Evaluation of the Effectiveness of Coatings in Reducing Dislodgeable Arsenic, Chromium, and Copper from CCA Treated Wood

Interim Data Report

Category II/Sampling and Analysis

EPA Report: EPA/600/R-05/050

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Contract Number:
EP-C-04-023
Work Assignment Number 1-05

Our Ref.:
RN990231.0005

Date:
9 May 2005

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Acronym List

As	Arsenic
av	Average
AWPA	American Wood Preservers' Association
BL	Baseline
CCA	Chromated Copper Arsenate
CD-Rom	Compact Disk – Read Only Memory
CL	Confidence Limits
CLP	Contract Laboratory Program
CPSC	Consumer Product Safety Commission
DA	Dislodgeable CCA Wood Analytes
DAs	Dislodgeable Arsenic
DCr	Dislodgeable Chromium
DCu	Dislodgeable Copper
DI	Deionized Water
DPD	Dew Point Depression
DQI	Data Quality Indicator
EPA	United States Environmental Protection Agency
ERC	Environmental Research Center (old building)
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
H&S	Health and Safety
ICP	Inductively Coupled Plasma
ICP-MS	Inductively Coupled Plasma—Mass Spectrometry
ID	Identification

mph	Miles Per Hour
MS	Matrix Spikes
MS/MSD	Matrix Spikes and Matrix Spike Duplicates
MSD	Matrix Spike Duplicates
NCDC	National Climate Data Center
NE	Northeast
NFG	National Functional Guidelines
NOAA	National Oceanic and Atmospheric Administration
NOPW	Number of Previous Wipes
NW	Northwest
NWS	National Weather Station
OLS	On-Site Laboratory Support
OPP	Office of Pesticide Programs
pcf	Pounds per Cubic Foot
PEA	Performance Evaluation Audit
PFA	Perfluoroalkoxy
PM	Project Manager
PSA	Primary Sampling Area
PTFE	Polytetrafluoroethylene
QA/QC	Quality Assurance and Quality Control
QAPP	Quality Assurance Project Plan
RDU	Raleigh—Durham International Airport
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
RSD/RPD	Relative Standard Deviation or Relative Percent Deviation

RTP	Research Triangle Park
SAP	Scientific Advisory Panel
Std. Dev.	Standard Deviation
STL	Severn Trent Laboratory
SYP	Southern Yellow Pine
TFE	Tetrafluoroethylene
TTPW	Time (Months) Since the Previous Wipe
U.S.	United States
WA	Work Assignment
UV	Ultraviolet

Executive Summary

EPA is approximately 20 months into a project to evaluate the performance of wood coatings for preventing arsenic, chromium, and copper exposure from the surfaces of CCA treated wood. Potential dermal exposure, as measured by wipe sampling dislodgeable CCA chemicals from the wood surfaces, is the primary evaluation criteria for the coatings testing in this study, but EPA is also concerned with exposure due to ingestion and inhalation. Ingestion is related to dermal exposure because of hand-to-mouth activities, particularly in children. Likewise, inhalation may potentially pose an exposure route when consumers are preparing wood surfaces for coating and recoating. The data collected and reported in this interim data report, which reports on results of the study through 11 months, will be used to inform the EPA risk assessment and to provide consumers recommendations on mitigating exposure to CCA on residential structures, such as decks. A critical component of this project is the development of a robust protocol for evaluating coating performance in mitigating exposure, since standardized protocols generally do not yet exist. As such, considerable effort has been placed on the development of the testing plan and the report addresses the development of test protocols in some detail.

The testing protocol involved the construction of a series of miniature decks (minidecks) to each of which one of twelve coatings was applied. Each minideck contained four CCA-treated boards: two from a relatively old source deck and two from a relatively new source deck. Each coating was applied to three minidecks and there are also three positive control (treated, uncoated) minidecks and one negative control (untreated, uncoated) minideck for a total of 40 minidecks. After coating, the minidecks have been subjected to natural outdoor weathering at a controlled site in North Carolina where an array of climatological measurements are recorded on a near-continuous basis. Dislodgeable CCA (DA) has been measured using a wipe sampling technique pre-coat (baseline), and at 1, 3, 7, and 11 months after coating in an effort to assess coating performance over time, subject to natural outdoor weathering. A number of other samples have been taken, as have visual observations, all of which are reported and discussed in the ensuing report.

The primary purpose of this study is to provide EPA with data needed to make and support guidance to consumers regarding mitigating health risks associated with the continued use of CCA treated wood structures, like decks. As such, the coatings that were tested were ranked based on their performance. Upper tier performers generally reduced dislodgeable arsenic (DAs) by about 90% or greater after 11 months, middle

tier performers generally reduced DAs by about 75% or greater at 11 months, and lower tier performers generally reduced DAs by about 75% or less at 11 months.

While the top two performers were film-forming coatings – the only two paints tested (coatings #9 and #10) – several other, more typical deck treatment products performed almost as well. The painted minidecks show significant weathering, with an oil-based paint seeming to resist chipping better than a water-based paint. However, there are significant concerns about the applicability of using paints as coatings for exposed outdoor surfaces subject to abrasion. Weathered paints can have a noticeably poor appearance, necessitating frequent recoating. Additionally, the chipping of paints and surface preparation techniques for recoating, which typically include sanding, can generate dust which may make inhalation of CCA-contaminated particles a serious health risk.

Another film-former, an elastic vinyl product designed to encapsulate CCA wood (coating #11), performed very well initially, but appeared to fall off slightly in comparison to other high-performing products over time. This product additionally exhibited significant biological growth and associated discoloration.

Within the remaining coatings, no clear trends with respect to product type or characteristics are immediately evident. The best non-film-forming products were identified as coatings #1, #3, and #8. Coating #1 is an oil-based semitransparent sealant in cedar tone. Coating #1 additionally contains a UV blocking agent. Another coating containing a UV blocker (coating #7) did not perform as well. Coating #3 is a clear, oil-based, acrylic, deep tone base stain to which no pigment had been added prior to application. Coating #8 is a clear, water-based, acrylic, tint base, solid stain to which no pigment had been added prior to application.

Additionally, we can say that:

- Rinsing the wood surfaces reduces DA measured by wipe sampling, although it may simply relocate the CCA chemicals to other places where exposure is possible.
- Coating the wood surfaces further reduces DA over uncoated surfaces.
- Weathering reduces the effectiveness of coatings as seen by increases in DA.

- Some coatings perform better than others in terms of DA reduction but there are inconsistencies between coatings within the same classification.

- Coating product trade names are not tied to specific formulations, potentially complicating the ability to communicate results and guidance effectively with the public.

Significant findings with regards to the test protocol include the following:

- The protocol appears robust and could be used by the coatings industry to develop coatings and to verify coating performance for CCA exposure mitigation.

- Cross-contamination has not been a problem.

- Baseline (pre-coat) DA can be determined either for each specific wipe area or averaged over each board. Precoat measurements should preferably be taken both before and after preparing the wood surface (e.g., washing, rinsing, etc.) for coating.

- The effects of abrasion resulting from the wipe sampling method used for this study appear to be negligible, thus avoiding potential complications, or false positive interferences, as a result of the sampling methodology.

- Rewipe effect – that is, the reduction in DA post-sampling may be significant.

- There appears a relatively strong correlation between DAs, DCr, and DCu. That is, wipe areas with high DA measurements for one CCA analyte generally also have high DA measurements for the other CCA analytes.

- The method by which coating efficacies are calculated or modeled did not appear to have an appreciable effect on the rank order of coatings.

The project will continue with sampling events having already been conducted at 15 and 19 months, and planned for 23 months post-coating.

Abrasion is considered another likely important coating performance factor which is not vigorously tested by the protocol currently employed. Future studies may include an assessment of the effect of abrasion on coating performance.

1. Project Description and Organization

1.1 Overall Project Objectives

The primary objective of this project is to evaluate the ability of selected coatings to reduce the amount of dislodgeable chromated copper arsenate (CCA) analytes (DA) on the surfaces of CCA-treated wood. Two sources of weathered CCA-treated southern yellow pine (SYP) were harvested from in-service decks and used to construct a series of miniature decks (minidecks), onto which selected coatings have been applied. Dislodgeable arsenic (DAs), chromium (DCr), and copper (DCu) are measured at specified intervals. The coated lumber is subjected to natural weathering outdoors. The ability of the coatings to reduce DA as the wood and coatings weather is being evaluated by periodically determining the amount of DA removed from the surface of the wood specimens using a wipe technique.

For the purposes of this study, DA is defined as the amount of CCA analyte removed from the surface of the test specimen by the dermal wipe procedure (with minor modifications) developed and demonstrated by the staff of the Consumer Product Safety Commission (CPSC), which is a collaborator on this project via an interagency agreement (CPSC-I-03-1235) between the United States Environmental Protection Agency (EPA) and CPSC. EPA-CPSC staff wipe comparison data (refer to EPA Wipe Comparison Study Report in Appendix A) indicates that measured DA values are method-specific and may depend upon a number of variables including wipe material, device used, number of passes, moisture content of the wipe, and the area of the surface wiped. It is believed that DA measured via the wipe sampling procedures utilized in this study is proportional to the surface area wiped. Other researchers have measured DA and reported DA on a mass per area wiped basis (Stilwell, et al., 2003; Stilwell 2003a, 2003b). Therefore, for the purposes of this study, DA is expressed in units of mass per surface area wiped ($\mu g/cm^2$).

The data obtained will be used by EPA and CPSC staff in support of efforts to inform the public regarding the use and maintenance of existing CCA-treated wood products, such as decks and playground equipment. A supplemental objective of this study is to evaluate and demonstrate the use of the test protocol and to begin to understand its utility and realism, and to identify future research needs. This second objective is relevant because there are currently no standardized protocols for determining the efficacy of coatings to reduce DA from CCA-treated wood. In this regard, the test is a pilot study that may set the stage for systematic development of standardized test methods that will promote development, evaluation, and

demonstration of products that mitigate the potential for dermal contact with DA from CCA-treated wood.

Note that few products are currently manufactured explicitly for the purpose of reducing DA from CCA-treated wood. Hence, EPA is primarily evaluating the efficacy of products to perform a task that is not necessarily related to the manufacturer's design or intent. As such, the test results should not be construed to represent an evaluation of a product's effectiveness for those purposes for which it was designed and warranted by the manufacturer.

This interim data report covers all baseline measurements taken, wood preparation and coating application data, and mitigation sampling at 1, 3, 7, and 11 months after coating application, in addition to other supporting data collected as part of the study to date. The test plan is described in detail in the Category 2 QAPP entitled, "Evaluation of the Effectiveness of Coatings in Reducing Dislodgeable Arsenic, Chromium, and Copper from CCA Treated Wood," dated September 24, 2003 (U.S. EPA 2003).

1.2 Background

CCA is a wood preservative registered under FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act) by EPA Office of Pesticide Programs (OPP) and impregnated under pressure to protect wood from decay and insect damage. In October 2001, EPA-OPP prepared a preliminary deterministic exposure assessment for selective internal and external peer review comments as an interim report intended to address child residential "playground" exposures. In addition, EPA requested guidance from the FIFRA Scientific Advisory Panel (SAP) for risk mitigation measures such as sealants and coating processes. The SAP Panel made "recommendations regarding the need for additional studies in this area..." because the "weight-of-evidence from available studies indicates that certain coatings can substantially reduce dislodgeable and leachable CCA chemicals." The Panel also recommended that "EPA inform the public of the ability of certain coatings to substantially reduce leachable and dislodgeable CCA chemicals…"

In March 2003, the registrants of CCA wood preservatives signed an agreement with EPA for voluntary cancellation of CCA-treated wood for residential uses (such as playsets and decks) effective beginning January 1, 2004. However, existing decks and playsets made of CCA-treated wood will still be in use. Therefore, the potential remains for dermal contact with arsenic, chromium, and copper residues on treated

surfaces, and the risk, especially to the most susceptible subpopulation, infants and small children, due to their close contact with surfaces and hand-to-mouth activities, is a concern. This project will provide EPA with information that can be used to provide the public with guidance on the use of coatings to prevent contact with DA from CCA-treated wood.

To provide consumers with effective guidance, EPA must have a basic understanding of the impact of key variables on the efficacy of coating and sealant systems. Key environmental variables include exposure to natural weathering phenomena including ultraviolet (UV) radiation, condensation, precipitation, and thermal shock. Efficacy of coatings may also be impacted by level and fixation of CCA treatment, age and condition of the wood at the time of coating, and type and dimensions of the treated wood. Due to the large number of variables, and EPA's desire to provide guidance quickly for in-service wood, this project evaluates selected coatings applied to aged CCA-treated wood [southern yellow pine (SYP)] exposed to natural outdoor weathering at a site in North Carolina. Accelerated chamber weathering testing was originally contemplated as a component of this study, but the decision was made, based on available resources and peer review comments, to focus on the more realistic outdoor testing strategy. An accelerated weathering chamber testing protocol may be developed as a companion piece to this research, although a number of technical and logistical issues must first be resolved. Accelerated weathering has the potential to allow an evaluation of the impact of weathering on efficacy of coatings in reducing DA in a relatively short time period (e.g., less than one year). While the study includes weathering, which is known to be a major factor in the degradation of coatings over time, it does not include abrasion, which is likely to be significant, particularly for walking surfaces, such as those on decks. Thus, abrasion testing has also been considered as a companion piece to the testing described herein.

Before proceeding further, it is essential to define the terminology used in this report. Wood nomenclature used in this report is defined in Figure 1-1. Note that a "board" is defined as the unit of wood purchased or removed from an existing structure, while "specimen" refers to the pieces of each board cut for this project (note that "specimens" are sometimes called "coupons" in weathering testing jargon). Furthermore, areas on specimens that were wipe-sampled during each sampling interval are termed "primary sampling areas" (PSA), in contrast to adjacent areas which were not sampled at each interval. Each specimen used in this project contained one PSA and one adjacent area.

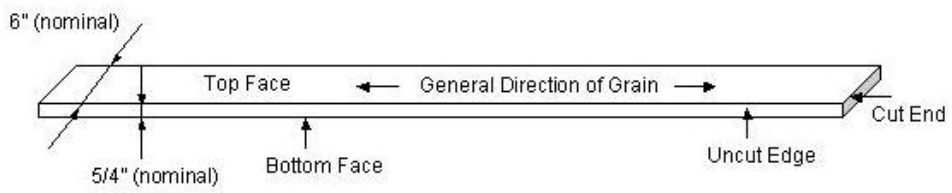


Figure 1-1. Wood Member Nomenclature

Note that all sampling was done on the top faces of the boards; that is, the face of the board that was originally exposed, facing up, on the source deck. Furthermore, note that a "grain-up" or "bark side up" board is defined as one where the tree rings, evident on the cut end of the board, form a convex pattern (a "hill") when observed with the face of the board that was exposed on the source deck facing up. Likewise, a "grain-down" or "bark side down" board is defined as one where these rings form a concave (a "valley") pattern when the exposed face is facing up. Since wood tends to deform along these ring lines, grain orientation may be an important variable in the measurement and mitigation of DA on surfaces of CCA-treated wood. Grain-down boards tend to deform in a manner which "cups" and holds water and moisture, while grain-up boards tend to deform in a manner which sheds water from the surface of the board. For this reason, it is typically recommended to build outdoor structures, like decks, with boards oriented grain-up, though it appears that many contractors do not control this particular variable and grain-up and grain-down boards are commonly found randomly located within a single deck.

1.3 Experimental Design and Scope

Weathering tests are being conducted using minidecks which are exposed to natural weathering conditions outdoors at a site in North Carolina. Because no standard outdoor weathering protocols for testing the efficacy of coatings in reducing DA exposure currently exist, the project can be thought of as a pilot study. It is hoped that the results gained through its execution not only support EPA's goals of evaluating and reducing risk of contact with chemicals dislodged from CCA-treated wood, but also provide a framework of methodology to inform the design of future studies (in addition to identifying areas needing future study).

Minideck surfaces were constructed of alternating untreated and CCA-treated specimens. The treated specimens were taken from two in-service CCA wood source decks. Prior to coating the minidecks, baseline DA concentrations were determined

by averaging the results of wipe samples from areas adjacent to the sampling areas which have been and are being sampled at regular intervals after coating. The minidecks were then prepared for coating according to that coating manufacturer's recommendations. As such, some of the minidecks were treated differently than others, depending on their coating. Coating was then applied to each minideck (three minidecks per coating) per coating manufacturer's instructions. After allowing the coatings to dry and cure, the minidecks were subjected to natural weathering outdoors at a site in North Carolina. Then, at specified intervals (1 month, 3 months, 7 months, and 11 months after coating), each specimen was wipe-sampled for measurement of DA.

1.4 Data Quality Objectives

The critical measurements for the natural weathering tests are total arsenic, total chromium, and total copper concentrations, which are subsequently converted to dislodgeable arsenic, chromium, and copper, which are reported on a mass per unit area basis. Data quality indicator (DQI) goals for concentration in terms of accuracy, precision, and completeness, as established in the QAPP for this project, are shown in Table 1-1. The QA review of the data, discussed in detail in Section 5, recommends different DQI goals, based on the results of this project to date. Such recommendations will be valuable to researchers designing and conducting similar future studies.

