wood in Playgrounds Petition

**Through** : Andrew G. Stadnik P.E., Associate Executive Director
Directorate of Laboratory Sciences
Warren Porter, Division Director, Division of Chemistry
Directorate of Laboratory Sciences

**FROM** : David Cobb, Chemist, Division of Chemistry

**SUBJECT** : Chromated Copper Arsenate (CCA) Pressure Treated Wood Analysis – Expoloratory Studies Phase I and Laboratory Studies Phase II

## BACKGROUND

The staff of the U.S. Consumer Product Safety Commission (CPSC) is currently addressing a petition to ban the use of chromated copper arsenate (CCA) treated wood in children's playground equipment. There has been some concern of potential chemical exposure from arsenic (As) migration from the surface of the wood. Previous studies[1,2] measured the amount of dislodgeable As from CCA-treated wood by rubbing the boards with a surrogate material such as nylon or polyester wipes. Actual hand data, in which dislodgeable As from hand contact with CCA-treated wood has been measured, was limited.

Studies were undertaken by CPSC staff to characterize various CCA-treated woods and assess exposure to As from CCA-treated wood. The studies consisted of several phases. This report describes results from the phase I and phase II studies. The first phase, referred to as Exploratory Studies concentrated on test method development and scoping experiments and included the first two hand studies. The second phase referred to as the Laboratory Study furthered the test method development and included the 3rd hand study.

## PURPOSE

The main purpose of the studies reported herein was to refine the test methodology being used to assess the amounts of dislodgeable arsenic from CCA-treated wood. The approach taken in these experiments included: (1) measuring total As in treated wood; (2) measuring dislodgeable As obtained by rubbing treated wood with a weight covered with polyester cloth; (3) evaluating effects of area rubbed, weight, and repeated rubbing on the amounts of dislodgeable As; (4) comparing levels of dislodgeable As obtained using several materials identified as candidate surrogates for the human hand and; (5) characterizing dislodgeable As levels that a bare hand can pick up from rubbing CCA-treated wood.

## SUMMARY of FINDINGS

A brief summary of the main findings are:

1. The amount of As in wood samples varied from 0.02 to 0.45%.
2. The amount of dislodgeable As that the polyester cloth picked up varied from board to board. The minimum As value was 30.4 μg. The maximum As value was 496 μg.
3. Increases in the weight used to rub, area rubbed, and the number of strokes the wipe was rubbed over the same area generally increased the amount of dislodgeable As.
4. The material used for wiping affected the amount of dislodgeable As. Chamois picked up similar amounts of dislodgeable As as polyester wipes, but presented some analytical problems. Kimwipes® picked up similar amounts of dislodgeable As as polyester wipes, but tore on rough boards. High density polyethylene (HDPE) picked up less dislodgeable As than polyester wipes.
5. Three adult hand studies were conducted during the course of this study. The first hand study revealed the difficulty of recovering all the dislodgeable As from the volunteer's hand with a simple rinse with deionized water. A more rigorous extraction (i.e. handwash) was developed for the second and third hand studies. These studies revealed that the bare hand consistently picks up much less dislodgeable As than the polyester wipes.

## METHODS/RESULTS

### Phase I. Exploratory Studies

Samples:

LS Staff purchased samples of new CCA-treated boards from local hardware stores. The list of samples and purchase dates are presented in Table 1.

**Table 1. List of CCA-Treated Wood Samples Purchased**

| Sample Number (Subs) | Purchase Date |
|---|---|
| 01-420-8457 (01-02) | June 2001 |
| 01-420-8457 (03-04) | June 2001 |
| 01-420-8458 (01-02) | June 2001 |
| 01-420-8459 (01-02) | June 2001 |
| 01-420-8460 (01-10) | July 2001 |
| 01-420-8461 (01-08) | August 2001 |
| 01-420-8462 (01-08) | August 2001 |
| 02-420-8400 (01-06) | October 2001 |
| 02-420-8403 (01-08) | October 2001 |
| 02-420-8404 (01-08) | December 2001 |
| 02-420-8407 (01-09) | January 2002 |
| 02-420-8409 (01-09) | January 2002 |

In addition to the new wood purchased, 2 decks were sampled. One deck was uncovered, exposed to the sun, and approximately one year old. The other deck was covered and over 5 years old. Boards exposed to the weather for 2, 6, 22 years also were sampled. The weathered boards were given a sample designation of 01-420-8406(05), 01-420-8405 (01-04), 01-420-8406 (01-04) respectively.

Total As in CCA-Treated Wood:

Wood shavings from several boards were digested in nitric acid and analyzed using inductively coupled plasma atomic emission spectroscopy (ICP) for As. The wood shavings were collected by drilling holes into the boards. The results are contained in Table 2.

**Table 2. Total As in CCA-Treated Wood Samples**

| *Sample* | *%As* |
|---|---|
| 01-420-8457-01 | 0.43 |
| 01-420-8457-03 | 0.22 |
| 01-420-8458-01 | 0.17 |
| 01-420-8459-01 | 0.02 |
| 02-420-8407 (01-09) average | 0.33 |
| Uncovered Deck Board 1[1] | 0.30 |
| Uncovered Deck Board 2[1] | 0.45 |
| Uncovered Deck Board 3[1] | 0.24 |

[1]Extra boards from the one year old uncovered deck

Dislodgeable As:

The primary wipe method conducted by LSC staff involved using a 1.1 kilogram (kg) disk that was 8 centimeters (cm) in diameter. Polyester wipes 4.5 in x 4.5 in were wetted with 0.9% saline until the weight of the wipe approximately doubled. The wetted wipe was stretched over the face of the disk and attached with a hose clamp. The wipe-covered disk was rubbed back and forth over a 400 $cm^2$ area that was 50 cm long for 10 strokes. A stroke is defined as a complete forward and back cycle of the disk over the sample area. The wipes were removed from the disk placed in test tubes containing 10% nitric acid, and extracted overnight (approximately 22 hours) at 60°C. The extracts were analyzed for total As using ICP. Detailed sampling and analysis procedures are contained in attachment (A). Table 3 contains the results from all polyester wipe rubbings done with a 1.1 kg weight, ten strokes, and a saline wetted wipe.

The polyester wipes were chosen for the primary surrogate material. The 1.1 kg weight disk, 400 $cm^2$ area, and ten strokes are similar to what were used in previous CPSC study[1]. The saline wetted wipes were chosen to simulate children's hands soaked with perspiration while playing on playground equipment.

**Table 3. Dislodgeable As in New Wood Samples, Using 1.1kg Weight, 10 Strokes, Single Polyester Wipe**

| Sample # | Sub # | Section | As µg |
|---|---|---|---|
| 01-420-8460 | 01 | B | 82.8 |
| 01-420-8460 | 02 | B | 70.4 |
| 01-420-8460 | 03 | B | 200.4 |
| 01-420-8460 | 05 | A | 49.2 |
| 01-420-8460 | 05 | B | 50 |
| 01-420-8460 | 05 | E | 56.8 |
| 01-420-8460 | 05 | F | 52.8 |
| 01-420-8460 | 06 | A | 111.2 |
| 01-420-8460 | 06 | B | 72 |
| 01-420-8460 | 06 | C | 93.6 |
| 01-420-8460 | 06 | D | 68.4 |
| 01-420-8460 | 06 | E | 294 |
| 01-420-8460 | 06 | F | 183.2 |
| 01-420-8460 | 06 | G | 244.8 |
| 01-420-8460 | 06 | H | 219.6 |
| 01-420-8460 | 07 | A | 101.6 |
| 01-420-8460 | 07 | B | 148.8 |
| 01-420-8460 | 07 | C | 136.4 |
| 01-420-8460 | 07 | D | 93.2 |

**Table 3. Continued**

| Sample # | Sub # | Section | As µg |
|---|---|---|---|
| 01-420-8460 | 07 | E | 78.8 |
| 01-420-8460 | 07 | F | 87.2 |
| 01-420-8460 | 07 | G | 71.2 |
| 01-420-8460 | 07 | H | 65.6 |
| 01-420-8460 | 08 | A | 84 |
| 01-420-8460 | 08 | B | 79.2 |
| 01-420-8460 | 08 | C | 118 |
| 01-420-8460 | 08 | D | 104.4 |
| 01-420-8460 | 08 | E | 158.4 |
| 01-420-8460 | 08 | F | 64 |
| 01-420-8460 | 08 | G | 63.6 |
| 01-420-8460 | 08 | H | 104 |
| 01-420-8460 | 09 | A | 88.8 |
| 01-420-8460 | 09 | B | 111.6 |
| 01-420-8460 | 09 | C | 109.2 |
| 01-420-8460 | 09 | D | 101.6 |
| 01-420-8460 | 09 | E | 76 |
| 01-420-8460 | 09 | F | 106.8 |
| 01-420-8460 | 09 | G | 96 |
| 01-420-8460 | 09 | H | 98.4 |
| 01-420-8460 | 10 | A | 66 |
| 01-420-8460 | 10 | B | 55.2 |
| 01-420-8460 | 10 | C | 94.4 |
| 01-420-8460 | 10 | D | 69.2 |
| 01-420-8460 | 10 | E | 93.2 |
| 01-420-8460 | 10 | F | 94.4 |
| 01-420-8460 | 10 | G | 118.4 |
| 01-420-8460 | 10 | H | 114 |
| 01-420-8461 | 1 | B | 62 |
| 01-420-8461 | 1 | E | 100 |
| 01-420-8461 | 2 | C | 230.8 |
| 01-420-8461 | 2 | F | 89.6 |
| 01-420-8461 | 3 | B | 125.2 |
| 01-420-8461 | 3 | E | 87.2 |
| 01-420-8461 | 4 | B | 74.4 |
| 01-420-8461 | 4 | E | 326 |
| 01-420-8461 | 5 | A | 73.6 |
| 01-420-8461 | 5 | D | 380.8 |
| 01-420-8461 | 6 | C | 164.8 |