Table 1-1. Data Quality Indicator Goals for Critical Measurements

Analyte	Method	Accuracy (%Recovery)	Precision (%RSD/RPD)	Completeness (%)
Arsenic (total)	SW-846 Method 6020 (modified)	90-110	10	90
Chromium (total)	SW-846 Method 6020 (modified)	90-110	10	90
Copper (total)	SW-846 Method 6020 (modified)	90-110	10	90

1.5 Project Organization and Responsibilities

The EPA Work Assignment Manager for this project is Mark Mason, who coordinates involvement by other EPA staff and CPSC staff via an interagency agreement (CPSC-I-03-1235) between EPA and CPSC staff, as appropriate. Paul Groff, EPA's QA Officer for this project reviews project QAPPs and reports, audits sampling methodology, and has stop-work authority on the project. Key CPSC staff

includes Jacque Ferrante, Dave Cobb, and Joel Recht. Key EPA Office of Pesticide Programs (OPP) staff includes Jack Housenger, Norm Cook, Nader Elkassabany, Timothy Leighton, and Jonathan Chen. The ARCADIS work assignment leader (WAL) is Victor D'Amato, who is intimately involved with most facets of the project including test plan development, data analysis, data reporting, project and fiscal management, and regular reporting tasks. Libby Nessley, with ARCADIS, serves EPA by providing quality assurance and quality control (QA/QC) management services, while Todd Thornton and Jerry Revis, both with ARCADIS, serve EPA by providing health and safety management services. Kevin Bruce, with ARCADIS, is the overall on-site laboratory support (OLS) project manager. Johannes Lee, with ARCADIS, is the assistant project manager for the OLS contract, and, as such, provides a variety of administrative support functions. Matt Clayton, with ARCADIS, procured, characterized, cut, prepared and coated wood samples, in addition to coordinating preparation of the test site. Peter Kariher, Michele Addison, and Sara Easterly, all with ARCADIS, have taken samples, prepared samples via digestion, and shipped digested wipe and control samples to the subcontract analytical laboratory, Severn Trent Laboratory (STL)-Savannah (Angie Weimerskirk, Project Manager). Michele Addison also manages the data generated via this study in addition to supporting other key project tasks. Krich Ratanaphruks, with ARCADIS, provides relational database and data management support and was responsible for producing many of the data analysis report graphics in this report. Len Stefanski, an EPA contractor at North Carolina State University, provides detailed statistical support to the analysis and interpretation of the data. An organizational chart is provided as Figure 1-2. Table 1-2 provides contact information for project staff.

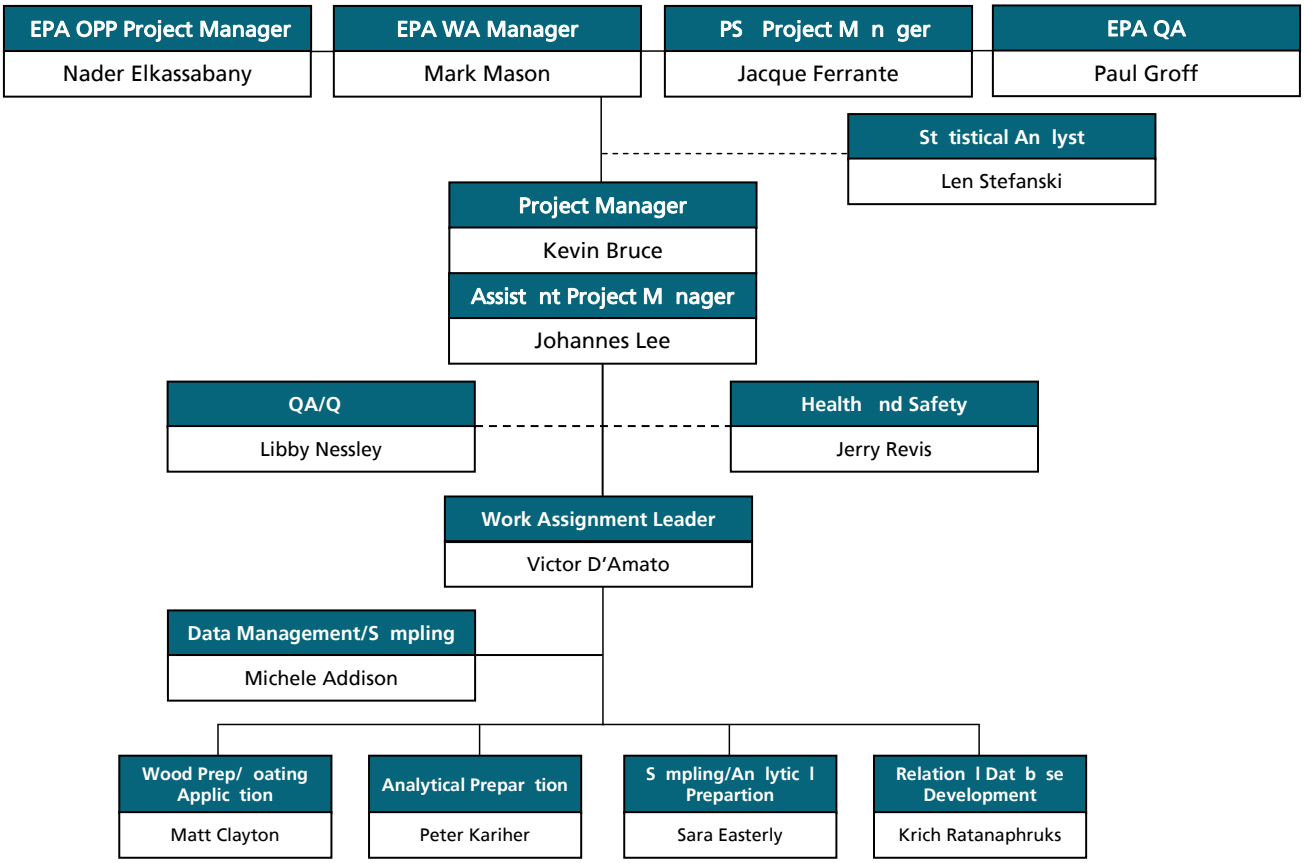


Figure 1-2. Organizational Chart for Weathering Testing

Table 1-2. Contact Information for Key Project Staff

Staff Contact	Organization	Position	Phone Number	E-mail Address
Mark Mason	EPA	Work Assignment (WA) Manager	(919) 541-4835	Mason.Mark.@ epa.gov
Paul Groff	EPA	EPA QA Manager	(919) 541-0979	Groff.Paul@epa.gov
Jacque Ferrante	CPSC	Health Sciences	(301) 504-7259	jferrante@cpsc.gov
Dave Cobb	CPSC	Lab Sciences	(301) 421-6421	dcobb@cpsc.gov
Joel Recht	CPSC	Lab Sciences	(301) 421-6421	jrecht@cpsc.gov
Jack Housenger	EPA-OPP	Associate Director	(703) 308-8163	Housenger.Jack@epa.gov
Tim Leighton	EPA-OPP	Exposure Assessor	(703) 305-7435	Leighton.Timothy@epa.gov
Norm Cook	EPA-OPP	Branch Chief	(703) 308-8253	Cook.Norm@epa.gov
Nader Elkassabany	EPA-OPP	Project Manager	(703) 308-8783	Elkassabany.Nader@epa.gov
Jonathan Chen	EPA-OPP	Toxicologist	(703) 305-1287	Chen.Jonathan@epa.gov
Victor D'Amato	ARCADIS	WA Leader	(919) 544-4535	vd'amato@arcadis-us.com
Libby Nessley	ARCADIS	QA Manager	(919) 544-4535	lnessley@arcadis-us.com
Todd Thornton	ARCADIS	Health & Safety (H&S) Manager	(919) 544-4535	tthornton@arcadis-us.com
Jerry Revis	ARCADIS	H&S Manager	(919) 544-4535	jrevis@arcadis-us.com
Kevin Bruce	ARCADIS	PM, Advisor	(919) 544-4535	kbruce@arcadis-us.com
Peter Kariher	ARCADIS	Lab Scientist	(919) 544-4535	pkariher@arcadis-us.com
Matt Clayton	ARCADIS	Lab Scientist	(919) 544-4535	mclayton@arcadis-us.com
Krich Ratanaphruks	ARCADIS	Database Analyst	(919) 544-4535	kratanaphruks@arcadis-us.com
Michele Addison	ARCADIS	Data Management	(919) 544-4535	maddison@arcadis-us.com
Angie Weimerskirk	STL-Savannah	Analytical Manager	(912) 354-7858	aweimerskirk@stl-inc.com
Len Stefanski	NCSU	Statistician	(919) 515-1945	stefanski@stat.ncsu.edu

2. Test Methods

The following subsections describe in detail the methods used in this study, including, but not limited to the selection of materials for testing, construction of minidecks, preparation of wood surfaces to be coated, application of selected coatings to the CCA-treated substrates, site preparation and maintenance, weather monitoring, and sampling and analysis procedures.

2.1 Overall Study Design

2.1.1 Scope

Twelve (12) coatings have been applied to minidecks constructed using two sources of aged CCA-treated wood, as well as new untreated wood as blank, cross-contamination controls. Each minideck contains nine decking specimens: two specimens from each of the aged wood sources (one specimen with bark side up grain orientation and one with bark side down orientation), separated by specimens of new untreated wood (all positioned bark side up) to prevent cross-contamination and to serve as blank controls to assess cross-contamination potential as a result of splash-over of rain water, for example. The minidecks were constructed with each of the aged wood specimens facing up; that is, with the same top face as the specimen had during its exposure on its source structure. Each of the twelve coatings has three (i.e., triplicate) associated minidecks constructed. Additionally, three uncoated minidecks are used as controls. Each aged wood specimen has been wipe-sampled from the same area at 1, 3, 7, and 11 months after coating. The results of samples taken 1 month after coating essentially yield “initial efficacy” results which may provide some information on the relationship between initial and longer-term efficacy and could thus inform the design of a relatively rapid screening study if appropriate. It is also significant that the samples taken 1 month after coating were taken from sampling areas that had never been sampled previously.

Coated minidecks are exposed to natural weathering conditions at a controlled site in North Carolina for which high quality meteorological data has been routinely collected; these data have been used to confirm the weather monitoring data collected during this project. Additionally, three identical, but uncoated, minidecks and one, untreated, uncoated minideck are included as controls. The position of each minideck on the site was randomized at the start of the test, though their directional orientation was the same. DA was determined via wipe sampling at prescribed intervals. These

DA results were compared with baseline DA in order to determine efficacy (percent reduction in DA) of each coating and to rank coatings at each sampling event.

Baseline measurement of DA as well as routine wipe samples for measurement of DA after coating application and as weathering progressed, were the primary samples taken during this testing. Supporting samples collected include wood core samples, and liquid samples of the coatings applied, among others. The natural outdoors weathering study methods are described in more detail later in the ensuing subsections.

2.1.2 Data Product and Use

The outdoor weathering test offers a means of evaluating the efficacy of coatings on horizontal surfaces with stresses on the specimens resulting from their attachment to the minideck support members and of course, per exposure to natural weathering conditions.

The efficacy of each coating in reducing DA on aged CCA-treated wood has been evaluated as a function of time exposed to natural weathering outdoors.

Post-coat DA has been determined by wipe sampling triplicate specimens of each coating on each of two aged wood sources with two different bark orientations. Percent reduction in DA has been calculated using several alternate computational techniques, described in more detail in Sections 3 and 4. Coatings have been ranked according to their efficacy based on average percentage reduction of DA.

2.1.3 Study Limitations

While the primary objective of the testing reported herein was to evaluate coatings for their efficacy in reducing DA when coated wood is subjected to weathering, available resources were limited and dictated that the project be focused in a way that precluded the ability to answer all of the myriad questions raised in the development and evaluation of this test protocol. Difficult choices had to be made in a number of important areas in order to meet the resource and time constraints posed by this project. The objective of the following discussion in this section is to better define study limitations, and unanswered questions that may be applicable as a focus for future research work.

2.1.3.1 Stress Factors

Due to the relatively small size of the minidecks, the stress factors generated by attached specimens during weathering may not be representative of those generated in full-sized structures. However, a 16-inch on-center placement of fastening screws has been used in the construction of the minidecks, as typical in the construction of full-sized decks.

2.1.3.2 Application Technique

It is possible that the method of applying coatings may contribute to measured DA levels. For example, applying coating using a brush may cause physical displacement of dislodged analytes and subsequent mixing with the applied coating or displacement of the analyte to the finished coated surface. As such, a pre-qualification study to evaluate coating application techniques (e.g., brush versus spray) was considered as a screening test component, but later determined to be outside of the scope and resource allocation available for this project. Wood was prepared and coatings were applied per manufacturer's instructions. A brush application coating technique was used for each coating. It is believed that such a technique represents the most common method employed by residential users of deck coatings.

2.1.3.3 Surface Preparation for Coating

The preparation of the wood surface prior to coating may be important in several ways. First, it is possible that the surface preparation method itself may constitute a significant exposure activity. For example, sanding CCA wood surfaces without proper respiratory equipment may facilitate exposure via inhalation. The surface preparation technique may also impact the pre-coat DA levels (see further discussion of this in section 2.1.3.5 in the discussion of baseline measurements) as well as future migration of CCA analytes to the surface of the wood. In this study, the coating manufacturer's printed instructions with regards to surface preparation were followed strictly. Baseline measurements, used in some calculations of efficacy, were taken prior to any surface preparation or rinse step.

2.1.3.4 Type and Condition of Aged Wood

Only two sources of aged CCA-treated wood are being tested, which is not likely to be representative of the universe of CCA wood structures currently in service. For

this study, the two sources represent different ages and conditions of the same species wood (southern yellow pine).

2.1.3.5 Re-rubbing Effects and Baseline Sampling

A significant logistical issue arises as a result of the sampling process itself and the fact that the wipe sampling technique changes the surface of the wood in at least two ways: by removing the CCA on the surface of the wood, and by potentially abrading the wood or its coating.

Ideally, initial surface wipe samples would be taken from each sampling area to be further tested. However, several studies suggest that, as could reasonably be expected, the act of wipe sampling the surfaces of CCA-treated wood removes a considerable amount of the DA from a test specimen (CPSC staff 2003a, Stilwell 2003a). Furthermore, wipe sampling is a form of "abrasion" which is suspected to be a significant variable in determining both uncoated DA as well as durability and efficacy of tested coatings. Clearly, there is virtually no alternative to wipe sampling coated surfaces to determine DA (except perhaps by leachate sampling for which no transfer relationships have been developed that relate mass leached from a sample to amount transferred to a hand). While it may be possible to attempt to artificially correct DA results for the effects of rerubbing (i.e., per the analysis of appropriate control samples and subsequent modification of measured DA on individual specimens), the decision was made to not sample the PSAs prior to coating, as such an approach could cause data analysis and complications in determining coating efficacy. The PSAs are those areas that were wipe-sampled during each sampling event (i.e., at 1, 3, 7, and 11 months after coating). Areas on the minidecks adjacent to the PSAs (termed "baseline areas" because they were used to calculate specimen-specific baseline DA values) were sampled prior to coating, as will be discussed in more detail below. However, subsequent post-coat samples from these baseline areas were not used in the calculation of percent reduction (efficacy) or for ranking coatings based on their performance. These baseline areas were, however, periodically re-wipe-sampled during the study in an attempt to answer specific questions regarding the study design (including an assessment of the effect of rewiping on DA measured), as will also be discussed in more detail below.

Individual specimen-specific baseline values of DA were instead determined for each PSA to be coated and tested by averaging the DAs from the two adjacent wipe sampling areas on either side of the PSA. This step avoided any data analysis and coating efficacy complications that may have arisen from coating pre-wiped testing

areas on the specimens. In selecting this method of baseline determination, existing data supported the assumption that intraboard (within-board) variability was relatively low. Research by Stilwell (2003a) showed an intraboard variability (RSD) of 17% versus an interboard (between-board) variability of 39%. It was further assumed that the variability would be even less for sampling areas that were closer to one another (intraboard, interspecimen variability between adjacent sampling areas), although this assumption was not supported by the data gathered for this project (Section 4.4.1).

Some consideration was given to wipe sampling the PSAs prior to coating and then waiting or even exposing the test specimen to weathering to induce more migration of CCA analytes to the surface of the specimen prior to coating. While this concept may be sound, the existing data supporting the design of such a method is fairly limited (Stilwell 2003a). That is, it has not yet been well-established how much time must elapse or under what conditions specimens must be maintained to ensure that surficial CCA analyte concentrations have rebounded to pre-wipe conditions.

Another option would have been to simply take an average of a number of initial DA measurements taken from sampling areas that would then be discarded and not used for the study in any other way. In such an approach, the baseline values used would not be unique to a specific PSA. Instead, a single baseline DA value might be used for numerous PSAs or even for all of the PSAs in the study. However, it was thought that this option might not provide the level of data resolution and statistical power required to adequately establish coating efficacy data for this project.

The final option that was seriously considered was to wipe sample the undersides of the test specimens to establish the baseline DA for each specimen. This was seen as a potentially good option for new CCA-wood specimens, but not for aged specimens, as their top faces are well defined and of much greater interest (given that these faces are the ones to which users are most likely to be exposed) than their bottom faces. The top faces of aged CCA wood specimens would be expected to have considerably different characteristics than their bottom faces, because, for example, they may have been exposed to direct sunlight, abrasion, and so forth, while their bottom faces have not. While the same is not necessarily true of new CCA wood, CPSC staff data suggests that sample variability along the length of a given board is less that the variability between the top and bottom faces of a specimen, even for new CCA-treated lumber (CPSC staff 2003a). As such, and as previously indicated, the weathering test employed a method whereby the DA of adjacent sampling areas were averaged in order to establish unique baseline DA values for each individual PSA.

It must also be noted here that baseline samples were taken using wipes that had been pre-washed in nitric acid to remove any trace contaminants. It was later determined that subsequent DI water rinsing steps were not sufficient in removing the nitric acid. It was decided to not continue to use this method of pre-washing wipes for the coating efficacy sampling events (samples taken 1, 3, 7, 11 months after coating) due to concerns about the unnatural and likely detrimental effect of the acid wipe on the coating. Therefore, subsequent sampling was done with "out of the bag" wipes, simply wetted with DI water. These methods are described in more detail in Section 2.10.

In the analysis of the data collected, several alternate methods to calculate efficacy have actually been utilized, several of which use unique baseline DA values calculated as the average of the DA of sampling areas adjacent to the PSAs. Alternate efficacy calculation methods utilize average DA values for uncoated positive control minidecks used in the study. These data analysis techniques and their effects on calculated efficacy will be discussed in more detail in Sections 3 and 4.

2.1.3.6 Effects of Nailholes and Other Surface Irregularities

Nailholes, knots, and other surface irregularities can be expected to have an impact on wipe sampling and measured DA. As such, these surface features have been avoided to the extent possible in this study. In particular, nailholes were completely avoided during wipe sampling events (wipe samples are taken between adjacent sets of nailholes). Furthermore, existing aged wood specimen nailholes were reused when assembling minidecks. Other surface irregularities were avoided as much as possible when selecting specimens to be used for assembling minidecks. To the extent that such irregularities could not be avoided, each specimen and sampling area were characterized visually in two ways: by filling out a specimen characterization form (described further in Section 2.3 and included in Appendix B) and via a photo record of each specimen, which included pre- and post-coating photographs of each minideck and photographs of each minideck prior to each regular sampling event.

2.1.3.7 Test Specimen Lengths

Eighty-six cm (34 in) specimens were used to construct the minidecks. A 38-cm (15-inch) wipe sampling length was used so that wipe samples could be taken from the area between existing nailholes spaced approximately 16-inches on-center. This is a shorter wipe length than that employed in the CPSC staff sampling protocol. While it is unclear to what extent wipe length has an effect on measured DA, data is presented

in units of $\mu g/cm^2$ based upon the assumption that measured DA correlates with wipe length. These results are easily converted to a mass per sample basis by multiplying by the area sampled.

2.1.3.8 Abrasion Effects

The effects of abrasion (e.g., by repeated contact and walking) have not yet been rigorously tested in this project, although we have attempted to derive some indication of its impact via comparisons of measured DA from the PSAs with those from the adjacent areas which are not wiped at each sampling interval, by considering the wipe sampling technique itself as a form of mild abrasion. The effect of abrasion on DA as well as on coating efficacy and durability is a major issue that should be addressed in future study efforts. Additionally, the transfer of CCA analytes via feet, pets, and other potential contact routes may be important but has not been addressed by this study to date.

2.1.3.9 CCA Analytes and Speciation

The speciation of CCA analytes could be an important determinant of contact risks. Only total arsenic, total chromium, and total copper are routinely measured in this study, due to resource limitations, as speciating CCA analytes is significantly more complex and costly.

2.1.3.10 Other Limitations

The following issues, among others, are not rigorously addressed by the proposed study:

- Performance of coatings on wood of different dimensions to which users may be exposed
- Performance of coatings on wood species other than SYP
- Directional exposure effects (e.g., south- versus north-facing decks)
- Performance of coatings in different climatic regions
- Performance of coatings on wood members oriented vertically or at angles
- Performance of coatings following various wood preparation techniques
- Recoat performance

2.2 Selection of Wood Sources

Because of the large number of variables that may affect the weathering of existing CCA-treated wood structures, establishing a consistent and representative source of aged wood for these tests was relatively challenging. It is expected that different sources of aged wood may have considerably different characteristics which are likely to impact coating performance. Because resources for this project were limited, only two sources of aged wood were used, each taken from a single existing outdoor structure; for this project, the source structures were residential and commercial decks.

Predetermined criteria were established in order to rank and select from candidate aged wood source structures. It was preferred that one aged wood source be relatively highly weathered, in service for between 5 and 10 years with no washing solutions or coatings having been applied within the past 5 years. The second wood source was preferably in relatively good condition, up to 5 years old, and with no history of washing or coating. To the extent possible, wood from the selected structures was taken from areas of the structure that had been exposed to similar abrasion (traffic) and weathering patterns. Of utmost concern was testing two sources of aged wood, where boards taken from each source structure were of a relatively consistent quality with respect to other boards taken from that source. The following were important characteristics to be considered and recorded with respect to the source of aged wood used.

- Location, site
- Type of use (e.g., residential deck, etc.)
- Age
- Abrasion pattern
- Exposure orientation (directional)
- Exposure level (shading vs direct exposure, etc.)
- Treatment history
- General condition (qualitative)
- Nailhole spacing
- Lengths and number of boards
- Grain orientation of boards

Information on these characteristics was gathered for multiple candidate sources which were then critically analyzed by EPA and ARCADIS for conformance with specified criteria and completeness of specified information about the source, in order to select aged wood sources.

Two excellent sources of aged wood were selected, based on these criteria. The two structures have the following characteristics.

Environmental Research Center (ERC) Deck: This structure was located outside of the cafeteria of EPA's old (leased) Research Triangle Park facility. It was a stand-alone deck with generally full exposure (except for several boards – which were not used – located under attached benches), with only moderate shading by adjacent buildings during low sun positions. Given its open, stand-alone nature, abrasion patterns appeared very consistent and the boards were visually similar to one another. Additional information on this source was gathered as it was being dismantled under the supervision of ARCADIS. The deck was constructed of SYP, treated to 0.40 pound per cubic foot (pcf) with Ground Contact CCA-C. This source was approximately 7 years old and was believed to have received one application of a standard deck sealant near the beginning of its use (over 5 years ago). The overall condition of the wood was considered fair: the coloration was gray and there was slight-to-moderate splintering. Specific locations and orientations of individual boards were documented during dismantling of the source structure; a map of the structure showing the location of each specimen tested was prepared. This map is shown in Figure 2-1. Photos are provided in Figure 2-2. This deck is referenced as the "A" source.

New Hill Deck: This source, donated for use during this project, was taken from an outdoor deck on a private residence. It represents an ideal source of relatively new, good-condition, aged CCA-treated wood. The coloration of the wood was light brown and relatively bright and there was minimal splintering. The New Hill Deck was an exposed, attached structure. There was no noticeable biological growth or other dampness-related defects. The deck was constructed of SYP, treated to 0.40 pcf with Ground Contact CCA-C, had been in service for just over one year, and had never been cleaned or treated. Specific locations and orientations of individual boards were documented during dismantling of the source structure; a map of the structure showing the location of each specimen tested was prepared. This map is shown in Figure 2-3. Photos are provided in Figure 2-4. This deck is referenced as the "C" source.

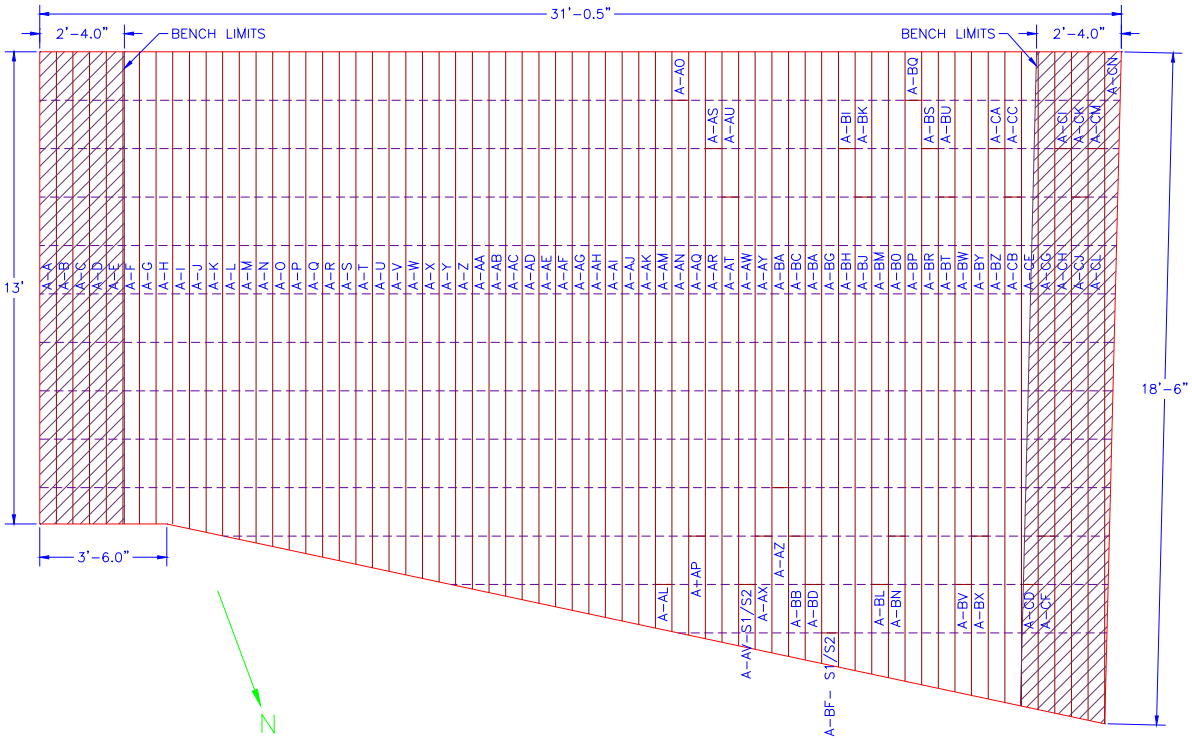


Figure 2-1. ERC Deck Map

Figure 2-2. Views of ERC Deck (note that moisture stains were temporary and that boards under benches were not used to construct minidecks)

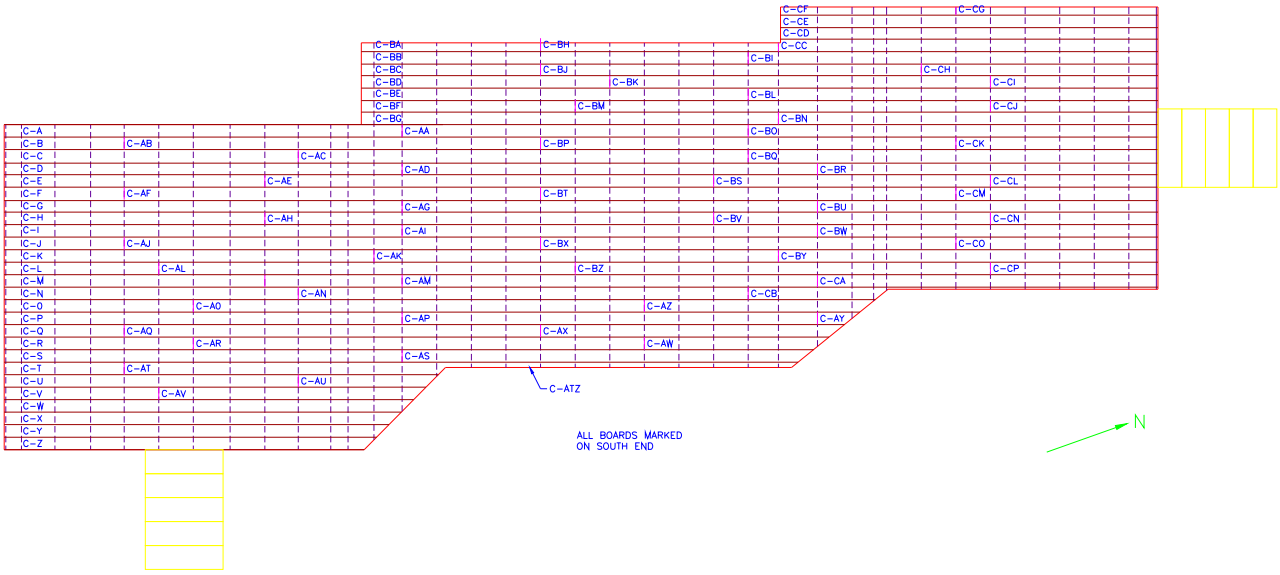


Figure 2-3. New Hill Deck Map

Figure 2-4. Views of New Hill Deck

2.3 Preparation and Characterization of Wood Sources

Wood specimens were prepared using aged, in-service SYP that was originally CCA-C treated to 0.40 pcf, in nominal 5/4" x 6" cross-sectional dimensions, taken from the source structures previously described. Care was taken to minimize handling and abrasion of the primary (i.e., 6" width) faces of the treated source boards, with the short edges of the board preferentially held during transport and cutting. New 5/4" x 6" SYP that was not CCA treated was used for the blank control specimens and the cross-contamination control specimens that were located at the ends of each minideck and between each of the four CCA-treated boards on each minideck.

For each aged CCA-treated board, the total board length was recorded along with visually-observable source wood characteristics, including predominant grain orientation (up versus down), predominant grain type (percent flat versus percent edge grain), predominant ring spacing (tight, medium, wide), predominant wood season (percent early versus percent late wood), and predominant wood type (percent heartwood versus percent sapwood). The percentages of the various grain characteristics, where reported, were gross visual observations and should only be considered estimates.

Grain orientation was assessed by viewing the end of a board and noting the shape of the grain pattern. A concave or "U" shape would be considered "grain down", while a convex or "hill" shape would be considered "grain up". The significance is that boards will tend to deform or warp over time in the direction of their grain. That is, a grain down board will tend to "cup" and may hold water, while a grain up board will tend to shed water.

Grain type was assessed by noting whether the board was cut across the grain (flat grain) or perpendicular through it (edge grain).

Ring spacing was determined by viewing the spacing of the tree's rings and recording whether they were spaced tightly, widely, or in-between (medium).

Wood season was determined based on the prevalence of large cells, or small dense cells within a growth ring. Early wood is characterized by large-celled, less dense wood, while late wood is characterized by small-celled, dense wood. If a majority of the concentric growth rings were light in color, a high percentage of early wood (springwood) would be indicated. Conversely, if the rings were predominantly dark

in color, late wood (summerwood) would be indicated. For characterizing the wood season, boards vastly predominant in one or the other were characterized as such. If, on the other hand, the dark and light-colored portions of the growth ring were more equally distributed, an approximate percentage split was recorded.

The *wood type* was determined by noting the relative color of the wood grain, with darker colors reflecting heartwood (from the center of the tree) and lighter colors reflecting sapwood (from the outer rings of the tree).

These visual assessments were made by an ARCADIS chemical engineer with no formal training in wood products or the timber industry.

Aged boards were cut using a circular table saw into lengths required for use as test specimens for the weathering tests. The outdoor, natural weathering tests required specimens of approximately 86 cm (34") lengths. These lengths were cut in such a manner as to capture three sets of existing nailholes on each aged wood specimen, and required that the nailholes were spaced on 16-inch centers as typical. Of utmost concern was that the PSAs be segments of the specimen with a 38-cm (15-in) or more clear distance between adjacent nailholes. Nailholes were not wiped during either the baseline or routine wipe sampling events. The saw was decontaminated between cutting the different types of wood utilized (aged CCA versus untreated) and the untreated wood was cut separately (after installation of a new blade) to prevent cross-contamination of samples. Decontamination followed a similar protocol to that used to clean the wipe sampling device between samples [i.e., using a deionized (DI) water moistened cloth wipe]. Where possible, the ends of each board were removed and archived and segments between each 86-cm test specimen were removed and archived, with some of these interior segments used to characterize the source wood via moisture content measurement and wood core sampling for total arsenic, chromium, and copper analyses. 86-cm wood specimens were visually inspected to ensure that they did not have excessive amounts of deformities, presence of heartwood, knots, resin pockets, or other defects. Each segment was identified with a unique alphanumeric code as follows:

- Aged board codes were prefixed by the letter "A" for source A, the ERC Deck source, and "C" for source C, the New Hill Deck (note that a source B was harvested but subsequently disqualified for use in the study).
- Each aged board from the two sources was identified with a unique letter (A, B, C, and so forth).

- Each space between adjacent nailholes was identified with an alphanumeric code, where the prefix "BL" refers to segments used for establishing baseline characteristics, while the prefix "M" refers to segments that were to be regularly wiped; that is, the PSAs. These codes were suffixed with sequential numbering (1, 2, 3,…) along the length of each source board.
- Unused, unwiped segments were designated with the prefix "X".

The specimen identification criteria presented above is illustrated by the example schematic in Figure 2-5. In this example, BL1, BL2, BL3, BL4, and BL5 would be wipe-sampled before cutting the board shown. These results would be used to establish baseline DA values for PSAs M1, M2, and M3. After cutting the boards to harvest 86-cm specimens (illustrated in the figure by the dashed boxes) for minideck construction, BL2 and BL5 would be subsequently used for taking one core sample each for total arsenic, chromium, and copper analyses, as well as moisture content. M1, M2, and M3 would be wipe-sampled during routine sampling events to determine coating efficacy. BL1, BL3, and BL4 would be wipe-sampled only periodically in an effort to determine the effects of abrasion and rewiping on coating efficacy and DA.

All cut specimens were identified on one cut end or uncut edge with its identification code, as well as with its "top" side using permanent marker. All numbered specimens were qualitatively and semi-quantitatively characterized for visually-observable wood condition characteristics, with data recorded on a standardized wood characterization data sheet (Appendix B). The characteristics recorded included knotting (number of knots for that specimen was recorded), splintering, cracking, and rotting (for these last three, a rating of 1 to 5, with 5 being like new wood and 1 being complete failure, was assigned). Additionally a photo record was made of all specimens which includes photographs taken at the beginning of the test (i.e., pre-coating), as well as at each sampling event after coating. Remaining segments of wood were retained and archived.