**Table 3. Continued**

| Sample # | Sub # | Section | As µg |
|---|---|---|---|
| 01-420-8461 | 6 | F | 70.4 |
| 01-420-8461 | 7 | A | 59.6 |
| 01-420-8461 | 7 | B | 67.2 |
| 01-420-8461 | 7 | C | 89.2 |
| 01-420-8461 | 8 | A | 186 |
| 01-420-8461 | 8 | B | 53.6 |
| 01-420-8461 | 8 | C | 42.8 |
| 01-420-8462 | 1 | C | 120 |
| 01-420-8462 | 1 | F | 85.6 |
| 01-420-8462 | 2 | A | 496 |
| 01-420-8462 | 2 | D | 50.4 |
| 01-420-8462 | 3 | A | 106.4 |
| 01-420-8462 | 4 | B | 30.4 |
| 01-420-8462 | 4 | E | 114.4 |
| 01-420-8462 | 5 | A | 89.2 |
| 01-420-8462 | 5 | D | 74.8 |
| 01-420-8462 | 6 | C | 83.2 |
| 01-420-8462 | 6 | F | 44.4 |
| 01-420-8462 | 7 | A | 226 |
| 01-420-8462 | 7 | B | 68 |
| 01-420-8462 | 7 | C | 91.6 |
| 01-420-8462 | 8 | A | 49.6 |
| 01-420-8462 | 8 | B | 89.2 |
| 01-420-8462 | 8 | C | 94 |
| 02-420-8400 | 1-5 | A | 107.2 |
| 02-420-8400 | 1-5 | E | 100.4 |
| 02-420-8400 | 1-5 | I | 135.2 |
| 02-420-8400 | 1-5 | M | 186.4 |
| 02-420-8400 | 1-5 | Q | 186 |
| 02-420-8400 | 1-5 | R | 182.8 |
| 02-420-8403 | 1 | C | 70.8 |
| 02-420-8403 | 1 | D | 65.6 |
| 02-420-8403 | 1 | E | 76 |
| 02-420-8403 | 1 | F | 54.4 |
| 02-420-8403 | 2 | B | 72 |
| 02-420-8403 | 2 | C | 70.4 |
| 02-420-8403 | 2 | D | 68.8 |
| 02-420-8403 | 2 | E | 79.2 |

**Table 3. Continued**

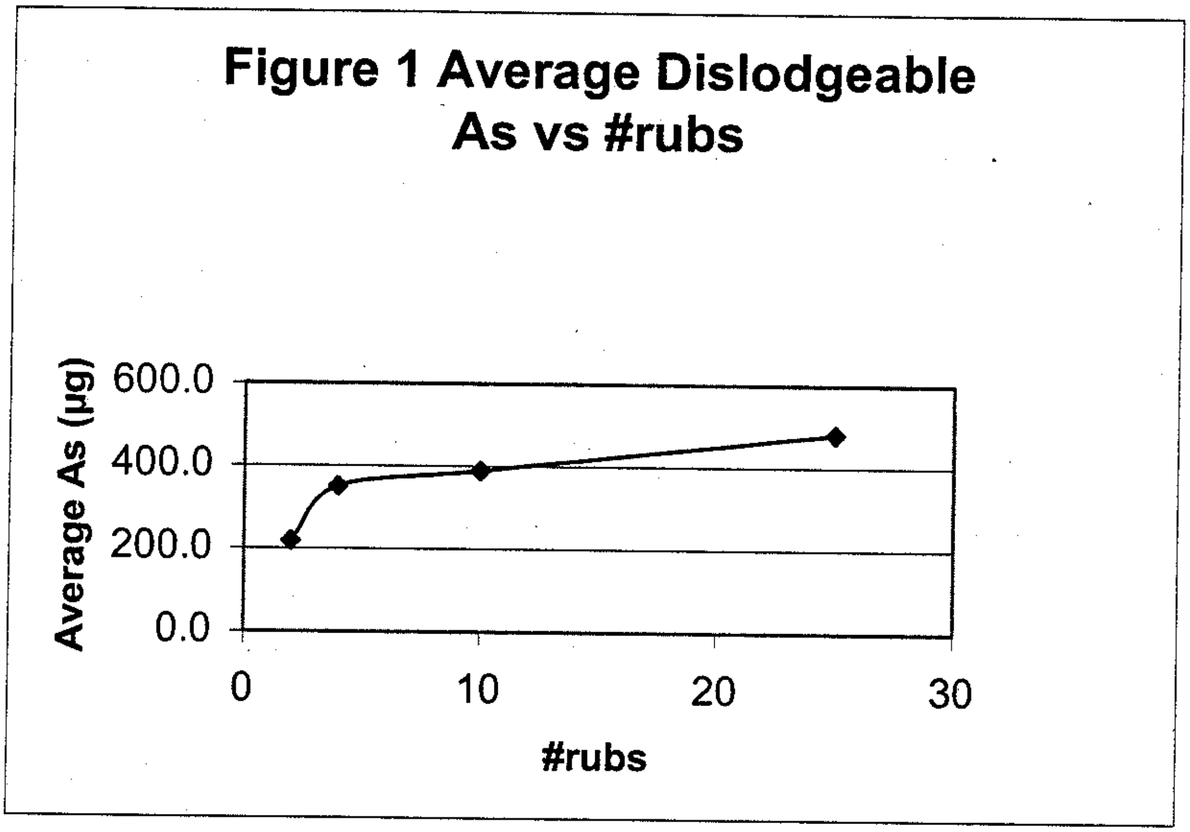
| Sample # | Sub # | Section | As µg |
|---|---|---|---|
| 02-420-8403 | 3 | A | 126 |
| 02-420-8403 | 3 | B | 61.2 |
| 02-420-8403 | 3 | G | 123.2 |
| 02-420-8403 | 3 | H | 80 |
| 02-420-8403 | 4 | A | 55.2 |
| 02-420-8403 | 4 | B | 83.6 |
| 02-420-8403 | 4 | G | 54.8 |
| 02-420-8403 | 4 | H | 72.8 |
| 02-420-8404 | 1 | B | 105.2 |
| 02-420-8404 | 2 | E | 63.6 |
| 02-420-8404 | 3 | A | 151.2 |
| 02-420-8404 | 4 | D | 162 |
| **Average** | | | 108.3 |
| **Minimum** | | | 30.4 |
| **Maximum** | | | 496 |
| **Standard Deviation** | | | 69.8 |
| **Median** | | | 89.2 |

Note: Sub # - Each board within a sample was given a sub #. A sample consisted of multiple boards of the same dimensions purchased from the same source at the same time. The boards were obtained from the same pile at the store location. Section – Each board was divided into sections large enough to conduct the 400-cm2 surface area rub. 8 foot long boards were typically divided into 4 sections per side of board.

The dislodgeable As results show a large variation, but most of the results tend to be between 40-200 µg under the conditions tested.

Several studies have been done to measure dislodgeable As using a weighted cloth wipe test[1,2], and they sometimes used varying methodologies. CPSC staff explored the variables in obtaining levels of dislodgeable As. Consideration of factors that might affect the levels of dislodgeable As include: 1) Number of strokes an area is rubbed; 2) Amount of weight used; 3) Type of cloth or material used for wiping; 4) Wet or dry wipe; 5) Number of times an area is rerubbed, and; 6) Extraction procedure.

*Number of Strokes:* 400 $cm^2$ areas were wiped back and forth with polyester covered disks 2, 4, 10, and 25 strokes. An increase in the number of strokes generally increased dislodgeable As, Increases were most noticeable from 2 to 10 stokes. The dislodgeable As levels off between 10 and 25 strokes. Figure 1 demonstrates the effect that the number of strokes has on dislodgeable As.



*Weight:* Weights ranging from 1.1 kg to 12.5 kg were placed on the polyester wipe covered disks. It was noted that generally, increases in the weight increased the dislodgeable As. The dislodgeable As approximately doubled when the weight was increased from 1.1 kg to 5 kg. The dislodgeable As started to level out at weights above 10 kg. Figure 2 shows the effect of weight on dislodgeable As. Table 4 contains all the results of testing done in which the weight and number of strokes were varied.

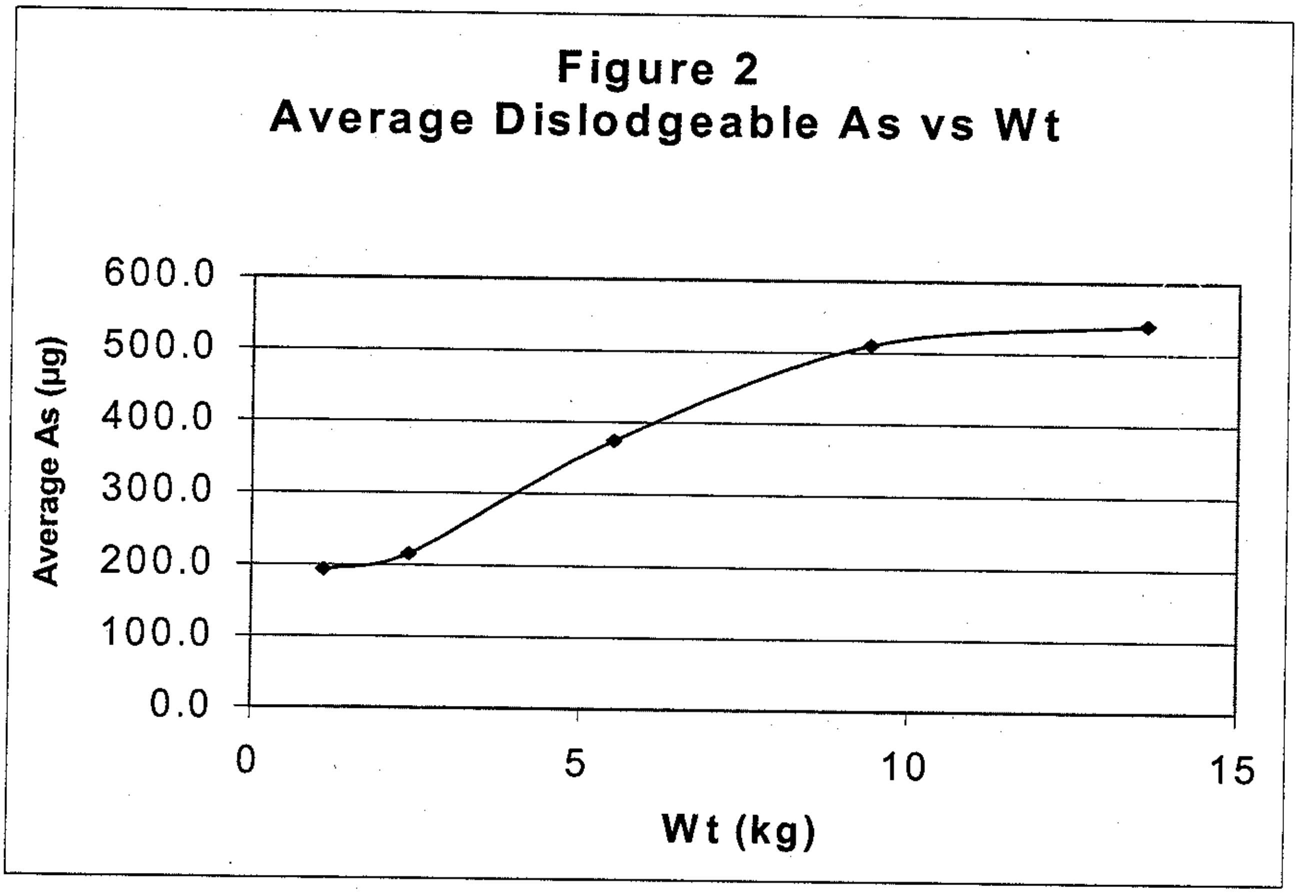


**Table 4. Dislodgeable As as a Function of Weight and Number of Wipe Strokes**
**Sample: 01-420-8460**

| Sub | Section | Wt (kg) | Strokes | As µg |
|---|---|---|---|---|
| 2 | A | 1.1 | 2 | 67.6 |
| 1 | A | 1.1 | 4 | 201.6 |
| 3 | A | 1.1 | 4 | 245.6 |
| 1 | B | 1.1 | 10 | 158.8 |
| 2 | B | 1.1 | 25 | 130 |
| 3 | B | 1.1 | 25 | 356 |
| 2 | E | 2.4 | 2 | 84.4 |
| 4 | A | 2.4 | 2 | 130.8 |
| 1 | E | 2.4 | 4 | 99.2 |
| 3 | H | 2.4 | 4 | 277.6 |
| 1 | F | 2.4 | 10 | 169.6 |
| 4 | B | 2.4 | 10 | 295.6 |
| 2 | F | 2.4 | 25 | 189.6 |
| 3 | G | 2.4 | 25 | 475.2 |
| 1 | D | 5 | 4 | 352.8 |
| 1 | C | 5 | 10 | 440.8 |
| 2 | H | 6.1 | 2 | 317.2 |
| 4 | E | 6.1 | 2 | 238.4 |
| 4 | F | 6.1 | 10 | 456.8 |
| 2 | G | 6.1 | 25 | 440.8 |
| 1 | H | 8.6 | 4 | 285.6 |
| 3 | D | 8.6 | 4 | 577.6 |
| 1 | G | 8.6 | 10 | 327.6 |
| 3 | C | 8.6 | 25 | 892.4 |
| 4 | H | 11.1 | 2 | 342.4 |
| 4 | G | 11.1 | 10 | 636.4 |
| 2 | D | 13.6 | 2 | 331.6 |
| 4 | D | 13.6 | 2 | 233.6 |
| 3 | E | 13.6 | 4 | 771.6 |
| 2 | C | 13.6 | 10 | 509.2 |
| 4 | C | 13.6 | 10 | 509.6 |
| 3 | F | 13.6 | 25 | 884 |

*Type of Material Used for Wipe:* Chamois, Kimwipes® (paper tissue wipes), and HDPE were tested as wipes to compare the effect of using different materials on dislodgeable As. The chamois was 100% cod oil tanned made by U.S. Chamois. The source of HDPE was Dupont Tyvek® 9"x12" envelopes. Wipes were conducted with a 1.1 kg disk on a board area of 400cm$^2$ for 10 strokes. Chamois and polyester wipes picked up similar amounts of dislodgeable As during rubbing. The HDPE picked up much less dislodgeable As. The Kimwipes® picked up about 25% the dislodgeable As as the polyester surrogates, but the area rubbed by the Kimwipes® was only 100 $cm^2$. The area rubbed by the polyester surrogates was 400 $cm^2$. Table 5 shows data using the different materials.

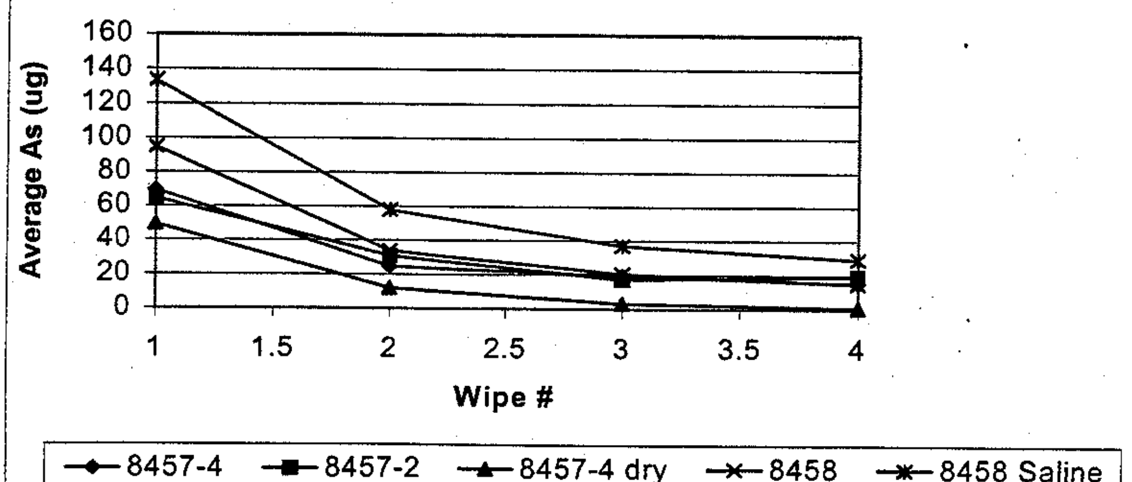
**Table 5. Dislodgeable As Using Different Wiping Material**

| **Sample 02-420-8403** | **Average As µg** |
|---|---|
| Chamois | 76.8 |
| Polyester | 69.6 |
| **Sample 02-420-8404** | |
| Polyester | 120.4 |
| Kimwipe | 22.3 |
| HDPE | 22.0 |

*Wet vs Dry Polyester Wipes:* Dry wipes, and wipes thoroughly wetted with deionized water or 0.9% saline until the weight of the wipe approximately doubles, were evaluated using the protocol described in the next section on re-rubbings. The dislodgeable As levels for the saline wetted wipes were about 40% higher than the wipes wetted with deionized water, and almost twice that obtained using dry wipes. Figure 3 compares dry wipes, deionized water wetted wipes, and saline wetted wipes.