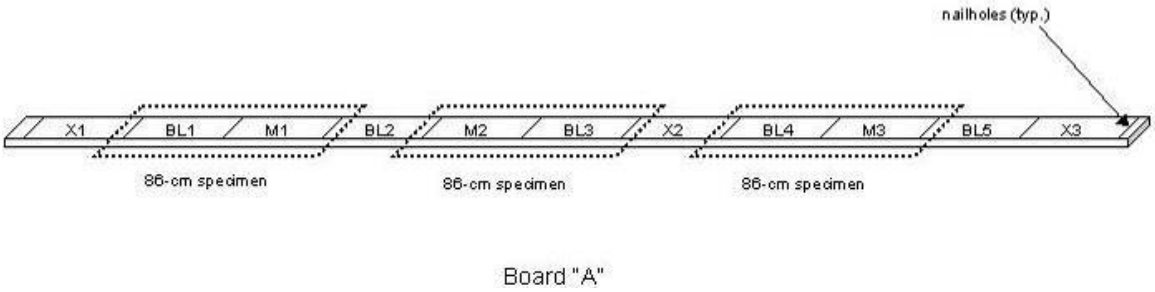


Figure 2-5. Specimen identification and baseline sampling scheme example.

2.4 Wood Core Sampling and Analysis

Up to four wood core samples were taken from each CCA treated board used to construct mindecks for this study. Core samples were generally taken from "typical" areas of the board being tested, so that the "average" would be representative. All of the segments of wood that were sampled have been archived, so specific samples could be qualitatively evaluated or resampled if necessary. Individual core samples were taken by advancing a ¼-inch diameter drill bit through the entire 1-inch (5/4" nominal) thickness of the board and collecting the wood shavings. Note that in commercial practice cores are typically only from the narrow faces of the boards (as opposed to the wide faces that were sampled here), and the assay zone is only the outer 15 mm of the core.

The wood shavings were then dried to constant weight in a drying oven at approximately 105 °C. The dry weight of the sample was recorded. The wood shavings were then digested in concentrated nitric acid using a similar protocol to that defined in Section 2.10.5 for the wipe samples. 10 mL of concentrated nitric acid was added to the wood in a digitube and the digitube was digested in a metals digestion system (Environmental Express HotBlock). After digestion, the sample was brought up to standard volume by adding DI water to a volumetric flask. This procedure is consistent with American Wood Preservers Association (AWPA) Standard A7-93 (microwave assisted nitric acid digestion). Digestates were analyzed by ICP-MS in a manner identical to that described in Section 2.10.5 for the wipe samples. This is consistent with AWPA Standard A21-00.

2.5 Minideck Construction

After cutting and marking specimens with their identification codes, source wood specimens were transported to the minideck host site, where the minidecks were

constructed per the drawing in Figure 2-6, after which the surfaces of the minidecks were prepared (e.g., washed, rinsed, etc.) in strict accordance with the particular coating manufacturer's recommendations for coating aged wood using their product. Flow sheets generically detailing the wood preparation procedures employed for each coating are provided as Appendix C. The surfaces of the minidecks for each coating (except coating #7, which did not call for a rinse prior to coating) were at least rinsed with a pressure washer at a 1,000-3,000 psi setting. Ten of the coatings also had a deck cleaning product applied, as specified in their instructions. Note that specific products used to prepare the minidecks for coating are not provided in order to maintain coating confidentiality. It is important to note here that the baseline measurements were taken before the wood surfaces were rinsed or otherwise prepared for coating. Thus, it is possible that the surface preparation procedures themselves may have impacted DA results during subsequent sampling events. The surfaces of the positive ("coating #13") and negative control minidecks were rinsed with a pressure washer at a 1,000-3,000 psi setting.

The minideck surfaces were initially constructed without leaving spaces between the boards. When this mistake was discovered, the three internal untreated boards per deck were removed and planed as described in Section 2.9. After this step, the surfaces were rerinsed with tap water and allowed to dry before coating.

Each of the 12 coatings and an uncoated positive control had three minidecks constructed (identified as 1-A, 1-B, 1-C, 2-A, and so on). Each minideck contained two 86-cm aged source "A" specimens, two 86-cm aged source "C" specimens, and five 86-cm untreated wood specimens. Furthermore, there was one minideck constructed similarly, except that its five specimens were all untreated SYP. Its three center specimens were wipe-sampled at the prespecified regular sampling event intervals as blanks (negative controls).

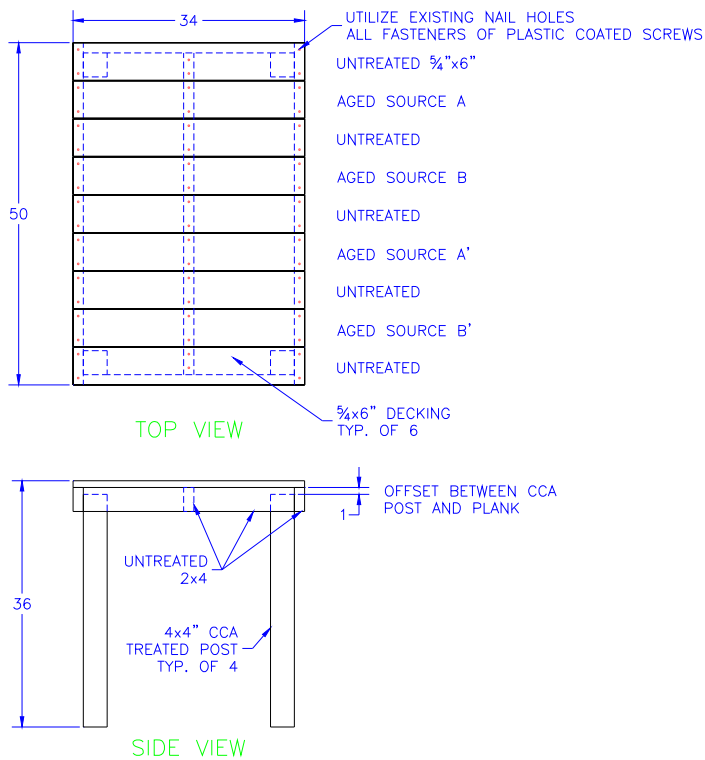


Figure 2-6. Schematic of Minideck Construction

(Note that untreated 34" specimens were planed so that 1/8" of space was provided between each pair of specimens)

New 4" x 4" CCA-C treated wood posts were used in the construction of the minidecks. Specimens were screwed directly into a grid of 2" x 4" untreated SYP supports. These supports were slightly offset above the tops of the posts to ensure that the treated posts did not have the opportunity to directly contact (and perhaps contaminate) the wood specimens used as the minideck decking. Plastic-coated screws were advanced through existing nailholes on the treated specimens in order to secure decking specimens to the minideck frames. For the untreated specimens, which were new at the time of construction, the same coated screws were used to attach them to the supports. The minidecks are free-standing (i.e., posts are not set into the ground). A photograph of a typical minideck is provided as Figure 2-7. Table 2-1 shows which specimens were used on each minideck. Specimens were matched with minidecks randomly.

Figure 2-7. Sample Minideck Photo

Table 2-1. Wood Specimens used to Construct Minidecks

Coating #	Deck ID	A – up	A – down	C – up	C–down
1	1-A	A-AE-M1	A-Z-M1	C-N-M1	C-BO-M2
	1-B	A-V-M3	A-AT-M3	C-BE-M2	C-CC-M1
	1-C	A-AJ-M1	A-BW-M4	C-S-M2	C-AA-M2
2	2-A	A-O-M3	A-BY-M2	C-BZ-M3	C-E-M3
	2-B	A-BC-M2	A-AH-M4	C-BI-M1	C-AN-M1
	2-C	A-AR-M1	A-P-M1	C-BY-M2	C-BX-M3
3	3-A	A-T-M1	A-L-M3	C-N-M3	C-CE-M2
	3-B	A-AG-M3	A-AF-M1	C-BJ-M2	C-AN-M3
	3-C	A-AD-M2	A-BW-M2	C-CD-M1	C-AA-M1
4	4-A	A-T-M2	A-BG-M4	C-CD-M2	C-AD-M2
	4-B	A-BC-M1	A-AH-M1	C-BM-M2	C-AM-M2
	4-C	A-I-M3	A-Q-M2	C-AC-M1	C-BT-M4
5	5-A	A-U-M2	A-L-M2	C-AC-M2	C-CE-M1
	5-B	A-AD-M1	A-Z-M3	C-BM-M3	C-BO-M1
	5-C	A-AR-M3	A-BG-M3	C-CA-M1	C-AD-M3
6	6-A	A-U-M1	A-BY-M1	C-BZ-M2	C-AA-M3
	6-B	A-AC-M2	A-AN-M3	C-AJ-M1	C-AI-M1
	6-C	A-BC-M3	A-P-M2	C-S-M3	C-CC-M2
7	7-A	A-O-M2	A-Y-M2	C-N-M2	C-AM-M3
	7-B	A-V-M1	A-AH-M3	C-BY-M1	C-BX-M1
	7-C	A-AJ-M3	A-BW-M1	C-BZ-M4	C-E-M2
8	8-A	A-AR-M2	A-BY-M3	C-BE-M1	C-AE-M3
	8-B	A-I-M1	A-AT-M1	C-AC-M3	C-AM-M1
	8-C	A-AG-M4	A-Z-M2	C-CA-M2	C-BX-M2
9	9-A	A-T-M3	A-P-M3	C-AP-M1	C-BW-M1
	9-B	A-AC-M1	A-AE-M2	C-BI-M2	C-AN-M2
	9-C	A-AG-M2	A-AN-M1	C-BZ-M1	C-AE-M2
10	10-A	A-AD-M3	A-BG-M2	C-AP-M3	C-AD-M1
	10-B	A-X-M1	A-Y-M1	C-BJ-M1	C-AK-M4
	10-C	A-AJ-M2	A-Q-M3	C-BU-M2	C-BT-M2

Coating #	Deck ID	A – up	A – down	C – up	C–down
11	11-A	A-U-M3	A-Q-M1	C-AP-M2	C-AI-M3
	11-B	A-X-M2	A-AH-M2	C-BE-M3	C-BW-M2
	11-C	A-AJ-M4	A-BW-M3	C-BJ-M3	C-AE-M1
12	12-A	A-O-M1	A-AN-M2	C-AJ-M2	C-AM-M4
	12-B	A-AC-M3	A-AE-M3	C-BI-M3	C-AD-M4
	12-C	A-V-M2	A-L-M1	C-BM-M1	C-BT-M1
13	13-A	A-AG-M1	A-Y-M3	C-S-M1	C-E-M1
	13-B	A-I-M2	A-AT-M2	C-AJ-M3	C-AI-M2
	13-C	A-X-M3	A-BG-M1	C-BU-M1	C-BT-M3

2.6 Selection of Coatings

The selection of coatings to be tested was critical and because of the number and variety of potentially applicable coatings on the market and the budgetary constraints of testing programs, was likely to be a limitation of any such evaluation of coatings. To put this task into perspective, the goal of selecting coatings was to distill a universe of hundreds or even thousands of potentially applicable coatings to 12 to be tested. While beyond the scope of this project, a thorough review of available coatings and their formulations and application techniques is needed to more completely understand the characteristics that may impact DA (this could include more focused involvement by the wood coating industry). For this project however, the approach was to gather basic formulation and, to a lesser extent, application information, for a number of products with reasonable availability to the project team in North Carolina (where the project site is located). This survey of available products was primarily conducted using Internet searches and visits to local retail hardware and home improvement stores. These searches allowed for the development of a “master list” of specific products. This master list of potential products included approximately 125 entries, including some products that are broadly intended for outdoor wood use, as well as some products that are not necessarily intended for such uses, but that were identified by the project team as promising.

The list is in spreadsheet format and includes fields for manufacturer, product name, product type, cover, base, and main ingredients. It must be noted that there are various levels of classifications for coatings and that no single standard can be

applied to adequately categorize each and every product identified. Additionally, many products overlap categories. Nevertheless, in order to communicate effectively about the products considered and tested, and maintain the confidentiality of product names, an attempt has been made to classify the products considered. As such, several main descriptors of coatings were used. These include: base (oil vs water), cover (clear, semi-transparent, opaque), and product type, which for this exercise, has been broken out into the following: paints, primers, sealants, stains, and other. The "other" category embodies a vast variety of products, including, but not limited to: varnishes, epoxies, lead encapsulation products, rubber coatings, fiberglass coatings, elastic vinyl coatings, preservatives, and other plastic coatings. Additional classification descriptors include ingredients (primarily alkyd or acrylic) and surface (penetrating vs film-forming).

The master list of about 125 products includes roughly 25 paints, 5 primers, 20 wood sealants, 50 stains, and 25 "other" products. Out of the paints, approximately 2/3 are water-based with the balance oil-based. Likewise, for the primers, two are oil-based while three are water-based. For the wood sealants and stains, most products are oil-based with a handful water-based. The cover – that is, the opacity of the coating on its substrate – for each of these product types is quite variable, and in fact, one "type" of coating may be available in a range of covers from clear to opaque. Likewise, the surface for each of the listed product types may also be variable, depending on the product. Paints and primers will almost invariably be considered film-forming products, while sealants, stains, and certainly "other" products may be penetrating or film-forming depending on their specific formulation. Existing research on coating efficacy suggests that film-forming coatings may be more effective, though they may also be more subject to unsightly and potentially compromising deterioration via abrasion. In particular, Lebow (2001) reported that each of three tested coatings significantly reduced leaching of CCA wood analytes from treated wood specimens, but that the two film-formers (latex and oil-based paints) reduced CCA analytes to below detection levels while the other coating (an oil water-repellant deck stain) did not. After an extensive literature (published and unpublished) review, Miller (2001) clearly recommends that CCA-treated picnic tables in Florida be preferentially coated with acrylic latex exterior flat house and trim solid color paint. She further emphasizes that more opaque sealants appear to provide better erosion prevention and longer protection when subject to weathering.

"Stains" can often be purchased as a base or pre-tinted. Stain bases generally require the addition of pigmentation (a "tint") to impart color. The tints that are added to a stain base may not be unique to that product manufacturer. Rather, the tints used may

be similar to those that would be added to say a paint base. With pigmentation added, the properties of the product should otherwise remain intact, because the amount of tint added is comparatively small (something on the order of one ounce of tint to one gallon of stain might be typical). The pigments that could be added could, for example, increase the UV protection (because of the opacity). On the other hand, characteristics like waterproofing and biocidal properties of coatings are less likely to be influenced by the addition of pigmentation. For this study, the "stains" were used as-is; that is, no pigmentation was added. For some of the stains, pigments had been preadded, while for others, the stains used were actually bases only, without pigmentation.

From the master list, 12 distinct products were selected for further evaluation based on the following criteria. Coating selection preference was given to:

1. Products that are commonly used for outdoor wood treatment (i.e., decks), with preference given to those that either have been tested or identified as promising by other researchers. These primarily include stains and sealants.

2. Products that may not be widely available, but that have been identified by their manufacturers to prevent DA exposure from CCA-treated wood.

3. Products that are relatively straightforward for consumers to apply (i.e., products that require professional application were disqualified). Multiple product systems generally were not considered, although it is recognized that some common products (e.g., paints) may require the application of another product as a primer. These situations were considered on a case-by-case basis.

4. Products that are not film formers. The overriding concern with film-formers is that they generally require sanding in preparation for recoating. Sanding may create a significant CCA dust inhalation hazard, thus making the use of film-forming products undesirable. Additionally, film-formers – paints in particular – are not as commonly used for coating decks and other outdoor structures as other products. There are concerns that film-forming sealants may perform well at first, but have significant potential for chipping and cracking over time and exposure to weathering and particularly abrasion, necessitating recoating. Nevertheless, to ensure that the list of coatings contained a wide range of products, it was decided to round out the list with two "porch and patio" paints (one water- and one oil-based) and the two other film-formers identified in #2 above that were specifically marketed to prevent DA exposure.

Thus, in addition to the two paints selected (refer to #4 above) and two products specifically marketed to prevent DA exposure (refer to #2 above), eight (8) representatives of the combined stains and sealants category were selected based on having four oil-based products and four water-based products, with one representative of the four specifying alkyd as the main ingredient, one specifying acrylic, one specifying both alkyd and acrylic as the main ingredients, and one specifying neither. Using these criteria to select products resulted in two products in each of the water- and oil-based subsets being classified as "sealants," with the other two classified as "stains."

Table 2-2 generically (to preserve required product confidentiality) lists and characterizes the 12 products selected for the study.

Table 2-2. Selected Products for Evaluation

#	Product Type	Base	Cover	Main Ingredients	Comments
1	Sealant	Oil	Semi		"Cedar" with UV blocker
2	Sealant	Oil	Clear	Acrylic, alkyd, urethane	"Clear"
3	Stain	Oil	Clear	Acrylic	"Deep tone base"
4	Stain	Oil	Clear	Alkyd	"Clear stain"
5	Sealant	Water	Clear		"Clear"
6	Sealant	Water	Clear	Acrylic, alkyd	"Clear"
7	Stain	Water	Semi	Alkyd	"Cedar" with UV blocker
8	Stain	Water	Clear	Acrylic	"Tint base, solid" with no tint added*
9	Paint	Water	Opaque	Acrylic	"Gray". Latex, designed for porches and floors
10	Paint	Oil	Opaque	Alkyd, polyurethane	"Gray". Designed for porches and floors
11	Other		Clear	Elastic vinyl	Designed for CCA encapsulation
12	Other		Clear	Polymer	Designed for CCA encapsulation
13	No coating				Uncoated control minidecks

* note that the labeling for product #8 specifically states that it must be tinted before use.

2.7 Coating Application

Minidecks were constructed as described in Section 2.4. After construction and baseline characterization of DA (described previously), all exposed surfaces of the decks were coated in accordance with coating manufacturers' recommendations,

including any wood preparation procedures instructed by the manufacturer as stated in the product's literature. Specific wood preparation flow schematics are provided for each coating in Appendix C. Coatings were applied to fully cover the top faces, exposed uncut edges, and cut ends of CCA-treated wood specimens in accordance with manufacturers' recommendations. For the paints, products #9 and 10, a common latex primer was first applied in accordance with the paint and primer manufacturers' instructions. Top faces were coated first, followed by the exposed edges and the cut ends. Because the coatings' manufacturers generally recommended that application not be done during periods of direct sunlight, a tent was set up on site temporarily to allow for coating minidecks in the shade. After 24-hours initial coating drying in the shade, minidecks were manually relocated to allow additional drying in exposed conditions.

Two types of brushes were used to apply coatings to the minidecks. They were both 2" chip brushes with either natural bristles or polyolefin bristles (to apply coatings that recommended a synthetic bristled brush). Prior to coating application, both brush types were analyzed in order to ensure that they did not contribute significant amounts of arsenic, chromium, or copper to the wood surfaces. Each type of brush used was prequalified for use per a set of two control samples whereby two brushes of each type were agitated in a 250 mL vessel containing 40 mL of deionized water for 30 seconds. The liquid samples were than transferred to Digitubes for digestion. Four milliliters of nitric acid were added to each tube and the samples were then digested at 95 ^{o}C for two hours. Digested samples were sent to STL for analysis. These results are presented in Section 4.8.1.

Dedicated brushes were used to apply each coating to each substrate (wood type) on each deck. In other words, a different brush was used to apply coating to each of the aged wood sources and to the new untreated wood surfaces. Thus, three brushes were used for each minideck. Untreated surfaces were coated first, followed by the aged CCA surfaces. Brushes were prepared for initial coating application in accordance with brush manufacturer's recommendations. After a particular coating was applied to a given group of triplicate minidecks, used brushes were archived.

Separate aliquots of coating were used for each minideck in order to prevent cross-contamination of coating by re-dipping the brush applicator. In addition, to prevent cross-contamination, separate aliquots were used for each of the aged CCA treated and new untreated boards. Thus, three aliquots of coating were used for each minideck: one for the "A" specimens, one for the "C" specimens, and one for the untreated (termed "N") specimens. Separate aliquots of coating liquid were poured

into disposable plastic graduated volumetric beakers, which were discarded after application of that coating to each given set of two specimens. The disposable beakers were acid-washed using a procedure similar to that specified in Section 2.10.5 prior to use. Coating remaining in similar beakers (i.e., the three beakers for each replicate of substrate and coating) were composited so that one sample was retained for each coating and wood type (new and untreated and the two, aged, CCA-treated sources). These samples are currently stored in sealed, unused paint containers and archived for possible future analyses. Application procedures and any notable observations were documented for each coating.

The weight of coating applied to each substrate on each minideck was determined as follows: A 200 to 300-mL aliquot of coating was transferred directly from the original coating container into a 400-mL graduated beaker. The starting volume of coating in the beaker and the final volume (after squeezing out excess coating from the brush used) were recorded and, from these, a calculation of the volume of coating applied was made. Additionally, the container containing the unused coating along with the new brush to be used for applying a given coating to a given substrate on a given minideck was pre-weighed. After coating was applied, the final weight of beaker and brush was measured and recorded. The weight applied was thus calculated as the difference between the initial and the final weights. Unused aliquots of each coating tested are to be sampled in duplicate, prepared, and analyzed in accordance with methods specified in Section 2.11.

A coating application data form was completed for each coating. A sample form is provided as Appendix D. Results are presented in Section 4-2.

The sequence of minideck construction, preparation, and sampling is summarized below; the actual timeline for these tasks is listed in Table 2-3.

1. Map, harvest, and label boards from source structure
2. Transport boards to staging area
3. Identify and characterize each sampling area and specimen
4. Conduct baseline sampling
5. Cut specimens to specified lengths
6. Construct minideck tops (nine boards affixed to untreated support frame)
7. Wash minideck tops in accordance with coating manufacturer's recommendations
8. Transport minideck tops to test site
9. Fasten minideck tops to posts
10. Coat minideck tops in the shade in accordance with manufacturer's recommendations

11. Allow to dry in shade for 24 hours, then allow full exposure

Table 2-3. Timeline Showing History of Project to Date

Task	Start Date	End Date (if more than 1 day)
Harvested source A wood	3/19/2003	3/21/2003
Moved source A wood to ARCADIS Facilities Lab	6/20/2003	
Baseline source A wipe samples	6/25/2003	7/11/2003
Harvested source C wood	7/1/2003	
Baseline source C wipe samples	7/3/2003	7/11/2003
Decks tops built	7/16/2003	7/18/2003
Prepare and rinse tops	7/21/2003	
Deck tops transported to Jenkins Road site	7/22/2003	
Deck tops set on legs	7/25/2003	
Planing, spacing, and re-rinsing of tops	8/1/2003	8/4/2003
Coating	8/6/2003	8/11/2003
Field site landscaping	8/18/2003	8/19/2004
Installation of plastic ovals	8/20/2003	
Decks moved to field	9/1/2003	
1 month post-coat sampling event	9/10/2003	9/12/2003
Relocate decks temporarily (Hurricane Isabel)	9/17/2003	9/19/2003
3 month post-coat sampling event	11/10/2003	11/12/2003
7 month post-coat sampling event	3/3/2004	3/5/2004
Weeding at field site	6/21/2004	6/25/2004
9 month post-coat sampling event	7/6/2004	7/9/2004
Weeding at field site	8/18/2004	
Weeding at field site	11/1/2004	
15 month post-coat sampling event	11/18/04	11/22/04
EPA Field Audit	11/18/04	
19 month post-coat sampling event	3/29/05	3/31/05

2.8 Outdoor Weathering

The objective of the natural weathering tests is to evaluate the effects of weathering in an actual outdoor environment on the efficacy of selected coating products in reducing DA from aged, in-service CCA-treated wood.

Outdoor weathering tests simply involve exposing the minidecks described previously to natural outdoor climatic conditions at a test facility in Research Triangle Park (RTP), North Carolina. Minidecks are arranged on-site in a grid with specific minidecks randomly assigned to gridded blocks at the start of testing with the following qualifications: minidecks featuring the same coating were not allowed in the same row, column, or diagonally immediately adjacent to one another. Minideck layout on the site was documented. The site layout showing sequentially numbered minideck locations is provided as Appendix E. The location of each minideck is summarized in Table 2-4. Note that the blocks listed in Table 2-4 correspond to those shown on the site plan in Appendix E. A photograph of the minideck site is provided in Figure 2-8.

The site was prepared for testing by:

- Setting up deposition samplers (constructed of new untreated wood) on-site and periodically wipe sampling them to assess the potential for atmospheric deposition of CCA analytes, in order to qualify the site. The results of the deposition samples showed that background levels of CCA analytes were negligible.
- Delineating a currently grassed, relatively remote area for testing minidecks, and preparing the area by tilling the ground to 6” total depth, leveling it to remove potholes, and lightly rolling it to prevent dust and erosion and prepare for graveling, but not overly compacting it. This area was then gridded using landscaping fabric and crushed stone to prevent vegetative growth, which would require maintenance, such as mowing, that might result in unacceptable impacts to the decks (e.g., dust and grass clippings). Note that the crushed stone and landscape fabric that were used were tested for arsenic content, which was determined to be negligible. The site layout is shown in Appendix E. Note that the space underneath the minidecks was not covered with landscape fabric or gravel. Vegetation in these areas is controlled manually, by hand, to accommodate bioavailability testing being conducted by other researchers.
- Delineating the perimeter of minideck test area to alert landscape maintenance staff to avoid the area. Note that the site is sufficiently remote that vandalism is not a problem. In fact, the site currently hosts valuable atmospheric monitoring

equipment that has not received any extraordinary security. The entrance road to the site has a gate that is locked every evening at 6:00 pm until the next morning.

- Clearance of saplings from the area to prevent unwanted shading.
- After placement within their assigned gridded spots, minidecks were leveled in both directions. Level placement was confirmed using an engineer's level, with untreated 2" x 4" spacer blocks to prevent direct contact between the level and the untreated end pieces of the minidecks.

Figure 2-8 Photograph of Minideck Site (note weather monitoring station on right)

Table 2-4. Minideck Block Assignments (Blocks correspond to those identified in Appendix E)

Minideck	Block	Minideck	Block
1-A	6	9-A	46
1-B	29	9-B	3
1-C	22	9-C	26
2-A	39	10-A	42
2-B	7	10-B	27
2-C	33	10-C	24
3-A	36	11-A	30
3-B	10	11-B	4
3-C	14	11-C	20
4-A	37	12-A	1
4-B	23	12-B	35
4-C	5	12-C	21
5-A	25	13-A	19
5-B	43	13-B	40
5-C	9	13-C	12
6-A	13	BC	8
6-B	28	NC	47
6-C	45	LH	15
7-A	2	SC1	31
7-B	41	SC2	38
7-C	34	SC3	16
8-A	18	LC1	44
8-B	32	LC2	11
8-C	48	LC3	17

- BC = the blank, negative control, minideck
- NC = 1 minideck with no CCA wood used (for a related bioavailability study being conducted)
- LH = 1 uncoated CCA minideck for leachate collection (for a related bioavailability study being conducted)
- SC1, SC2, SC3 = 3 soil controls (for a related bioavailability study, no minidecks are located in these blocks)
- LC1, LC2, LC3 = 3 leachate controls (for a related bioavailability study, no minidecks are located in these blocks)

Weather data have been collected for the outdoor weathering tests using a Davis Instruments Vantage ProPlus weather monitoring station. The station is located as shown on the site plan in Appendix E, and in the photo in Figure 2-8. No substantial differences in exposure across the minideck site have been noted. Through the use of available software (WeatherLink for VantagePro), data from the weather station has been compiled and downloaded to a Microsoft Excel file. The WeatherLink software allows the user to store data in the VantageProPlus console and download to a computer at their convenience. Data routinely collected via the Vantage ProPlus are listed in Table 2-5.

The National Oceanic and Atmospheric Administration (NOAA) in RTP, North Carolina, has collected data on wind speed and direction, temperature, precipitation amount, direct solar radiation, and total solar radiation at the site used for minideck weathering. A summary of the data collected by NOAA at the site are listed in Table 2-6. Other parameters are collected by the NOAA's National Climate Data Center (NCDC), at their Raleigh-Durham International Airport (RDU) weather station, and are available in monthly summaries, detailing specified conditions on a daily basis. The weather data available from NOAA at the test site, however, had generally been collected on strip charts requiring conversion to allow comparison with data obtained from the Vantage ProPlus weather station.

The test site NOAA metrology instrumentation is calibrated against working standards that are traced to world standards at Eppley Laboratories. This calibration has been done periodically based on the stability of the instrument. The temperature system has been checked against certified data from NOAA's RDU weather station on stable days and also with a sling psychrometer. The weighing rain gage has been calibrated with weights and also against a manual rain gage with each precipitation event. The Aerovane wind system records wind speed in miles per hour (mph) and only begins to register at 3 mph. It has also been checked against RDU on stable windy days. The operators of the weathering monitoring equipment have a great deal of experience and their involvement and oversight has been important for QA/QC.

NOAA-generated data from the test site were compared to data from the Vantage ProPlus weather monitoring station dedicated for use during this project. Spot checks of all parameters common to both the NOAA and Vantage ProPlus unit were conducted and showed good agreement. Because the on-site NOAA weather data became unavailable several months into the study, certified data from NOAA's RDU station has also been used to confirm the on-site weather monitoring station data. Details of these spot check results are provided in Appendix F. All sets of

comparisons are in good agreement, thus confirming the accuracy of the on-site weather monitoring station data.

Table 2-5. Vantage ProPlus Weather Station Data

	Units			
Barometric Pressure	in Hg	mm Hg	hPa (Tor)	mb
Inside Humidity	%			
Outside Humidity	%			
Dew Point	°F	°C		
Rainfall	in	mm		
Rate of Rainfall	in/hr	mm/hr		
Solar Radiation	W/m2			
UV Index & Dose	index	Meds		
Inside Temperature	°F	°C		
Outside Temperature	°F	°C		
Apparent Temperature	°F	°C		
Wind Speed	mph	m/s	km/h	
Predominant Wind Direction	N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW			
Wind Chill	°F	°C		
The data can be archived at 1 min, 5 min, 10 min, 15 min, 30 min, 1 h, or 2 h.				
Data is archived at 30-minute intervals.				
All data points are discrete except for Rate of Rainfall and UV Dose.				

Table 2-6. NOAA-Generated Weather Data

Parameter	Unit	Remarks
Required		
Irradiance (UV)	W/m^2	Direct and total radiation is available.
Temperature	°F	
Precipitation, Duration	hours	Can be determined from strip chart, although certain losses may occur due to evaporation.
Precipitation, Amount	inches	Automated rain gage.
Dew Point (Measure of dew formation)	°F	Dew point could be used to calculate dew

Parameter	Unit	Remarks
		point depression (diff. with temp.) If DPD is small, there is likely to be dew overnight.
Wind direction + speed		

2.9 Timeline

The history of this project is summarized in Table 2-3.

Several items in the timeline require clarification:

1. Planing, spacing, re-rinsing of tops: After constructing the minideck tops, it was discovered that no space was left between boards, as typically recommended in the construction of decks. To resolve this issue, all of the untreated boards (five per minideck) were removed by backing out their plastic coated screws. They were then planed sufficiently on either edge enough to be spaced using 16p nails from adjacent boards. They were then reattached and the deck tops were rinsed with tap water and allowed to dry sufficiently before coating.

2. Installation of plastic ovals: A side project is being conducted by EPA at this site to look at bioavailability of CCA wood analytes in the soils beneath the minidecks. To accommodate this research, oval plastic barriers are used to segregate surficial soil immediately beneath the decks with surrounding soil. The minideck example photo in Figure 2-7 clearly shows the plastic barrier referenced.

3. Hurricane Isabel deck relocation: Shortly into the study, Hurricane Isabel threatened the mid-Atlantic U.S. coast. Fearing tree or other storm damage, all of the minidecks were collected from the site and brought indoors until the storm passed, when they were relocated to the test site.

2.10 Wipe Sampling

Wipe samples were taken directly from the top faces of the four aged specimens per minideck by wiping the specimens per the procedures described in this section on site. Wipe samples were taken between nailholes, with care not to wipe over nailholes. Each specimen has three sets of nailholes and thus two possible sampling

areas. One sampling area was used to help establish baseline DA concentrations. These areas were wipe-sampled using wipes that had been pre-washed in nitric acid, in an attempt to remove trace contaminants from the wipes, as described in Section 2.10.2. The other sampling area was not wipe-sampled prior to coating and was used as the PSA. These areas were wipe-sampled using wipes that were straight out of the bag, as described in Section 2.10.3, to avoid any potential detrimental effects of residual acid from the wipe washing procedure on the performance of the coatings. Wipe samples were taken from the top faces of each specimen only. The length of the wipe was 15 inches to avoid contact with nailholes which are typically spaced 16 inches on-center.

Wipe comparison testing (Appendix A) has revealed that wipes with higher moisture contents (i.e., higher spiked DI water content) yield higher DA values than do drier wipes. Thus, the surface moisture of the minideck specimens when they are wiped may be expected to also impact DA. It is difficult to adequately ascertain the surface moisture of a specimen, particularly quantitatively. The interior moisture content of a specimen may be measured using the techniques described in Section 2.13, which include oven-drying and moisture probe methods. However, both of these quantitative measures could compromise the integrity of the specimen, and perhaps more importantly, its coating. Therefore, for this project, several more qualitative measures have been taken to qualify and document wipe-sampling events:

- Wipe sampling events were only conducted when specimens appeared dry and when weather forecasts indicated that there was a reasonable likelihood that consistent, relatively dry weather (i.e., no rain) would prevail for the entire sampling event. Actual climatic conditions were recorded and well-documented throughout the entire study, including sampling events.

- During each sampling event, each minideck was digitally photographed, with wiped and unwiped areas identified, in a running photolog.

Individual baseline DA values were determined for each PSA on each specimen to be coated and tested. The baseline DA of a PSA was determined by averaging the pre-coating baseline DAs from the two adjacent BL specimens on either side of the PSA, as described in Section 2.1.

As previously indicated, routine wipe sampling of test specimens was conducted at 1, 3, 7, and 11 months after coating. Future events have been conducted at 15 and 19

months, and are planned at 23 months post-coat. During each sampling event, a sampling event data form was completed. A blank form is provided in Appendix G.

Furthermore, a variety of routine control samples were taken. These include:

- Three negative control wipe samples taken from the blank minideck constructed using a total of five untreated, uncoated specimens. These control measurements provide an indication of whether there is significant atmospheric deposition of CCA analytes at the site.

- One minideck per coating has its baseline-sampled areas (its sampling areas identified with the BL prefix) on each of its aged specimens additionally sampled during each third routine sampling event. In other words, one of the triplicate minidecks has its baseline areas wipe-sampled during the first, fourth and seventh sampling events, one has its baseline areas wipe-sampled during the second and fifth sampling events, and one has its baseline areas wipe-sampled during the third and sixth sampling events. It was hoped that these samples would provide some information on "rerubbing effect," as discussed in Section 2.1.3, and may, upon comparison with results from adjacent areas wiped more frequently, provide information on the effects of abrasion induced by wipe sampling on coating efficacy and DA.

- During each wipe sampling event, one untreated (but coated, for minidecks prefixed 1 through 12) specimen from each minideck was wipe-sampled. Since there are five untreated specimens on each minideck, there are a total of 10 such potential sampling areas. The specific areas sampled during each routine sampling event were randomly selected for each minideck and were different for each sampling event.