*Number of Times an Area is Rerubbed:* Sections of CCA-treated boards were rerubbed with fresh polyester wipes using a total of 4 wipes per section. The wipes were conducted sequentially with as little time as possible elapsing between a section being rerubbed. Under the conditions tested, it was noted that the dislodgeable As decreased with repeated rubs. The 2nd polyester wipe picked up less than half the amount of CCA of the 1st wipe. Results leveled off between the 3rd and 4th wipes. Figure 3 demonstrates the effect of rerubbing polyester wipes over the same area of CCA-treated wood on the levels of dislodgeable As.

**Figure 3. Arsenic Dislodged After Sequential Rubbing with Saline Wetted, Deionized Water Wetted, and Dry Polyester Wipes**



*Nitric Acid Extraction Efficiency:* In the Stillwell (1998) study[2], wipes were extracted with 10% nitric acid at 60°C for 2 hours with recoveries greater than 90% being reported. The extraction procedure developed by CPSC staff was similar except the extractions were carried out overnight (15-24 hours). In this study, As recoveries from polyester wipes were greater than 95% when the wipes were extracted with 10% nitric acid at 60°C for approximately 22 hours. The polyester wipes were spiked with 100µl of 1000 ppm solutions of As. The wipes were also spiked with milled wood particles of known As concentration. Recoveries with other solvents were not as complete. Table 6 shows the average recovery rates of As with various solvents.

**Table 6. Recovery Rates**

| Solvent | Average % As Recovery |
|---|---|
| 10% Nitric Acid | 97 |
| Deionized Water | 26 |
| 0.01 N HCl | 55 |
| 5% Acetic Acid | 92 |

**Hand Studies:**

Several studies were conducted to evaluate actual As loading onto bare hands contacting treated wood. A relationship between polyester wipes and the bare hand was sought in order to use polyester wipes as a surrogate for bare hands in subsequent field studies.

*Hand Study 1:* In the first CPSC hand study of dislodgeable As six volunteers rubbed new boards and boards from two decks with their bare hand, a polyester gloved hand, and the polyester covered disk. Some of the new boards were washed to remove any residual CCA that might be easily removed through early weathering. The washed boards were sprayed with a garden hose for 5 minutes and allowed to dry before any testing was conducted. One deck was covered and was over 5 years old. The second deck was a year old, and was uncovered. The dislodgeable As was collected from the bare hands by rinsing with 100 ml of 5% acetic acid followed by a rinse with 100 ml of deionized water. The rinses were concentrated by evaporation and analyzed by ICP for As. The volunteers' hands were washed prior to each sampling. The hands were rinsed with deionized water and dried prior to each hand-rubbing test. The deionized water rinses were collected and analyzed. As was not detected in the pre-rub deionized water rinses. This indicates the background level of As on the volunteers' hands prior to rubbing the boards was negligible. Results of the first hand study showed the following observations:

1. The polyester gloved hand picked up more dislodgeable As than the weighted polyester wipe. This may be due to the larger surface area of the gloved hand.
2. The bare hands picked up much less dislodgeable As than the polyester wipes or the polyester gloves.
3. Many bare hand samples, especially from the old wood rubs, were below the method

detection limit. However, as shown in Hand Study 2, this may be due to inadequate collection methodology after sampling.

4. There was a correlation between the weighted disk and glove on the amount of dislodgeable As picked up, but no correlation with the bare hand and the polyester covered weight.[3]
5. There was no noticeable difference in the results between washed and unwashed new boards.

Table 7 shows the results obtained with the disk, glove, and hand for both new and old boards. The first letter in the designation refers to the condition of boards:
N= New unwashed boards
W= New washed boards
C= Covered deck boards
U= Uncovered deck boards
The remaining numbers and letters in the designation refer to the volunteer, sub number of the board, and location on the board. The average results for each type of board and sampling condition are highlighted in bold at the end of Table 7.

**Table 7. Hand Study 1 – New and Old Wood Treated with CCA**

| Type | Designation | As µg |
|---|---|---|
| Disk | N16A | 106.5 |
| Disk | N16D | 98.4 |
| Disk | N25A | 495.8 |
| Disk | N25D | 50.4 |
| Disk | N33B | 125.0 |
| Disk | N33E | 87.3 |
| Disk | N41C | 62.0 |
| Disk | N41F | 99.9 |
| Disk | N52C | 230.9 |
| Disk | N52F | 89.6 |
| Disk | N64C | 119.9 |
| Disk | N64F | 85.6 |
| Disk | W12A | 73.7 |
| Disk | W12D | 380.9 |
| Disk | W25A | 89.3 |
| Disk | W25D | 74.6 |
| Disk | W31B | 74.5 |
| Disk | W31E | 326.1 |
| Disk | W43C | 164.8 |
| Disk | W43F | 70.2 |
| Disk | W56C | 83.0 |
| Disk | W56F | 44.5 |
| Disk | W64B | 30.4 |
| Disk | W64E | 114.5 |

**Table 7. Continued**

| Type | Designation | As µg |
|---|---|---|
| Glove | N16C | 90.9 |
| Glove | N16F | 106.5 |
| Glove | N25B | 820.5 |
| Glove | N25E | 86.5 |
| Glove | N33C | 193.7 |
| Glove | N33F | 194.7 |
| Glove | N41B | 136.9 |
| Glove | N41E | 184.8 |
| Glove | N52B | 299.6 |
| Glove | N52E | 145.8 |
| Glove | N64A | 158.8 |
| Glove | N64D | 139.2 |
| Glove | W12C | 97.5 |
| Glove | W12F | 457.5 |
| Glove | W25B | 112.0 |
| Glove | W25E | 104.1 |
| Glove | W31C | 92.9 |
| Glove | W31F | 637.0 |
| Glove | W43A | 420.2 |
| Glove | W43D | 191.1 |
| Glove | W56B | 136.6 |
| Glove | W56E | 68.8 |
| Glove | W64A | 54.8 |
| Glove | W64D | 143.1 |
| Hand | N16B | 39.6 |
| Hand | N16E | 3.4 |
| Hand | N25C | 20.0 |
| Hand | N25F | 0.0 |
| Hand | N33A | 75.6 |
| Hand | N33D | 33.9 |
| Hand | N41A | 4.6 |
| Hand | N41D | 8.0 |
| Hand | N52A | 49.7 |
| Hand | N52D | 0.0 |
| Hand | N64B | 8.4 |
| Hand | N64E | 37.6 |
| Hand | W12B | 0.0 |
| Hand | W12E | 33.0 |

| Table 7. Continued | | |
|---|---|---|
| **Type** | **Designation** | **As µg** |
| Hand | W25C | 42.2 |
| Hand | W25F | 0.0 |
| Hand | W31A | 0.0 |
| Hand | W31D | 9.2 |
| Hand | W43B | 43.2 |
| Hand | W43E | 36.4 |
| Hand | W56A | 26.6 |
| Hand | W56D | 35.3 |
| Hand | W64C | 0.0 |
| Hand | W64F | 9.1 |
| Disk | C25C | 128.6 |
| Disk | C63A | 123.8 |
| Disk | C16B | 63.4 |
| Disk | C32A | 122.5 |
| Disk | U13C | 103.8 |
| Disk | U34B | 115.6 |
| Disk | U66A | 115.5 |
| Disk | U25B | 131.6 |
| Glove | C25B | 74.3 |
| Glove | C63C | 67.1 |
| Glove | C16A | 63.7 |
| Glove | C32B | 104.7 |
| Glove | U13B | 205.6 |
| Glove | U34C | 310.3 |
| Glove | U66B | 219.5 |
| Glove | U25A | 194.0 |
| Hand | C63B1 | 8.6 |
| Hand | C16C1 | 2.9 |
| Hand | C25C1 | 2.9 |
| Hand | C32C1 | 13.8 |
| Hand | U13A1 | 0.0 |
| Hand | U25C1 | 0.0 |
| Hand | U34A1 | 0.0 |
| Hand | U66C1 | 0.0 |
| | | |
| | | |

| Table 7. Continued | | |
|---|---|---|
| Type | Designation | As µg |
| Disk | Average N | 137.6 |
| Disk | Average W | 127.2 |
| Disk | Average C | 109.6 |
| Disk | Average U | 116.8 |
| Glove | Average N | 213.2 |
| Glove | Average W | 209.6 |
| Glove | Average C | 77.6 |
| Glove | Average U | 232.4 |
| Hand | Average N | 23.6 |
| Hand | Average W | 19.6 |
| Hand | Average C | 7.2 |
| Hand | Average U | 0 |

*Hand Study 2:* A second hand study with two volunteers was done to determine the effects of a dry, wet, or oily hand on the ability to pick up dislodgeable As in order to examine hand loading and attempt to establish a maximum hand load. The study was also done to determine if all the As was being removed from the hand by the 5% acetic acid rinse. Five boards were placed together, and the rubbing was done across the five boards. The area wiped by the hands was increased to 2100 $cm^2$, and the area wiped using the polyester covered disks was 560 $cm^2$. The hand area was increased to 2100 $cm^2$ in an attempt to maximize the hand load. Rubbing across 5 boards was thought to minimize any inter-board variability. All the board sections were rubbed 10 strokes. After the rubbing the hands were rinsed with 100 ml of 5% acetic acid, then the hands were wiped with a polyester wipe that had been wetted with 5% acetic acid. The wipes and rinses were collected and analyzed separately. The results showed the following observations:

1. The 5% acetic acid rinse alone was not removing all the As from the hand. The polyester wipes had significant amounts of As.
2. The total amounts of As picked up by the hand were greater than in the first study, but the amounts of As per 100 $cm^2$ of rub area were less.
3. The bare hand picked up much less dislodgeable As than the polyester weighted disk.
4. The wet hand picked up slightly more As than the dry or oily hand.

Results in Table 8 are the combined acetic acid rinse and polyester wipe for each hand test. Table 9 contains the individual acetic acid rinse and polyester wipe results for the hand test along with the weighted disk results. Figure 4 compares the average results obtained for the dry, wet, and oily hands. Figure 5 shows the relative amounts of CCA found in the 5% acetic acid rinse and the polyester wipe used on the hand (derived from data in Table 9).

**Table 8. Hand Wipe Results of 1st Hand Study:**
**Summation of 5% Acetic Acid Rinse and Polyester Wipes**

| Board Section | Dry/Wet/Oil (D/W/O) | As µg |
|---|---|---|
| B | D | 20.2 |
| C | W | 30.2 |
| D | O | 20.8 |
| F | D | 33.2 |
| G | W | 38.2 |
| H | O | 23.9 |
| J | D | 32.1 |
| K | W | 53.1 |
| L | O | 54.8 |
| N | D | 27.7 |
| O | W | 48.9 |
| P | O | 13.0 |
| Avg Dry | | 28.3 |
| Avg Wet | | 42.6 |
| Avg Oil | | 28.1 |
| Avg All | | 33.0 |

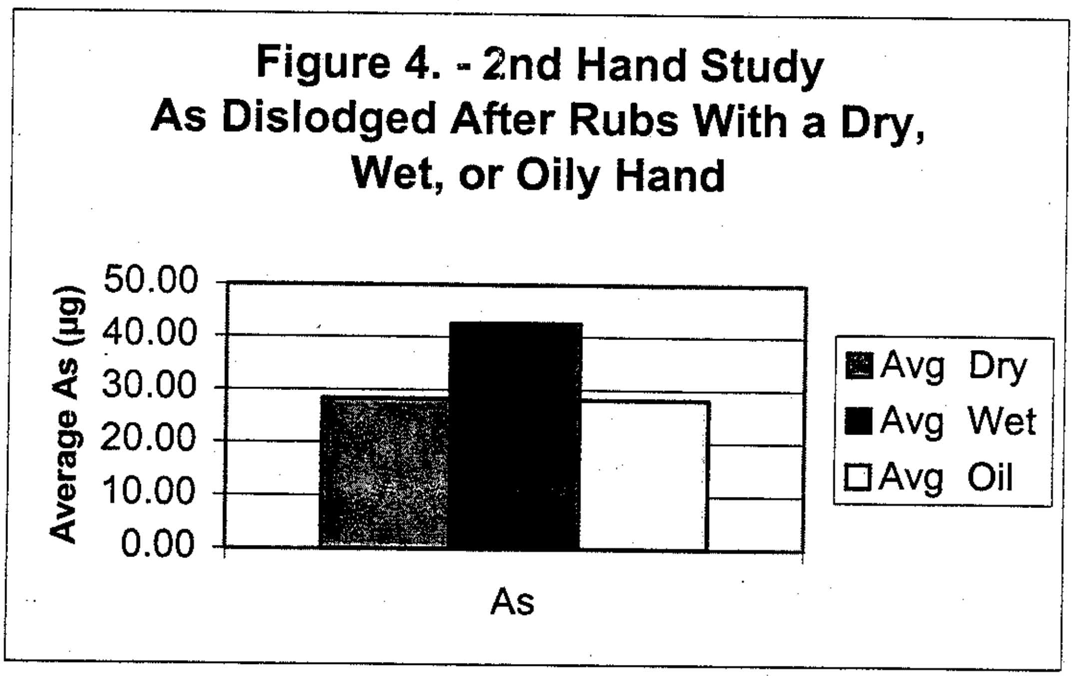


**Figure 5. Removal of As from Hand Using 5% Acetic Acid Rinse Followed by Polyester Wipe**

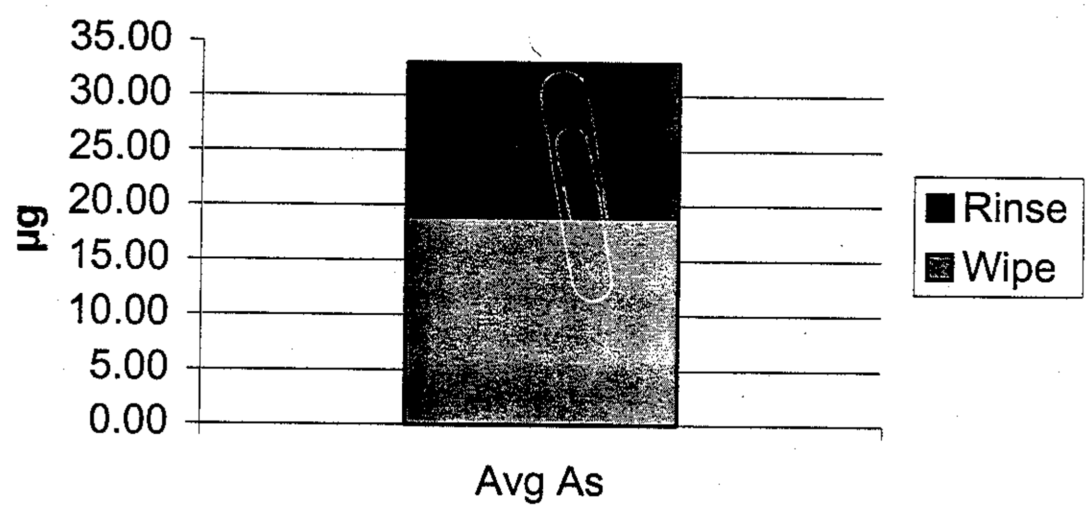


**Table 9. Results of 2nd Hand Study: Individual Results for all Sampling Conditions**

| Location | Condition | Rinse/wipe | As µg |
|---|---|---|---|
| A | Disk | | 150.0 |
| B | Dry | Rinse | 6.4 |
| B | Dry | Wipe | 13.8 |
| C | Wet | Rinse | 10.4 |
| C | Wet | Wipe | 19.8 |
| D | Oil | Rinse | 6.4 |
| D | Oil | Wipe | 14.4 |
| E | Disk | | 140.6 |
| F | Dry | Rinse | 12.4 |
| F | Dry | Wipe | 20.7 |
| G | Wet | Rinse | 20.0 |
| G | Wet | Wipe | 18.3 |
| H | Oil | Rinse | 8.4 |
| H | Oil | Wipe | 15.6 |
| I | Disk | | 189.0 |
| J | Dry | Rinse | 19.4 |
| J | Dry | Wipe | 12.9 |
| K | Wet | Rinse | 30.2 |
| K | Wet | Wipe | 22.8 |
| L | Oil | Rinse | 15.0 |
| L | Oil | Wipe | 39.9 |
| M | Disk | | 261.0 |
| N | Dry | Rinse | 13.2 |
| N | Dry | Wipe | 14.4 |
| O | Wet | Rinse | 24.0 |
| O | Wet | Wipe | 24.9 |
| P | Oil | Rinse | 3.4 |
| P | Oil | Wipe | 9.6 |
| Q | Disk | | 260.3 |
| R | Disk | | 255.8 |
| **Average** | **Disk** | | 209.4 |
| **Average** | **Wet** | **Total** | 28.3 |
| **Average** | **Oil** | **Total** | 42.6 |
| **Average** | **Dry** | **Total** | 28.1 |

**Phase II. Laboratory Study**

*Hand Study 3:* The third hand study was done to determine a loading curve for the hand, looking at the effects of repeated rubbing on dislodgeable As the hand can pick up. A more rigorous washing procedure on the hand was also used to determine if all the As was being removed from the hand. Before each rubbing the volunteers washed their hands with soap and tap water. The hand the volunteer used for rubbing was then rinsed with 100 ml of deionized water and dried. The deionized water was collected and analyzed to ensure low As levels on the volunteers' hands prior to rubbing. After the rubbing, the hands were rinsed with 100 ml of 5% acetic acid, wiped with a polyester wipe that had had been wetted with 5% acetic acid, rinsed again with 100 ml of 5% acetic acid. The rinse, wipe and second rinse were combined as one sample. The rinse, wipe, rinse procedure on the hand was repeated a second time, and all three were combined as a second sample.

In the third study, four new boards from sample 02-420-8404 were used, and four volunteers participated. Each board was divided into six sections. Four of the sections were used for hand rubbing. The two remaining sections were used for rubbing with a disk covered with a Kimwipe® or polyester wipe. The area wiped by the polyester surrogate was 400 $cm^2$. The area wiped by the Kimwipe® was 100 $cm^2$. In the sections designated for the hand, the volunteers rubbed the section of wood for 2, 5, 10, or 20 strokes as designated by the randomization scheme developed by the CPSC statistician. Each section area rubbed by the hand was 14 cm wide by 50 cm long for a total area of 700 $cm^2$. The section designated for 5 strokes was rerubbed three additional times, doing 5 strokes each time. The hand results for the new wood are contained in Table 10. The results from the rerubbed sections are designated R1 to R3 in the section column. R1 is the first repeated rub, R2 is the second, and R3 is the third. Table 11 contains the disk results for the Kimwipe® and polyester wipe.