Wipe sampling techniques utilized are based on the method developed and documented by CPSC staff, using the wipe sampling device designed and constructed by CPSC staff, shown in Figure 2-9. The CPSC staff wipe sampling device utilizes a 1.1 kg disc that is approximately 8.65 cm in diameter as the wiping block (note that the actual width of 5/4" x 6" decking is approximately 5.5" or 14 cm). With the 38-cm wipe length utilized, the sampling area is approximately 314 cm^2. The referenced CPSC staff method has been described previously (CPSC staff 2003b). There are several differences between the procedures employed by EPA and those employed by CPSC staff. The EPA wipe technique is described in detail below, along with wipe preparation and sample extraction and analysis procedures for both

researchers, while the differences between techniques are enumerated in Section 2.10.7.

Figure 2-9 CPSC Wipe Sampling Apparatus

2.10.1 EPA Wipe Method (Adaptation of Referenced CPSC Staff Method)

The wipe method employed by EPA for the referenced minideck study is as follows:

1. Prior to starting a new wipe sample, sampling staff put on new pairs of disposable nitrile or latex gloves. Then, the rubber-coated side of the steel rubbing disk is covered with plastic wrap (SaranWrap or similar). The wetted wipe is then removed from the PTFE tube, folded in half, and placed over the plastic wrap and secured with a plastic tie-wrap strap.

2. The disk is lowered so that it is in contact with the wood.

3. Sampling staff slide the disc along the tracks of the sampling apparatus forward and backward for five 38-cm (15-inch) strokes between nailholes while another person holds the end of the wiping device in place. A stroke consists of one forward and back movement. The speed of sampling is variable depending on the quality of the area being wipes, with rougher wipe areas requiring longer sampling times (slower average speeds). Smooth wipe areas may take one second to wipe in each direction, while rough areas may take up to 30 seconds. Splinters and sampling area imperfections can “hold up” the sampler requiring the person doing the wipe to adjust the horizontal force they exert on the weight to continue moving it forward. So, during most of the “additional time” required to sample rough surfaces, the block is stationary: the motion is more stop-start for rough surfaces versrus a slow and consistent horizontal motion. If the wipe areas were all smooth, the sample speed would have been very consistent.

4. The wipe is rotated 90° on the rubbing disk, which is then slid forward and back for five more strokes, for a total of 10 front-and-back strokes.

5. Sampling staff then remove the wipe from the disk and place it back into its PTFE extraction vessel. Wood splinters larger than a grain of rice are removed prior to placing the wipe in the extraction vessel.

6. After the sample is taken, the plastic wrap is discarded and the wiping apparatus is decontaminated by wiping the rails of the apparatus which were in contact with the wood surfaces with lint-free wipes wetted with DI water. Then the apparatus is checked for structural integrity and any loose bolts are tightened. Finally, sampling staff remove and discard their gloves and, for the next sample, steps 1 through 6 are repeated.

2.10.2 EPA Acid-Wash, Rinse, and Saturate with DI Water Wipe Preparation Technique (A2 Method)

For the baseline samples, the following acid-wash wipe preparation procedure was employed:

1. Wipes (TexWipes TX1009 cleanroom wipes, 100% continuous filament polyester) are cut in half using a new razor blade that had been cleaned using acetone and a lint-free wiper (i.e., Kimwipe) on a lab bench which has also been cleaned with acetone.

2. After cutting, the half-wipes are placed in a wide mouth glass bottle and soaked in a 10% solution of Trace Metals Grade Nitric Acid.

3. The bottle is placed in an oven at 85 ºC overnight.

4. The bottle is removed from the oven, nitric acid solution is decanted, and wipes are rinsed in the bottle five times with deionized H_2O.

5. After the final rinse, each wipe is then removed and squeezed by hand so that they are damp but no more water could be removed. This technique was subsequently determined to yield moisture contents of 2.1 ± 0.1 (1 standard deviation) times the dry wipe weight.

6. The damp wipes are individually placed into individual Digitubes until they are used for wipe sampling.

Note that nitrile gloves are worn during all handling of wipes.

2.10.3 EPA 2X DI Water Wipe Preparation Technique (2X Method)

The EPA wipe preparation procedure for subsequent sampling events (samples taken 1, 3, 7, 11 months after coating) for the referenced minideck study was as follows:

1. Wipes (TexWipe TX1009 cleanroom wipes, 100% continuous filament polyester) are cut in half using a new razor blade or scissors cleaned using acetone and a lint-free wipe (i.e., Kimwipe) on a lab bench which has also been cleaned with acetone.

2. After cutting, the half-wipes are inserted into PTFE tubes, into which two times the wipe weight in DI water is added to be soaked up by the wipe. Therefore the wet wipe, as used, is three times its dry weight.

3. Wetted wipes are stored in their sealed PTFE tubes until use. Sampling staff cutting, transferring, and wetting the wipes wears nitrile or latex gloves.

2.10.4 CPSC Staff 1X 0.9% Saline Wipe Preparation Technique (CPSC Method)

The wipe method employed by CPSC staff for their related minideck study was as follows:

1. Wipes (TexWipes TX1009 cleanroom wipes, 100% continuous filament polyester) are cut into quarters using scissors cleaned with acetone and a lint-free wiper (e.g., Kimwipe).

2. After cutting, the wipes are weighed and then soaked in 0.9% saline solution. The wipes are squeezed and shaken until the wipe weighs twice its dry weight (i.e., it is retaining an equal weight of saline solution).

3. Wetted wipes are stored in sealed glass test tubes until use. Sampling staff cutting, transferring, wetting and sampling the wipes wears nitrile or latex gloves.

4. The rubber-coated side of the steel rubbing disk is covered with a clean piece of Parafilm for each sample wipe. The wetted wipe is removed from the test tube and placed over the Parafilm. The wipe is secured to the disk with a rubber band and hose clamp. The wipe should be smoothly stretched over the disk.

5. The wipe-covered disk is attached to the lower arm of the wiper.

6. The wipe covered rubbing disk is placed at one end of the wiper. Then the wiper is placed over the area of the board to be sampled. The rubbing disk is then slid along the tracks of the wiper forward and back for five 50-cm strokes. The rubbing disk is lifted from the board, rotated 90°, and slid forward and back five more strokes for a total of 10 strokes. As for the EPA method, the speed of sampling is variable depending on the quality of the area being sampled.

7. The wipe is removed from the disk. Any wood splinters larger than a grain of rice are removed. The edges of the wipe that did not contact the board during sampling are cut and the wipe is placed back in the glass test tube, and covered. Any splinters are noted.

8. After the sample is taken, the Parafilm strip is discarded and the wiping apparatus is decontaminated by wiping the rails that are in contact with the wood surfaces with lint-free wipes wetted with DI water. Then the apparatus is checked for structural integrity and any loose bolts are tightened. Finally, sampling staff remove and discard their gloves and for the next sample, steps 4 through 7 are repeated.

2.10.5 EPA Laboratory Wipe Extraction and Analysis Techniques

Wipe samples were prepared for analysis using techniques similar to those employed by other researchers including CPSC staff (2003) and Stilwell, et al. (2003), adapted for use with laboratory equipment available for this project. As such, a microwave- or heat-assisted extraction and digestion procedure comparable to that used in prior studies, and similar to SW-846 Methods 3051 and 3052, was employed. Steps involved in the extraction procedure are outlined following:

1. Pre-cleaned disposable digestion vessels are used for sample collection and digestion. All volumetric glassware is prepared by acid cleaning. Volumetric glassware is cleaned by leaching with hot 1:1 nitric acid for a minimum of two hours, then rinsed with deionized water and dried in a clean environment.

2. 30 ± 0.1 mL 10% nitric acid (trace metal grade HNO_3, DI H_2O) is added slowly to the digestion vessel containing the wipe sample to allow for pre-extraction. Once any initial reaction has ceased, the sample is capped and introduced into an Environmental Express HotBlock metals digestion system. Using this device, 54 samples may be digested in a single batch.

3. Using temperature and pressure curves developed under other research programs for EPA as a guide, the vessels are placed into the digestion system and heated for 1 hour at 95 °C.

4. After digestion system extraction, sample vessels are allowed to cool for a minimum of 5 min. prior to removing them from the system. Then the liquid is poured off into a 100 mL volumetric flask. As much extraction liquid as possible

is squeezed by hand from each wipe; the funnels and flask necks are rinsed with DI H_2O.

5. The extracted wipe is then placed back into the extraction flask with an additional 30 mL of 10% HNO_3.

6. Again, the vessels are placed into the digestion system and heated for 1 hour at 95 °C.

7. After extraction, the liquid is poured off into the aforementioned 100 mL volumetric flask. As much extraction liquid as possible is squeezed by hand from each wipe and the funnels and flask necks are rinsed with DI H_2O.

8. The wipe is placed back into the extraction vessel and 20 mL of 10% HNO_3 is added to each extraction vessel before the digestion system cycle is repeated.

9. The extract is then poured into the 100 mL volumetric flask. Deionized water is used to rinse the extraction vessel; rinsate is added to the 100mL volumetric flask. If necessary, deionized water is added to take the contents to the 100 mL level.

10. The contents of the 100 mL flasks are then transferred to and stored in two plastic tubes (duplicate or split samples) with plastic caps. One is sent to a contract laboratory for analysis, while the other is archived, under refrigeration or freezer storage. These tubes are manufactured by SCP Science and are certified contaminant-free.

Note that nitrile or latex gloves are worn during all handling of wipes.

Per the specified analytical method, the hold time for all metals other than mercury is 6 months, and samples are stored at 4 °C until analysis. Sample containers are of tetrafluoroethylene (TFE) or perfluoroalkoxy (PFA) in accordance with the analytical method recommendations.

Analyses for total arsenic, chromium, and copper are conducted by STL in Savannah, Georgia, using a modification of SW-846 Method 6020 (ICP-MS). STL utilizes ICP-MS for arsenic analysis, modifying the technique to utilize hydrogen plasma, rather than argon as classically performed. This modification eliminates concerns over the formation of $Ar^{40}Cl^{35}$, which can create a positive bias when measuring As. STL-

Savannah's analytical method has reporting limits of 0.10 µg/L for all three CCA analytes (this corresponds to a DA of 0.000032 µg/cm^2)

STL is an accredited laboratory, participating in the Contract Laboratory Program (CLP), as well as numerous state programs. In addition to prequalifying the laboratory for use in the minidecks study, each set of samples submitted includes blind blanks and spiked samples, allowing for continued monitoring of laboratory performance.

2.10.6 CPSC Staff Technique Laboratory Wipe Extraction and Analysis Techniques

The extraction and analysis procedures used by CPSC staff are outlined as follows:

1. After sampling, the wipes are carefully rolled up and placed back in the glass test tube in which the wipe was stored prior to sampling.

2. 20 ± 0.1 mL of 10% nitric acid (trace metal grade HNO_3, DI H_2O) is added to each test tube containing a sample wipe. The test tubes are covered.

3. The test tubes are placed in a hot water bath at 60 °C overnight (approximately 15-24 hours). The test tubes are removed from the water bath and allowed to cool to room temperature.

4. The test tubes are vortexed prior to analysis to ensure mixing. The wipe remains in the test tube throughout the extraction and analysis process.

5. Analysis for total arsenic, chromium, and copper are conducted at the CPSC laboratory in Gaithersburg, Maryland using a modification of EPA Method 200.7. CPSC staff utilizes ICP for analysis.

2.10.7 Differences Between EPA and CPSC Staff Wipe and Sample Preparation Procedures

Differences between the CPSC staff and EPA 2X methods for collection and analysis of surrogate wipes on CCA-treated wood are as follows:

1. ARCADIS uses plastic wrap to cover the rubber-coated side of the rubbing disk rather than Parafilm.

2. C-clamps are not used by EPA to secure the horizontal wiper (because the boards being wiped are part of a deck structure). An assistant holds the wiper in place.

3. In the EPA method, poly wipes are immediately placed directly into the vessels in which extraction will take place.

4. A three-step extraction and digestion procedure, as detailed above, is used by EPA rather than the CPSC staff one-step water bath extraction and digestion.

5. EPA uses a 2x DI water spike (wetted wipe weight is three times the dry wipe weight) to pre-wet the wipes while CPSC staff uses a 1x 0.9% saline solution spike (wetted wipe weight is two times the dry wipe weight).

6. EPA uses a 38-cm (15-in) wipe length (nominal 314 cm^2 sampling area) and samples between nailholes of boards supported 16 inches on-center, while CPSC staff uses a 50-cm (19.7-in) wipe length (nominal 386 cm^2 sampling area).

2.10.8 Wipe Sampling Method Limitations and Recommendations for Improvements

Wipe sampling is typically a relatively imprecise method of sampling. During this study, several notable observations have been made regarding the wipe sampling procedure. Most notably, the apparatus does not always appear to apply even wipe sampling pressure during sampling, particularly if the wood member is even slightly deformed, warped, or cupped. It appears that the rigid structure of the weighted disc to which the wipe is affixed does not allow for much in the way of "form-fitting" the wood member being sampled. The use of a less rigid face for the weight (perhaps something like a beanbag or gel-filled pad) may allow the wipe to fit better to the areas being sampled. An additional concern is that the average "speed" of wipe sampling may vary depending on the roughness of the surface being sampled. This appears difficult to avoid in that nearly any wipe sampling method utilizing a cloth or fabric wipe will occasionally hang up on rough or splintered surfaces.

2.11 Preparation and Analysis of Coating Samples

Total arsenic, chromium, and copper in the coatings themselves will be determined in a manner similar to that used to analyze the wipe samples (acid digestion and extraction followed by ICP-MS). The coating to be analyzed will be thoroughly shaken to ensure homogeneity and then an aliquot transferred to a tared PTFE digestion vessel and allowed to dry. Following loss of volatiles through drying, the

residue will be digested using concentrated nitric acid as described in EPA SW-846 Method 3052. Hydrofluoric acid will be added if necessary to ensure complete digestion in accordance with the method. The digestate will be quantitatively transferred to a volumetric flask and diluted to a known volume prior to submission to the contract laboratory for ICP-MS analysis (SW-846 Method 6020).

2.12 Archiving of ICP-MS Samples

Analysis of the samples by ICP-MS consumes only a fraction of the submitted sample. ARCADIS is archiving an aliquot of each digestate until the completion of the project. Samples are being archived by storing them in TFE or PFA containers under refrigeration. Additionally, any remaining sample volume at the contract analytical laboratory was archived until the analytical results were confirmed.

2.13 Moisture Analysis of Wood Specimens

Wood moisture content was measured using a hand-held meter, after the technique had been qualified and calibrated via side-by-side testing with the drying oven technique, ASTM D4442 (Primary Oven Drying). Per ASTM D4442, a small representative wood sample was weighed prior to drying overnight at 103° C in a forced air oven. After 24 hours, the sample was cooled in a desiccator, weighed, then returned to the oven. The process was repeated until weight changes between weighings was within ± 5%.

2.14 Photographs

Digital photographs of each minideck were taken before coating and monthly sampling events.

2.15 Miscellaneous Samples

Other miscellaneous samples that were collected, and archived or analyzed are summarized in Table 2-7.

Table 2-7. Miscellaneous Samples to be Collected

Sample Description	# Samples Analyzed	# Samples to be Archived
*Unaltered coating	2 for each coating	Leftover coating to be stored
Leftover brush-applied coating	N/A	1 for each coating and wood type
Brush wash water	2 for each brush type	Brushes are retained
Wood	Up to 4 cores per board	Leftover wood is stored

*Not yet done

Unless otherwise stated, all samples indicated in Table 2-7 to be archived shall be held at least until the initial report of results has been finalized. Longer archiving times for certain samples may be warranted upon further consideration.

2.16 Quality Control Samples

A variety of control samples were taken. These include the following: 1. positive (CCA-treated, uncoated) controls, 2. negative (untreated, uncoated) controls, 3. cross-contamination controls, 4. wipe frequency (rewipe, abrasion) controls. Each is discussed briefly below.

2.16.1 Positive (CCA-Treated, Uncoated) Controls

The three minidecks prefixed by the number 13 are constructed in exactly the same way as the minidecks for coatings #1 through #12, except that they are not coated. The results from these minidecks, therefore, can be used to determine how the DA values change over time without considering the effect of coating. As such, average baseline DA values can be calculated at each sampling event by simply using the results from the positive control minidecks. These baselines can then be used to define alternate methods of calculating coating efficacy. The advantage to using the positive control minidecks for this purpose is that other potentially important factors are incorporated in the minideck 13 results, including: the effect of rinsing the boards pre-coating (via comparison of pre-coat and samples taken 1 month after coating for the positive control minidecks), the effect of weathering between subsequent sampling events, and the effect of climatic conditions during the sampling itself. For example, it may be that the DA results per the sampling technique employed in this study correlate with some climatic condition (e.g., higher DA with higher relative humidity). The use of the positive control minideck DA results thus allows for this and other potential sources of bias to be factored out in the calculation of efficacy.

2.16.2 Negative (Untreated, Uncoated) Controls

The single uncoated minideck, labeled BC (for "blank control"), consisting of five untreated specimens, was used to routinely take blank samples to measure the background levels or atmospheric deposition of analytes. Wipe samples were taken from the same areas of the middle three boards on this deck during each monitoring event, similar to samples taken from the other minidecks.

2.16.3 Cross-Contamination Controls

The untreated specimens separating the CCA-treated test specimens on each deck serve as sources for cross-contamination control samples. During each wipe sampling event, one untreated (but coated, for minidecks prefixed 1 through 12) specimen from each minideck was wipe-sampled. Since there are five untreated specimens on each minideck, there are a total of 10 potential sampling areas. The specific areas sampled during each routine sampling event were randomly selected for each minideck and were different for each sampling event. The results of these samples have been used to assess the level of cross-contamination expected for adjacent samples as a result of, for example, splash-over of rainwater from one specimen to the next.