Two volunteers also rubbed old boards that had been weathered. Boards from sample number 01-420-8457 had been exposed to the weather for six months at the laboratory. Boards from sample 02-420-8405 were obtained from a staff member. The boards were left over from a deck construction, and had been stored under the deck for six years. The boards from sample 02-420-8405 were noticeably weathered. Each board was divided into four sections. Two of the sections were used for hand rubbing. One of the remaining sections was used for rubbing with a disk covered with a polyester wipe. In the sections designated for the hand, the volunteers rubbed the section 10 or 20 strokes as designated by the randomization scheme. Each section area rubbed by the hand was 14 cm wide by 50 cm long for a total area of 700 $cm^2$. The section designated for 10 strokes was rerubbed two additional times, doing 10 stokes each time. The hand results for the old wood are contained in Table 12. Table 13 contains the disk results for the polyester wipe.

Table 10. 3rd Hand Study, Phase 1: Hand Results on New Boards

| | | | | | | Total Both Rinse/Wipes |
|---|---|---|---|---|---|---|
| **Vol ID** | **Board ID** | **Section** | **Rinse** | **Strokes** | **As µg** | **As µg** |
| 1 | 2 | A | 1 | 5 | 12.6 | 14.2 |
| 1 | 2 | A | 2 | 5 | 1.6 | |
| 1 | 2 | A R1 | 1 | 5 | 13.2 | 14.2 |
| 1 | 2 | A R1 | 2 | 5 | 1.0 | |
| 1 | 2 | A R2 | 1 | 5 | 9.6 | 10.7 |
| 1 | 2 | A R2 | 2 | 5 | 1.1 | |
| 1 | 2 | A R3 | 1 | 5 | 8.8 | 10.4 |
| 1 | 2 | A R3 | 2 | 5 | 1.6 | |
| 1 | 2 | B | 1 | 10 | 19.4 | 21.6 |
| 1 | 2 | B | 2 | 10 | 2.2 | |
| 1 | 2 | C | 1 | 2 | 15.6 | 17.6 |
| 1 | 2 | C | 2 | 2 | 2.0 | |
| 1 | 2 | F | 1 | 20 | 9.0 | 10.6 |
| 1 | 2 | F | 2 | 20 | 1.6 | |
| 2 | 3 | B | 1 | 20 | 19.6 | 22.0 |
| 2 | 3 | B | 2 | 20 | 2.4 | |
| 2 | 3 | C | 1 | 2 | 15.2 | 16.8 |
| 2 | 3 | C | 2 | 2 | 1.6 | |
| 2 | 3 | D | 1 | 5 | 23.2 | 26.4 |
| 2 | 3 | D | 2 | 5 | 3.2 | |
| 2 | 3 | D R1 | 1 | 5 | 9.6 | 10.8 |
| 2 | 3 | D R1 | 2 | 5 | 1.2 | |
| 2 | 3 | D R2 | 1 | 5 | 12.0 | 13.6 |
| 2 | 3 | D R2 | 2 | 5 | 1.6 | |
| 2 | 3 | D R3 | 1 | 5 | 9.8 | 10.8 |
| 2 | 3 | D R3 | 2 | 5 | 1.0 | |
| 2 | 3 | F | 1 | 10 | 21.8 | 24.2 |
| 2 | 3 | F | 2 | 10 | 2.4 | |
| 3 | 1 | A | 1 | 5 | 31.2 | 33.0 |
| 3 | 1 | A | 2 | 5 | 1.8 | |
| 3 | 1 | A R1 | 1 | 5 | 29.0 | 31.0 |

**Table 10. Continued**

| Vol ID | Board ID | Section | Rinse | Strokes | As µg | Total Both Rinse/Wipes As µg |
|---|---|---|---|---|---|---|
| 3 | 1 | A R1 | 2 | 5 | 2.0 | |
| 3 | 1 | A R2 | 1 | 5 | 28.0 | 29.4 |
| 3 | 1 | A R2 | 2 | 5 | 1.4 | |
| 3 | 1 | A R3 | 1 | 5 | 13.8 | 15.3 |
| 3 | 1 | A R3 | 2 | 5 | 1.5 | |
| 3 | 1 | C | 1 | 2 | 15.8 | 17.6 |
| 3 | 1 | C | 2 | 2 | 1.8 | |
| 3 | 1 | D | 1 | 10 | 24.0 | 25.4 |
| 3 | 1 | D | 2 | 10 | 1.4 | |
| 3 | 1 | F | 1 | 20 | 25.6 | 27.6 |
| 3 | 1 | F | 2 | 20 | 2.0 | |
| 4 | 4 | A | 1 | 5 | 34.4 | 37.0 |
| 4 | 4 | A | 2 | 5 | 2.6 | |
| 4 | 4 | A R1 | 1 | 5 | 30.4 | 32.2 |
| 4 | 4 | A R1 | 2 | 5 | 1.8 | |
| 4 | 4 | A R2 | 1 | 5 | 15.8 | 16.8 |
| 4 | 4 | A R2 | 2 | 5 | 1.0 | |
| 4 | 4 | A R3 | 1 | 5 | 15.8 | 17.4 |
| 4 | 4 | A R3 | 2 | 5 | 1.6 | |
| 4 | 4 | B | 1 | 2 | 15.6 | 17.8 |
| 4 | 4 | B | 2 | 2 | 2.2 | |
| 4 | 4 | C | 1 | 20 | 35.3 | 38.5 |
| 4 | 4 | C | 2 | 20 | 3.2 | |
| 4 | 4 | E | 1 | 10 | 54.4 | 58.0 |
| 4 | 4 | E | 2 | 10 | 3.6 | |

**Table 11. 3rd Hand Study, Phase 1: Polyester vs Kimwipe Sampling**

| Vol ID | Board ID | Section | Wipe | As µg | As µg per 100 $cm^2$ |
|---|---|---|---|---|---|
| 4 | 4 | D | Poly | 162 | 40.5 |
| 4 | 4 | F | Kim | 41.5 | 41.5 |
| 3 | 1 | B | Poly | 105.2 | 26.3 |
| 3 | 1 | E | Kim | 11.4 | 11.4 |
| 2 | 3 | A | Poly | 151.2 | 37.8 |
| 2 | 3 | E | Kim | 21.6 | 21.6 |
| 1 | 2 | E | Poly | 63.6 | 15.9 |
| 1 | 2 | D | Kim | 14.6 | 14.6 |
| | | **Avg** | **Poly** | **120.4** | **30.1** |
| | | **Avg** | **Kim** | **22.3** | **22.3** |

Note: Polyester surrogates were used to wipe 400 $cm^2$ area and Kimwipes were used to wipe 100 $cm^2$ area.

Table 12. 3rd Hand Study, Phase 1: Hand Results on Old Boards

| | | | | | | Total both Rinse/Wipes |
|---|---|---|---|---|---|---|
| Vol ID | Board ID | Section | Rinse | Strokes | As µg | As µg |
| 4 | 8405 | 1A | 1 | 20 | 12.2 | 45.0 |
| 4 | 8405 | 1A | 2 | 20 | 32.8 | |
| 4 | 8405 | 1B | 1 | 10 | 16.8 | 19.8 |
| 4 | 8405 | 1B | 2 | 10 | 3.0 | |
| 4 | 8405 | 1B R1 | 1 | 10 | 14.0 | 40.2 |
| 4 | 8405 | 1B R1 | 2 | 10 | 26.2 | |
| 4 | 8405 | 1B R2 | 1 | 10 | 16.2 | 17.0 |
| 4 | 8405 | 1B R2 | 2 | 10 | 0.8 | |
| 4 | 8457 | 2A | 1 | 10 | 18.2 | 19.2 |
| 4 | 8457 | 2A | 2 | 10 | 1.0 | |
| 4 | 8457 | 2A R1 | 1 | 10 | 7.2 | 7.8 |
| 4 | 8457 | 2A R1 | 2 | 10 | 0.6 | |
| 4 | 8457 | 2A R2 | 1 | 10 | 7.0 | 7.6 |
| 4 | 8457 | 2A R2 | 2 | 10 | 0.6 | |
| 4 | 8457 | 2B | 1 | 20 | 10.6 | 26.8 |
| 4 | 8457 | 2B | 2 | 20 | 16.2 | |
| 2 | 8405 | 2A | 1 | 20 | 9.4 | 9.6 |
| 2 | 8405 | 2A | 2 | 20 | 0.2 | |
| 2 | 8405 | 2B | 1 | 10 | 5.0 | 5.8 |
| 2 | 8405 | 2B | 2 | 10 | 0.8 | |
| 2 | 8405 | 2B R1 | 1 | 10 | 5.0 | 5.4 |
| 2 | 8405 | 2B R1 | 2 | 10 | 0.4 | |
| 2 | 8405 | 2B R2 | 1 | 10 | 2.4 | 2.8 |
| 2 | 8405 | 2B R2 | 2 | 10 | 0.4 | |
| 2 | 8457 | 1B | 1 | 10 | 9.0 | 10.2 |
| 2 | 8457 | 1B | 2 | 10 | 1.2 | |
| 2 | 8457 | 1B R1 | 1 | 10 | 15.2 | 16.0 |
| 2 | 8457 | 1B R1 | 2 | 10 | 0.8 | |
| 2 | 8457 | 1B R2 | 1 | 10 | 1.8 | 2.2 |
| 2 | 8457 | 1B R2 | 2 | 10 | 0.4 | |
| 2 | 8457 | 1C | 1 | 20 | 7.4 | 8.2 |
| 2 | 8457 | 1C | 2 | 20 | 0.8 | |

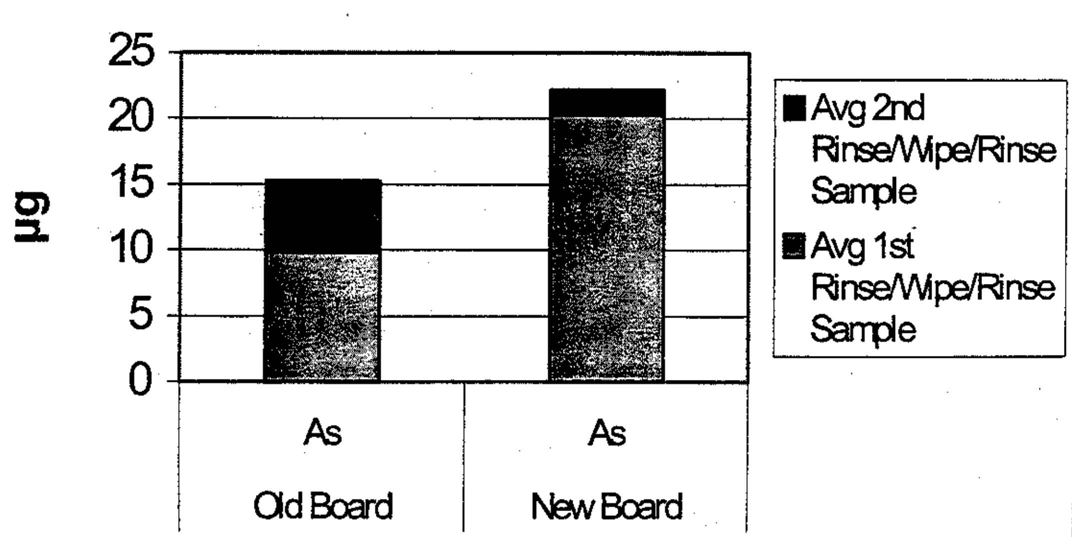
**Table 13. 3rd Hand Study, Phase 1: Polyester Wipes on Old Boards**

| Vol ID | Board ID | Section | As µg |
|---|---|---|---|
| 2 | 8457 | 1A | 60.0 |
| 2 | 8405 | 2C | 32.8 |
| 4 | 8457 | 2C | 12.0 |
| 4 | 8405 | 1C | 38.0 |
| | | Avg | 35.6 |

A second part of the study was designed to determine the correlation between hand wipes and surrogate materials. In the second phase of the hand study, two volunteers rubbed both new and old boards for 10 strokes over an area of 700 $cm^2$. HDPE, dry polyester, and wet polyester surrogates were used to wipe the same boards. The surrogate materials were wiped over 400 $cm^2$ for 10 strokes. Table 14 contains the results. The results of the 3rd hand study showed the following observations:

1. The polyester wipes and Kimwipes® picked up similar dislodgeable As amounts per unit of area rubbed and consistently picked up more dislodgeable As than the hand.
2. About 80-90% of the average dislodgeable As obtained from the hand rubs of new wood was found in the first rinse/wipe/rinse sample. Figure 6 shows the average relative amounts of As found in each rinse/wipe/rinse sample.
3. The hand results for the new and old boards were similar, but the disk results using the polyester wipe were 2-3 times higher on the new boards than the old boards. This is opposite of what was observed in the 1st hand study.
4. The dislodgeable As decreased with repeated rubbings on the same section. Figure 7 compares the average results for the repeated rubbings on the new boards
5. The dislodgeable As increased slightly when the number of strokes increased, but appeared to level off after 10 strokes for the new wood. Figure 8 compares the average results for the new boards.

**Figure 6. As Recovery in 3rd Hand Study**



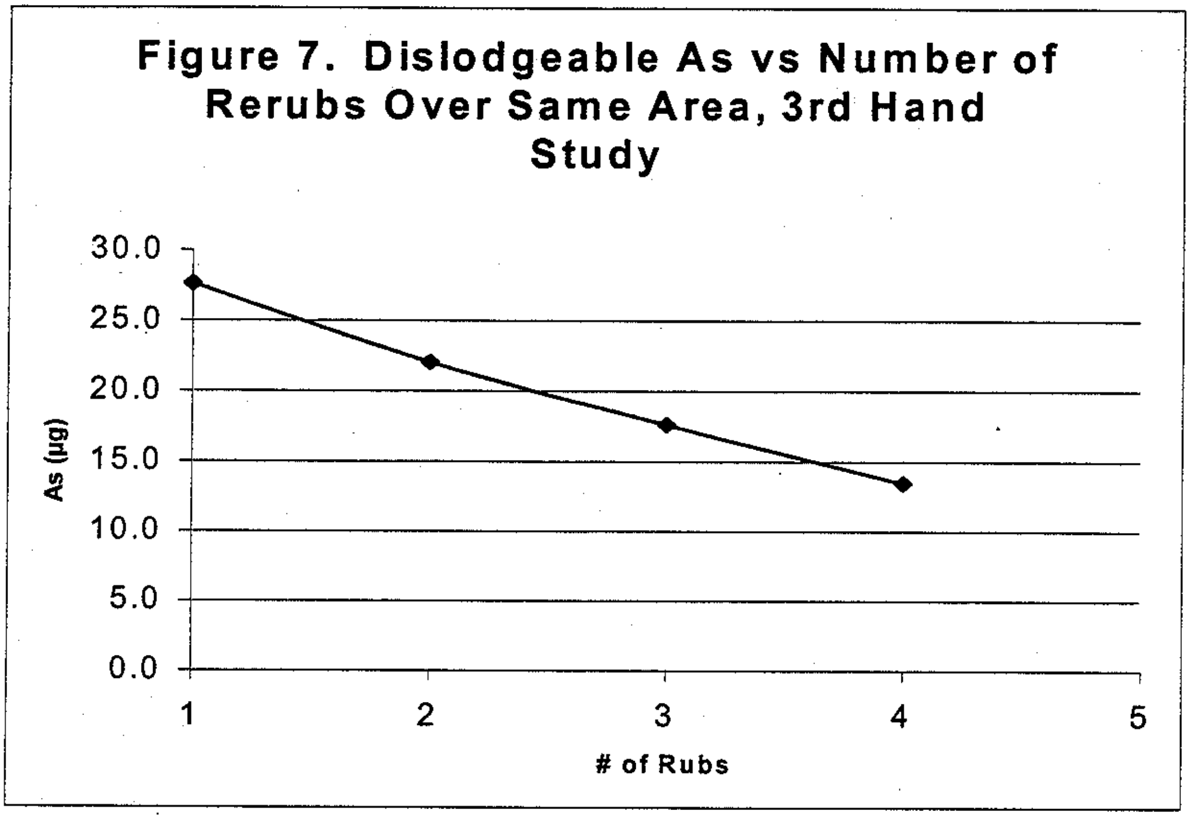



**Figure 7 Effect of rerubbing a board area: The 700 cm$^2$ board sections were rubbed 10 strokes. The rinse/wipe/rinse procedure was used to remove As. The board section was rerubbed. This was repeated a total of 4 times.**