2.16.4 Wipe Frequency (Rewipe, Abrasion) Controls

Each CCA-treated test specimen on each minideck includes two sampling areas: a PSA (prefixed "M") and an adjacent baseline sampled area (prefixed "BL"). BL areas are those that were initially wiped prior to coating to establish baseline DA. A subset of the BL areas are resampled during each sampling event. Specifically, all of the BL areas on one of the three minidecks per coating (as well as the positive control minidecks) are sampled during each sampling event. Therefore, since there are three minidecks per coating, a given BL area is resampled every third sampling event. In other words, one of the triplicate minidecks has its baseline areas wipe-sampled during the first, fourth and seventh sampling events, one has its baseline areas wipe-sampled during the second and fifth sampling events, and one has its baseline areas wipe-sampled during the third and sixth sampling events. As such, the coatings on these sections of lumber have not been abraded by wiping to the same extent as the coatings on the PSAs in order to assess the effect that wiping has on coating efficacy. It was hoped that these samples would provide some information on "rerubbing effect," as discussed in Section 2.1.3, and may, upon comparison with results from adjacent areas wiped more frequently, provide information on the effects of abrasion induced by wipe sampling on

coating efficacy and DA. Additional information regarding the analysis of this data can be found in Sections 3.4.3 and 4.7.

2.16.5 Analytical (Contract Laboratory) Control Samples

A series of laboratory control samples were sent with each batch of samples tested by the subcontract analytical laboratory. Each set of digested wipe samples submitted to the subcontract analytical laboratory included 5% additional blind field blanks (extracted unused wet wipes), one blind blank (extraction fluid only), one set of three different concentration-spiked samples, and duplicates (split samples) for 5% of the wipe sample digestates being analyzed to assess laboratory performance. Control samples were not identified as such to the contract laboratory performing the analyses. So, for example, assuming that a total of 200 wipe samples were taken for this study, shipped to the subcontract laboratory in a single batch, the following additional samples were included:

- Ten (10) field blank samples prepared by taking unused wetted wipes and extracting them in accordance with the procedures previously specified
- One (1) blank consisting of extraction fluid only
- One (1) digestion fluid sample spiked to 1.0 µg/L (0.015 µg in 15 mL digestion fluid) with As, Cr, and Cu
- One (1) digestion fluid samples spiked to 50 µg/L (0.75 µg in 15 mL digestion fluid) with As, Cr, and Cu
- One (1) digestion fluid samples spiked to 1000 µg/L (15 µg in 15 mL digestion fluid) with As, Cr, and Cu
- Ten (10) duplicates (selected split samples of digested wipes from actual samples generated)

Furthermore, the subcontract analytical laboratory analyzed project-specific post-digestion spiked samples for each analyte, in addition to equipment blanks run on each batch of samples analyzed for this project.

3. Data Reduction and Analysis Methods

3.1 Data Reduction

3.1.1 Calculation of DA from Extraction Fluid Concentrations

Raw data from the subcontract analytical laboratory were reported in units of µg/L and represents the mass of analyte per unit volume of extraction solution sent to the laboratory. For standard wipe sample results, data were reduced in order to characterize the mass of analyte per unit surface area wipe-sampled, in units of µg/cm^2, using the following equation:

$$C_{DA} = \frac{C_{DF} \times \frac{V}{1000}}{A} \qquad \text{(Equation 3.1)}$$

Where: C_{DA} = DA of a sample (µg/cm^2)

C_{DF} = Concentration of analyte in extraction fluid (µg/L)

V = Total volume of extraction fluid (mL)

A = Area of wiped surface (cm^2) = 314 cm^2

3.1.2 Calculation of Percent Reduction of DA

Raw data from the subcontract analytical laboratory are reported in units of µg/L and converted to DA (the mass of analyte per unit surface area wipe-sampled), in units of µg/cm^2, per Equation 3.1. Because there are different ways of assessing efficacy, for this project, efficacy (percent reduction) for each coating has been calculated using four alternate methods. The results of all four methods (described below) are reported.

The first and second methods (Methods 1 and 2) used to calculate percent reduction utilized Equation 3.2:

$$R_{DA} = \frac{C_{initial} - C_{final}}{C_{initial}} \times 100 \qquad \text{(Equation 3.2)}$$

Where: R_{DA} = Reduction in DA (%)

$C_{initial}$ = Baseline DA (µg/cm^2)

C_{final} = Final DA (µg/cm^2)

In method 1, R_{DA} is calculated for each PSA at each of the four sampling events. The R_{DA} results are then averaged by groupings of coating (coatings #1 through #13), source (A versus C), and sampling interval (1 through 4). This method can be thought of as "calculating the average of the efficacies".

In method 2, averages are first taken of $C_{initial}$ for each grouping of coating and source, pre-coating (baseline), and then of C_{final} which is the average DA for each grouping of coating, source, and sampling interval. Then, Equation 3.2 is then used to calculate R_{DA} for each grouping of coating, source, and interval, based these averages. This method can be thought of as "calculating the efficacy based on the averages".

Method 3 utilizes a different equation, Equation 3.3, for calculating efficacy, and is based on the average positive control minideck (i.e., coating #13) results for each source and time interval. The equation used is as follows:

$$R_{DA} = \frac{\overline{C}_{deck13,time=t,source=s} - \overline{C}_{coating=c,time=t,source=s}}{\overline{C}_{deck13,time=t,source=s}} \times 100 \qquad \text{(Equation 3.3)}$$

Where: R_{DA} = Reduction in DA (%)

$\overline{C}_{deck13,time=t,source=s}$ = Average DA for "M" labeled samples for coating #13 for given source wood, at specified time interval (µg/cm^2)

$\overline{C}_{coating=c,time=t,source=s}$ = Average DA for "M" labeled samples for specified coating, given source wood, and at specified time interval (µg/cm^2)

In method 4, the estimates of coating efficacy relative to coating #13 were calculated using the analysis of variance model used to compare and rank coatings (described in Section 3.4.2). Using standard linear model results, estimated differences in coating main effects on the log-scale, C_i–C_{13}, were calculated along with lower and upper

confidence limits. The efficacy ($R_{DA,i}$) of coating i to coating #13 was then calculated per Equation 3.4.

$$R_{DA,\,i} = 1 - \exp(C_i - C_{13}) \qquad \text{(Equation 3.4)}$$

Where: $R_{DA,i}$ = Reduction in DA for a given coating, coating i (%)

C_i = DA for coating i, averaged over all conditions

C_{13} = DA for coating #13, averaged over all conditions

A similar calculation applied to the lower and upper confidence limits of the estimated effect difference provided the upper and lower confidence limits of the estimated efficacies.

In effect, this approach yields a composite measure of efficacy averaged over both source decks, all time periods, and the grain orientation of the boards, and after adjusting for baseline measurements. The statistical model has the conceptual form:

$$\ln(DA/DA_{BL}) \Rightarrow \text{coating} + \text{sourcedeck} + \text{grain} + \text{interaction_terms}$$

where DA_{BL} represents the baseline DA results, and "coating" models the main effect of the coating; "sourcedeck" models the main effect of the source deck, and so on.

This approach has the advantage of correlating well with the statistical method used to compare coating performance (Section 3.4.2); the models are essentially the same, but their application is different. Furthermore, the model results are based on the effects of the coatings after adjusting for baseline measurements.

A fundamental characteristic of this approach is that it averages over the other factors (source, grain orientation, and sampling interval). This can be both good and bad. For example, it is certainly possible the efficacies of the coatings might depend on one or more of these other factors, and method 4 averages over all of these factors. The dominant factor, however, is probably elapsed time since coating. So by computing an average (over time) efficacy, in some approximate sense an average annual efficacy is being computed. In other words, method 4 is best targeted to answer the question:

"what is the yearly-exposure efficacy of a coating from time of application to one year later?"

3.2 Data Reporting

For each series of tests, raw and reduced data are reported, as applicable. Coating efficacy results are expressed in terms of DA (µg/cm^2) and percent reduction. All data validation criteria have been reported along with the associated data.

3.3 Relational Databasing

Data have been compiled using a relational database that includes a variety of information. A schematic of the database design is provided in Appendix H.

The relational database was constructed to store pertinent experimental data and observations. The database is constructed using Microsoft Access 2002 (XP) while the database format was maintained at the Microsoft Access 2000 version to assure wide compatibility. The database is designed to balance the normal form considerations and the speed and convenience of usage. Most fields in a particular table are directly related to its primary key to reduce the information redundancy. Table 3-1 shows the 6 primary tables and their associated primary and foreign keys.

Table 3-1. Relational Database Table Summary

Table Name	Description	Keys
SpecimenList	Table composed of all specimens and the directly related data such as name of specimen, core concentrations, and moisture content.	Primary Key: SpcID Foreign Key: SpcDeckID, DataID, SpcType
IntervalData	Table consisted of data pertaining to a particular sampling event.	Primary Key:DataID
InfoDecks	Table consisted of data specific to each minideck.	Primary Key: MiniDeckID Foreign Key: Coating ID
InfoCoatings	Table consisted of coating data	Primary Key: CoatingID
BoardInfo	Table consisted of data pertaining to each board such as length, grain, and bark face.	Primary Key:BrdID
lku Specimens Type	Type of specimen, including blank, sample, and unused.	Primary Key: SpcTypeID

3.4 Statistical Analysis Approach

3.4.1 Wipe Method Correction Factors

Toward the beginning of this study, a separate wipe comparison study was conducted, with a main goal of determining whether a correction was needed to convert the baseline (precoat) wipe sample results taken using acid washed wipes (the "A2" method) to the 2X method (as used for the subsequent sampling events) wipe preparation results, and, if so, what the correlation equations should be. Other factors were considered as variables including: grain orientation (up, down), source deck (A, C), sample date (1 month, 3 months, 7 months, 11 months), rinse (rinsed, unrinsed), and prep lab (EPA, CPSC). "Unrinsed" boards in this context refers to boards that were taken directly from storage and wipe-sampled, while "rinsed" boards were thoroughly hosed down with tap water and allowed to dry for several days before wipe sampling. "Prep lab" refers to which laboratory digested or extracted the wipes and subsequently either analyzed the samples in-house (CPSC) or sent them out to a subcontract laboratory for analysis (EPA). The full wipe comparison report is provided as Appendix A but the main results affecting this study are summarized herein.

Statistical model selection was used to identify calibration equations for predicting method 2X DA measurements from method A2 DA measurements and the other factors, including grain orientation (up, down), source deck (A, C), sample date (1 month, 3 months, 7 months, 11 months), rinse (rinsed, unrinsed), and prep lab (EPA, CPSC). Based on these analyses, separate calibration equations are suggested for rinsed and unrinsed boards, but not for any of the other factors. In other words, when models for predicting DA using 2X wipes from DA using A2 wipes, grain, source deck, sample date, rinse, and prep lab are considered, the identified prediction model depends only on DA using A2 wipes and rinse.

The wipe method correction factors are summarized as follows:

For arsenic:

Rinsed Specimens: As-2X = 1.42 (As-A2), 95% Confidence Interval: (1.18, 1.66)
Unrinsed Specimens: As-2X = 0.80 (As-A2), 95% Confidence Interval: (0.72, 0.88)
The R-square value for the combined models is 0.78

For chromium:

Rinsed Specimens: Cr-2X = 1.31 (Cr-A2), 95% Confidence Interval: (1.05, 1.57)
Unrinsed Specimens: Cr-2X = 0.81 (Cr-A2), 95% Confidence Interval: (0.73, 0.89)
The R-square value for the combined models is 0.62.

For copper:

Rinsed Specimens: Cu-2X = 1.18 (Cu-A2), 95% Confidence Interval: (0.94, 1.42)
Unrinsed Specimens: Cu-2X = 0.83 (Cu-A2), 95% Confidence Interval: (0.75, 0.91)
The R-square value for the combined models is 0.81.

Because the baseline analyses for this study were done on unrinsed boards, the unrinsed specimen equations were used to adjust the baseline results accordingly. In this report, only "corrected" baseline (samples taken before coating) DA is reported. Likewise, reported values which are calculated using baseline DA in the calculation (e.g., the percent reduction values) always use the corrected baseline values. DA from all subsequent sampling events are reported uncorrected, as they were conducted using the 2X wipe method.

3.4.2 Intercoating Comparison and Ranking

Standard analysis-of-variance methods were used to analyze the data for the purpose of comparing coatings. The particular analysis-of-variance model used was chosen to match the experimental design. The key features of the design are the longitudinal (time series) nature of the study, the replication of mini decks for each coating in the study, the use of boards from two source decks, the placement of boards in both grain-up and grain-down positions, and the baseline measurements for each board. Apart from the additional feature of baseline measurements, the design (in terms of the main factors: coating, source deck, grain orientation, and time) is similar to that of a split plot in space and time as described in Steel, et al. (1997).

The specimen-specific baseline measurements were used to normalize the main study measurements from the corresponding specimen. For the analysis of DA measurements, the dependent variable used in the analysis of variance was $\ln(DA/DA_{BL})$, the natural logarithm of DA/DA_{BL}, where DA is the DA measured on a given PSA during a given sampling interval, and DA_{BL} is the corresponding PSA-specific baseline arsenic value. DCr and DCu measurements were analyzed similarly. The analysis on the log-ratio scale has some important advantages. The fact that the

baseline measurements were made using a different wipe preparation method (A2) than the main-study measurements (2X), and that statistical analysis of available data suggested that A2 method measurements are approximately proportional to 2X method measurements (Appendix A) means that the constant of proportionality becomes an additive constant on the log scale, and thus does not affect comparisons among coatings. Taking logarithms also homogenizes residual variation among treatments, thereby ensuring greater conformance with the standard analysis-of-variance distributional assumptions.

In summary, the statistical model used was a split plot in space and time with minidecks playing the role of plots, coating as the whole plot factor, and source deck and grain as the split plot factors. The model differed slightly from a textbook split plot in that the replication was not in blocks. The model was fit using standard software for mixed analysis of variance models.

3.4.3 Wipe Frequency and Number of Wipe Analysis

Although the experiment was not specifically designed to provide detailed information about the effects of wipe frequency (rewipe effect) and the number of previous wipes (abrasion), the data collected provide a limited opportunity to investigate these factors. To this end two new predictive variables were defined for the purpose of quantifying the amount of previous wiping and the elapsed time since the previous wipe:

1) NOPW = number of previous wipes;
2) TTPW = time (months) since the previous wipe.

The first, NOPW, is a surrogate for total prior post-coat abrasion; and the second, TTPW, measures wipe frequency, or more specifically, the time interval between wipe samples on a given sampling area. Possible effects of these two factors were investigated using the combined dataset {i.e., both the sample [M] and baseline [BL] DA results}. The statistical model used was that described in Section 3.4.2 augmented with linear terms in the new variables NOPW and TTPW. The model facilitated the investigation of trends (either increasing or decreasing) in NOPW and TTPW after adjusting for all of the other factors. Because the experiment was not designed specifically for the purpose of assessing abrasion and wipe-frequency effects, the information in the data for assessing these factors is not great, and the analysis was intended primarily for exploratory purposes.

4. Results and Discussion

4.1 Wood Characterization Data

A variety of source board characterization data was collected for the wood harvested and used to construct the minidecks for this project. Source wood characterization data are summarized in Table 4-1. Additionally, each specimen used in the construction of the minidecks was semiquantitatively rated on several characterization factors. These results are provided in full in Appendix I. Note that Table 2-1 can be used to cross-reference minidecks with specimens (and thus source boards).