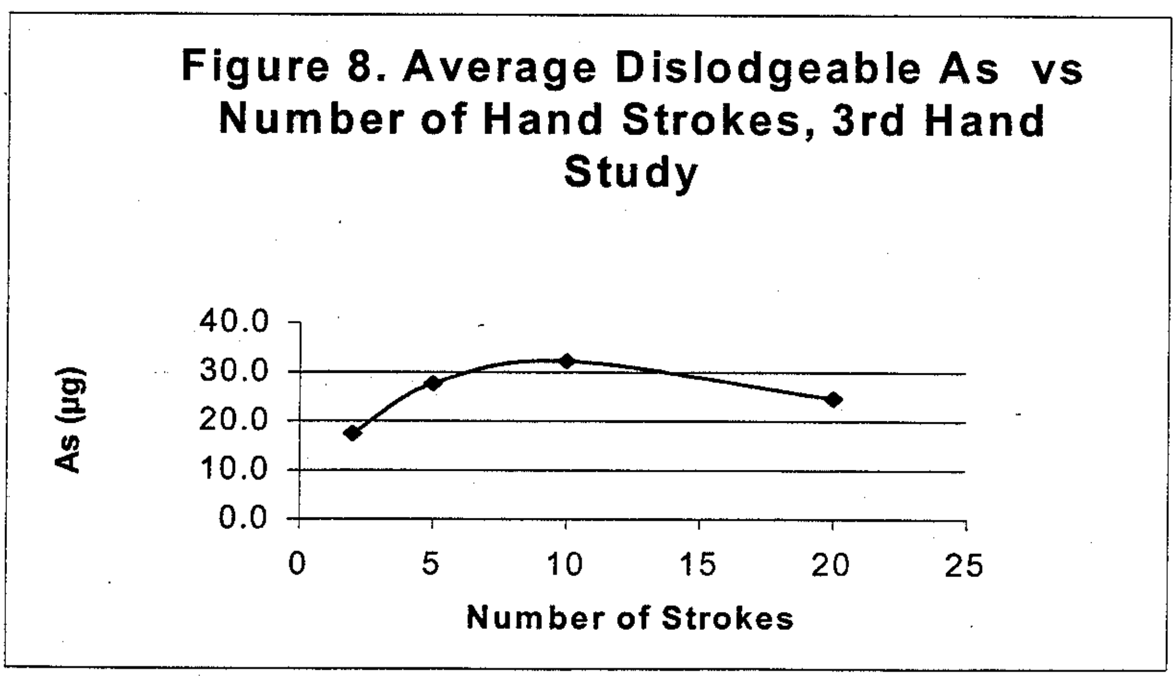


**Table 14 3rd Hand Study, Phase 2: Hand vs Surrogate Wipes**

| Vol ID | Board ID | Section | Wipe/Type | As µg |
|---|---|---|---|---|
| 1 | 8405-03 | A | HDPE | 10.1 |
| 1 | 8405-03 | B | Hand | 17.0 |
| 1 | 8405-03 | C | Wet Polyester | 88.4 |
| 1 | 8405-03 | D | Dry Polyester | 42.6 |
| 1 | 8406-04 | A1 | Wet Polyester | 175.5 |
| 1 | 8406-04 | A2 | Dry Polyester | 94.2 |
| 1 | 8406-04 | B | Hand | 41.6 |
| 1 | 8406-04 | C1 | HDPE | 30.3 |
| 1 | 8406-05 | D | Wet Polyester | 205.5 |
| 1 | 8406-05 | E | Hand | 22.2 |
| 1 | 8406-05 | F | HDPE | 19.2 |
| 1 | 8409-09 | F | HDPE | 44.4 |
| 1 | 8409-09 | G | Wet Polyester | 208.5 |
| 1 | 8409-09 | H | Dry Polyester | 129.0 |
| 1 | 8409-09 | I | Hand | 115.6 |
| 3 | 8405-02 | A | Wet Polyester | 98.6 |
| 3 | 8405-02 | B | HDPE | 6.3 |
| 3 | 8405-02 | C | Hand | 11.2 |
| 3 | 8405-02 | D | Dry Polyester | 50.1 |
| 3 | 8406-03 | A | Hand | 64.2 |
| 3 | 8406-03 | B1 | Wet Polyester | 217.5 |
| 3 | 8406-03 | B2 | Dry Polyester | 49.2 |
| 3 | 8406-03 | C1 | HDPE | 8.6 |
| 3 | 8406-05 | A | HDPE | 38.3 |
| 3 | 8406-05 | B | Hand | 30 |
| 3 | 8406-05 | C | Wet Polyester | 261.0 |
| 3 | 8409-09 | A | HDPE | 86.3 |
| 3 | 8409-09 | B | Dry Polyester | 38.1 |
| 3 | 8409-09 | C | Wet Polyester | 256.5 |
| 3 | 8409-09 | D | Hand | 23 |

**Additional Testing Done:**

*Vertical Wipe:* A test apparatus to be used on vertical posts was developed at the CPSC laboratory. Dislodgeable As results of boards tested vertically in the laboratory were similar to results obtained on boards tested horizontally. The wipes were conducted on sample 01-420-8460. All boards in this sample were 1"x6"x8". The wipes were conducted with the 1.1 kg disk over an area of 400 $cm^2$ for 10 strokes using saline wetted polyester wipes. Table 15 contains the results.

**Table 15. Vertical vs Horizontal Wipe Tests.**

| Sub | Location | Vertical/ Horizontal | µg As | Avg CCA per board (H vs V) µg As |
|---|---|---|---|---|
| 6 | A | H | 111.2 | 161.9 |
| 6 | B | H | 72 | |
| 6 | G | H | 244.8 | |
| 6 | H | H | 219.6 | |
| 6 | C | V | 93.6 | 159.8 |
| 6 | D | V | 68.4 | |
| 6 | E | V | 294 | |
| 6 | F | V | 183.2 | |
| 7 | A | H | 101.6 | 96.8 |
| 7 | B | H | 148.8 | |
| 7 | G | H | 71.2 | |
| 7 | H | H | 65.6 | |
| 7 | C | V | 136.4 | 98.9 |
| 7 | D | V | 93.2 | |
| 7 | E | V | 78.8 | |
| 7 | F | V | 87.2 | |

*Dry Polyester Surrogate:* Dry polyester wipes were used to rub various areas of boards to determine loading potentials and suitability as a possible surrogate for future field testing. Wipes were conducted on samples 02-420-8407. Nine boards designated as subs 01-09 were used for this study. Each side of the 9 boards was divided into 4 sections. On one side of the board the sections were designated A-D. On the opposite side of the board the sections were designated E-H. Figure 9 shows the arrangement of the 8 locations along a board. The board areas tested were 240 $cm^2$, 400 $cm^2$, and 800 $cm^2$, and the number of strokes varied from 5 to 25. One section of the board was used for the 240 $cm^2$ and 400 $cm^2$ areas. Two adjacent board sections were required for the 800 $cm^2$ area. After rubbing the boards, each wipe was removed from the disk; placed in a test tube containing 10% nitric acid, and extracted over night (approximately 22 hours) at 60°C. The extracts were analyzed for As using ICP.

**Figure 9: Sample Locations on Boards**

| | | | |
|---|---|---|---|
| A | B | C | D |
| E | F | G | H |

The results of the dry polyester testing are contained in table 16. The dry polyester picked up increasing amounts of As when the area of the board was increased. It appears an increase in area results in a proportionate increase in dislodgeable As.

A discussion of these data as they pertain to the exposure assessment from CCA-treated wood can be found in Thomas (2003)[4] and Levenson (2003)[3].

The following results were noted:

1. There appears to be a maximum loading capacity of a material to pick up dislodgeable As, This maximum capacity is much higher for the polyester wipes than the hand The maximum loading capacity of the bare hand is much lower and seems to have been reached during hand study experiments discussed in this report.

**Table 16. Dislodgeable Amounts of Arsenic using Dry Polyester Wipes**

| Sub | Location | Area ($cm^2$) | Strokes | As (µg) | Average As (µg) |
|---|---|---|---|---|---|
| 3 | C | 240 | 5 | 45.0 | 48.6 |
| 3 | F | 240 | 5 | 25.7 | |
| 4 | A | 240 | 5 | 75.2 | |
| 3 | D | 240 | 10 | 73.1 | 52.9 |
| 3 | G | 240 | 10 | 38.7 | |
| 4 | B | 240 | 10 | 46.8 | |
| 3 | E | 240 | 25 | 27.3 | 48.8 |
| 3 | H | 240 | 25 | 37.8 | |
| 4 | C | 240 | 25 | 81.3 | |
| 2 | B | 400 | 5 | 45.5 | 70.2 |
| 2 | E | 400 | 5 | 98.9 | |
| 2 | H | 400 | 5 | 66.3 | |
| 2 | C | 400 | 10 | 81.0 | 119.0 |
| 2 | F | 400 | 10 | 128.4 | |
| 3 | A | 400 | 10 | 147.5 | |
| 2 | A | 400 | 25 | 99.8 | 118.6 |
| 2 | D | 400 | 25 | 125.3 | |
| 2 | G | 400 | 25 | 130.7 | |
| 7 | GH | 800 | 5 | 186.0 | 236.0 |
| 8 | EF | 800 | 5 | 129.0 | |
| 9 | CD | 800 | 5 | 393.0 | |
| 8 | AB | 800 | 10 | 219.0 | 155.8 |
| 8 | GH | 800 | 10 | 147.0 | |
| 9 | EF | 800 | 10 | 101.3 | |
| 8 | CD | 800 | 25 | 192.0 | 226.2 |
| 9 | AB | 800 | 25 | 372.8 | |
| 9 | GH | 800 | 25 | 113.9 | |

Averages are average results obtained for the 3 wipes that were done on the same size area with the same number of stokes

**REFERENCES**

1. Memorandum to Elaine Tyrell (EX-PM) from Bhawanji Jain, LSC *Report on Leaching, Distribution and Dislodgeable Arsenic and Copper from Pressure-treated and untreated Wood* Jan 1990, CPSC
2. Stillwell, D.E., Arsenic from CCA-treated wood can be reduced by coating. *Frontiers of Plant Science.* Fall 1998. pp 6-8
3. Memorandum to Patricia Bittner (HS) from Mark Levenson (EPHA), *Statistical Analysis of Laboratory Studies of CCA Wood: Phases I and II* 2003, U.S. Consumer Product Safety Commission
4. Memorandum to Patricia Bittner (HS) from Treye Thomas (HS) *Determination of Dislodgeable Arsenic Transfer to Human Hands and Surrogates From CCA-Treated Wood* January 2003, U.S. Consumer Product Safety Commission