Table 4-1. Source Wood Characterization Data Summary

Board ID	Board Length (in)	Board Length (cm)	Predominant Grain Type	Predominant Grain Orientation	Predominant Ring Spacing	Predominant Wood Type	Predominant Wood Season
A-AC	181.4375	460.9	40F/60E	Up	Tight	Sapwood	Late
A-AD	182.75	464.2	Flat-Grained	Up	Wide	Sapwood	Early
A-AE	184.1875	467.8	Flat-Grained	Up	Medium	Sapwood	Early
A-AF	185.0	469.9	Flat-Grained	Down		20H/80S	70E/30L
A-AG	186.25	473.1	Flat-Grained	Up	Medium	Sapwood	Early
A-AH	187.5	476.3	40F/60E	Down	Wide	Heartwood	Early
A-AJ	190.125	482.9	30F/70E	Up	Tight	Heartwood	Late
A-AN	178.375	453.1	Flat-Grained	Down	Wide	Sapwood	Late
A-AR	161.25	409.6	Flat-Grained	Up	Wide	Heartwood	Early
A-AT	147.0	373.4	20F/80E	Down	Medium	Heartwood	Late
A-BC	163.0	414.0	Flat-Grained	Up	Medium	Sapwood	Early
A-BG	193.25	490.9	Flat-Grained	Down	Wide	Sapwood	Early
A-BW	178.875	454.3	Flat-Grained	Down	Medium	Heartwood	Early
A-BY	162.875	413.7	30F/70E	Down	Wide	Heartwood	Early
A-F	156.0625	396.4	30F/70E	Up	Medium	Sapwood	Late
A-I	157.0	398.8	Flat-Grained	Up	Tight	Sapwood	Late
A-L	160.625	408.0	Flat-Grained	Down	Wide	Sapwood	Early
A-O	164.25	417.2	Flat-Grained	Up	Wide	Heartwood	60E/40L
A-P	165.375	420.1	50/50	Up	Medium	Sapwood	Early

Board ID	Board Length (in)	Board Length (cm)	Predominant Grain Type	Predominant Grain Orientation	Predominant Ring Spacing	Predominant Wood Type	Predominant Wood Season
A-Q	166.3125	422.4	40F/60E	Down	Wide	Heartwood	Early
A-T	170.4375	432.9	Flat-Grained	Up	Medium	Sapwood	Late
A-U	171.6875	436.1	Flat-Grained	Up	Close	Heartwood	50/50
A-V	172.875	439.1	Flat-Grained	Up		Heartwood	Late
A-X	175.5	445.8	Flat-Grained	Up	Medium	Sapwood	Early
A-Y	176.625	448.6	Flat-Grained	Down	Medium	Sapwood	Early
A-Z	177.75	451.5	Flat-Grained	Down	Wide	Sapwood	50/50
C-AA	160.0	406.4	Flat-Grained	Down	Medium	Sapwood	Late
C-AC	191.5	486.4	Flat-Grained	Up	Tight	Sapwood	Late
C-AD	192.125	488.0	Flat-Grained	Up	Medium	Heartwood	Early
C-AE	191.625	486.7	Flat-Grained	Down	Wide	Sapwood	Early
C-AI	192.125	488.0	Flat-Grained	Down	Medium	Sapwood	Early
C-AJ	193.625	491.8	Flat-Grained	Up	Medium	Sapwood	Early
C-AK	186.875	474.7	30F/70E	Down	Tight	Sapwood	Early
C-AM	191.9375	487.5	Flat-Grained	Down	Medium	Sapwood	Early
C-AN	191.875	487.4	30F/70E	Down	Tight	Heartwood	Early
C-AP	174.25	442.6	Flat-Grained	Up	Medium	Heartwood	60E/40L
C-BE	178.375	453.1	Flat-Grained	Up	Medium	Sapwood	70E/30L
C-BI	188.125	477.8	Flat-Grained	Up	Wide	Heartwood	Early
C-BJ	177	449.6	Flat-Grained	Up	Wide	Sapwood	Early
C-BM	192.625	489.3	Flat-Grained	Up	Tight	Sapwood	Early
C-BO	188.5	478.8	Flat-Grained	Down	Medium-wide	Sapwood	Early
C-BT	192.625	489.3	30F/70E	Down	Tight	Heartwood	Early
C-BU	156.375	397.2	Flat-Grained	Up	Wide	Sapwood	40E/60L
C-BW	156.375	397.2	30F/70E	Down	Tight	Heartwood	Early
C-BX	192.375	488.6	30F/70E	Up	Medium	Heartwood	Early
C-BY	174	442.0	Flat-Grained	Up	Wide	Sapwood	Early
C-BZ	192.125	488.0	Flat-Grained	Up	Medium	Sapwood	Early
C-CA	156.625	397.8	Flat-Grained	Up	Medium	Sapwood	Late

Board ID	Board Length (in)	Board Length (cm)	Predominant Grain Type	Predominant Grain Orientation	Predominant Ring Spacing	Predominant Wood Type	Predominant Wood Season
C-CC	174	442.0	Flat-Grained	Down	Medium	Sapwood	Early
C-CD	174.5	443.2	Flat-Grained	Up	Tight	Heartwood	Late
C-CE	174.5625	443.4	Flat-Grained	Down	Medium	Sapwood	Early
C-E	136	345.4	40F/60E	Down	Medium	Heartwood	Early
C-N	152.25	386.7	Flat-Grained	Up	Medium	Sapwood	50/50
C-S	189.1875	480.5	Flat-Grained	Up	Wide	Sapwood	Early

4.2 Coating Application Data

The volumes of coating applied to the A boards, the C boards, and the N boards (the untreated boards) on each minideck were determined as was the mass of coating applied (no coating mass data are provided for coating #1, because the decision to measure mass was made after the coating #1 decks were coated). These data are summarized in Table 4-2. Figure 4.1 shows the total volume and mass of each coating applied sorted by coating ID. Note that coatings were applied in strict accordance with manufacturers' printed instructions, including the number of coatings to apply. Film thickness proved to be quite difficult to measure on wood substrates, so film thicknesses were only measured on several minidecks; these data are not presented.

4.3 Wood Core Sample Data

Each source board used in the construction of the minidecks had up to four core samples taken from it. They were subsequently digested and analyzed for CCA content. The wood core data are presented in Table 4-3 (for source A) and Table 4-4 (for source C), with averages, standard deviations, and relative standard deviations (RSD) presented for each board and with summary statistics at the end of each table for each source (A and C). Note that some of the boards listed in the tables below were not used to construct minidecks; however, they are included here for completeness. Complete data showing the results of each individual measurement are provided in Appendix J.

Table 4-2. Coating Application Data Summary

Minideck ID	A Board App. Vol. (mL)	C Board App. Vol. (mL)	N Board App. Vol. (mL)	A Board App. Mass (g)	C Board App. Mass (g)	N Board App. Mass (g)
1-A	100	60	100	--	--	--
1-B	100	80	90	--	--	--
1-C	100	80	110	--	--	--
N	3	3	3	0	0	0
Average	100.0	73.3	100.0	--	--	--
Std. Dev.	0.0	11.5	10.0	--	--	--
RSD	0.0%	15.7%	10.0%	--	--	--
2-A	70	55	65	53.5	46	49.3
2-B	60	45	55	52.4	39.9	47.2
2-C	60	55	70	46.6	50.5	57.1
N	3	3	3	3	3	3
Average	63.3	51.7	63.3	50.8	45.5	51.2
Std. Dev.	5.8	5.8	7.6	3.7	5.3	5.2
RSD	9.1%	11.2%	12.1%	7.3%	11.7%	10.2%
3-A	80	50	110	23.4	15.1	36.4
3-B	80	50	90	22.3	12.9	40
3-C	70	60	110	26.1	18.2	35.9
N	3	3	3	3	3	3
Average	76.7	53.3	103.3	23.9	15.4	37.4
Std. Dev.	5.8	5.8	11.5	2.0	2.7	2.2
RSD	7.5%	10.8%	11.2%	8.2%	17.3%	6.0%
4-A	60	30	55	38.3	38.3	42.5
4-B	60	45	60	47.3	35.5	47.6
4-C	60	40	80	44.1	43.1	55.4
N	3	3	3	3	3	3
Average	60.0	38.3	65.0	43.2	39.0	48.5
Std. Dev.	0.0	7.6	13.2	4.6	3.8	6.5
RSD	0.0%	19.9%	20.4%	10.6%	9.9%	13.4%
5-A	25	30	50	30.4	27.2	51.8
5-B	25	25	30	32.9	28.4	52.1
5-C	30	35	65	27.2	33	62.3
N	3	3	3	3	3	3
Average	26.7	30.0	48.3	30.2	29.5	55.4
Std. Dev.	2.9	5.0	17.6	2.9	3.1	6.0
RSD	10.8%	16.7%	36.3%	9.5%	10.4%	10.8%

Minideck ID	A Board App. Vol. (mL)	C Board App. Vol. (mL)	N Board App. Vol. (mL)	A Board App. Mass (g)	C Board App. Mass (g)	N Board App. Mass (g)
6-A	60	40	70	51.3	43.3	54
6-B	50	70	50	36.2	48.1	49.4
6-C	45	40	45	48.5	38.9	46.7
N	3	3	3	3	3	3
Average	51.7	50.0	55.0	45.3	43.4	50.0
Std. Dev.	7.6	17.3	13.2	8.0	4.6	3.7
RSD	14.8%	34.6%	24.1%	17.7%	10.6%	7.4%
7-A	40	35	45	38	33.9	43.7
7-B	50	45	55	51.2	42.8	52.3
7-C	50	40	45	53.6	37	47.9
N	3	3	3	3	3	3
Average	46.7	40.0	48.3	47.6	37.9	48.0
Std. Dev.	5.8	5.0	5.8	8.4	4.5	4.3
RSD	12.4%	12.5%	11.9%	17.6%	11.9%	9.0%
8-A	50	40	50	45.9	30.6	46.4
8-B	50	30	60	41.9	36.4	52.6
8-C	45	35	60	34.8	32.4	50.7
N	3	3	3	3	3	3
Average	48.3	35.0	56.7	40.9	33.1	49.9
Std. Dev.	2.9	5.0	5.8	5.6	3.0	3.2
RSD	6.0%	14.3%	10.2%	13.8%	9.0%	6.4%
9-A	35	15	30	34.5	27.9	52.2
9-B	35	30	40	34.1	33.1	46.4
9-C	45	30	15	39.3	35.2	47.2
N	3	3	3	3	3	3
Average	38.3	25.0	28.3	36.0	32.1	48.6
Std. Dev.	5.8	8.7	12.6	2.9	3.8	3.1
RSD	15.1%	34.6%	44.4%	8.0%	11.7%	6.5%
10-A	80	80	115	34.6	29.3	58.4
10-B	60	50	100	33.4	24.6	53.3
10-C	70	60	100	31.6	24.4	49.5
N	3	3	3	3	3	3
Average	70.0	63.3	105.0	33.2	26.1	53.7
Std. Dev.	10.0	15.3	8.7	1.5	2.8	4.5
RSD	14.3%	24.1%	8.2%	4.5%	10.6%	8.3%

Minideck ID	A Board App. Vol. (mL)	C Board App. Vol. (mL)	N Board App. Vol. (mL)	A Board App. Mass (g)	C Board App. Mass (g)	N Board App. Mass (g)
11-A	90	85	110	82	73	80.5
11-B	80	90	95	77.6	57.8	110.7
11-C	80	65	75	80.9	52.6	109.5
N	3	3	3	3	3	3
Average	83.3	80.0	93.3	80.2	61.1	100.2
Std. Dev.	5.8	13.2	17.6	2.3	10.6	17.1
RSD	6.9%	16.5%	18.8%	2.9%	17.3%	17.1%
12-A	60	40	80	58.3	48.9	71.6
12-B	60	50	90	63.5	44.7	85.3
12-C	70	50	90	64.9	52.4	88.8
N	3	3	3	3	3	3
Average	63.3	46.7	86.7	62.2	48.7	81.9
Std. Dev.	5.8	5.8	5.8	3.5	3.9	9.1
RSD	9.1%	12.4%	6.7%	5.6%	7.9%	11.1%
13-A	--	--	--	--	--	--
13-B	--	--	--	--	--	--
13-C	--	--	--	--	--	--
N	0	0	0	0	0	0
Average	--	--	--	--	--	--
Std. Dev.	--	--	--	--	--	--
RSD	--	--	--	--	--	--

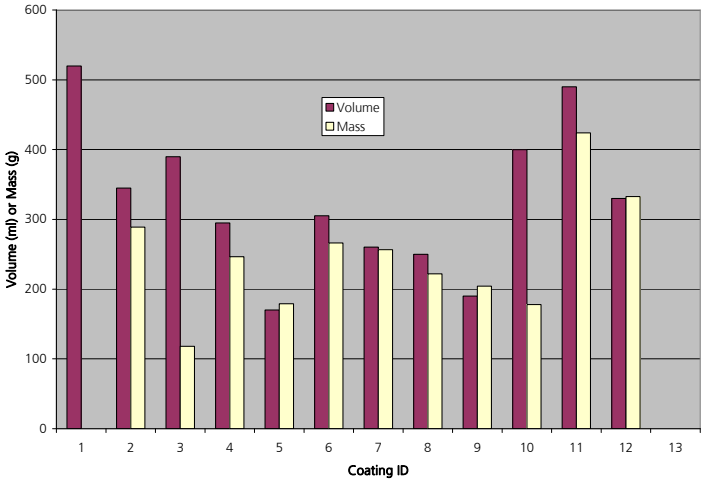


Figure 4.1 Coating Application (total of triplicate minidecks and both A and C sources)

Table 4-3. Wood Core Sample Results for Source A

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board A-AB			
N	3	3	3
Average	2148.4	2704.3	1698.4
Std. Dev.	179.2	224.9	87.9
RSD	8.3%	8.3%	5.2%
Board A-AC			
N	4	4	4
Average	1499.9	1959.0	1224.0
Std. Dev.	327.5	204.7	134.6
RSD	21.8%	10.5%	11.0%
Board A-AD			
N	4	4	4
Average	2675.3	3280.5	1791.4
Std. Dev.	75.5	335.5	191.6
RSD	2.8%	10.2%	10.7%
Board A-AE			
N	4	4	4
Average	851.1	1023.2	610.5
Std. Dev.	977.9	1190.2	656.1
RSD	114.9%	116.3%	107.5%
Board A-AF			
N	3	3	3
Average	1424.4	1691.5	982.9
Std. Dev.	142.2	188.9	118.5
RSD	10.0%	11.2%	12.1%
Board A-AG			
N	4	4	4
Average	1865.1	2227.3	1288.3
Std. Dev.	395.9	413.3	323.4
RSD	21.2%	18.6%	25.1%
Board A-AH			
N	4	4	4
Average	1106.0	1293.7	770.8
Std. Dev.	738.1	871.1	530.6
RSD	66.7%	67.3%	68.8%

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board A-AJ			
N	4	4	4
Average	1238.3	2007.8	1090.7
Std. Dev.	886.2	484.7	501.1
RSD	71.6%	24.1%	45.9%
Board A-AK			
N	4	4	4
Average	2008.6	2192.7	1256.0
Std. Dev.	1115.4	1220.4	661.9
RSD	55.5%	55.7%	52.7%
Board A-AN			
N	3	3	3
Average	2116.7	2656.0	1667.6
Std. Dev.	228.0	222.4	89.7
RSD	10.8%	8.4%	5.4%
Board A-AR			
N	4	4	4
Average	382.8	499.1	281.1
Std. Dev.	444.9	518.6	275.6
RSD	116.2%	103.9%	98.1%
Board A-AZ			
N	4	4	4
Average	2501.0	2967.5	1781.7
Std. Dev.	642.6	544.5	213.5
RSD	25.7%	18.4%	12.0%
Board A-BC			
N	3	3	3
Average	1846.0	2543.7	1515.8
Std. Dev.	144.2	295.1	229.7
RSD	7.8%	11.6%	15.2%
Board A-BE			
N	3	3	3
Average	35.7	36.6	27.4
Std. Dev.	6.4	4.6	6.2
RSD	18.1%	12.6%	22.5%

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board A-BG			
N	4	4	4
Average	2188.1	2589.0	1543.0
Std. Dev.	370.5	346.8	202.2
RSD	16.9%	13.4%	13.1%
Board A-BN			
N	1	1	1
Average	1521	1741	1079
Std. Dev.	-	-	-
RSD	-	-	-
Board A-BW			
N	2	2	2
Average	1452.3	1692.5	1013.2
Std. Dev.	126.1	236.2	193.5
RSD	8.7%	14.0%	19.1%
Board A-BY			
N	3	3	3
Average	1149.7	1404.1	859.3
Std. Dev.	220.3	220.7	121.1
RSD	19.2%	15.7%	14.1%
Board A-I			
N	3	3	3
Average	1953.0	2270.1	1218.6
Std. Dev.	382.9	285.5	195.3
RSD	19.6%	12.6%	16.0%
Board A-L			
N	3	3	3
Average	1510.1	1954.2	1206.2
Std. Dev.	309.2	276.7	221.6
RSD	20.5%	14.2%	18.4%
Board A-N			
N	4	4	4
Average	1117.7	1333.5	825.0
Std. Dev.	616.5	722.8	512.7
RSD	55.2%	54.2%	62.1%

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board A-O			
N	3	3	3
Average	1598.4	2191.4	1292.2
Std. Dev.	51.2	297.7	188.2
RSD	3.2%	13.6%	14.6%
Board A-P			
N	3	3	3
Average	1763.6	2189.6	1209.0
Std. Dev.	275.4	416.1	245.9
RSD	15.6%	19.0%	20.3%
Board A-Q			
N	3	3	3
Average	2549.2	3177.5	2002.8
Std. Dev.	433.5	554.1	301.6
RSD	17.0%	17.4%	15.1%
Board A-R			
N	3	3	3
Average	1913.6	2606.8	1558.4
Std. Dev.	435.3	135.5	146.8
RSD	22.7%	5.2%	9.4%
Board A-S			
N	3	3	3
Average	1559.7	1824.3	1027.1
Std. Dev.	92.3	138.3	107.8
RSD	5.9%	7.6%	10.5%
Board A-T			
N	3	3	3
Average	1927.8	2316.2	1375.7
Std. Dev.	105.9	140.7	67.6
RSD	5.5%	6.1%	4.9%
Board A-U			
N	2	2	2
Average	885.0	1146.3	711.3
Std. Dev.	1193.5	1568.0	943.0
RSD	134.9%	136.8%	132.6%

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board A-V			
N	3	3	3
Average	759.8	1012.6	535.1
Std. Dev.	305.4	364.8	199.2
RSD	40.2%	36.0%	37.2%
Board A-X			
N	4	4	4
Average	1711.8	2387.5	1461.6
Std. Dev.	424.4	325.8	149.6
RSD	24.8%	13.6%	10.2%
Board A-Y			
N	3	3	3
Average	2696.8	3250.2	1847.6
Std. Dev.	524.4	614.1	309.0
RSD	19.4%	18.9%	16.7%
Board A-Z			
N	3	3	3
Average	2496.0	2921.6	1618.5
Std. Dev.	710.0	613.2	327.1
RSD	28.4%	21.0%	20.2%
For All A Boards			
N	104	104	104
Average	1645.4	2045.3	1203.4
Std. Dev.	787.7	917.0	543.5
RSD	47.9%	44.8%	45.2%
Min	28	34	21
Max	3445	3933	2186

Table 4-4. Wood Core Sample Results for Source C

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board C-AA			
N	4	4	4
Average	2185.7	2302.8	1517.3
Std. Dev.	787.9	707.9	309.9
RSD	36.0%	30.7%	20.4%
Board C-AC			
N	4	4	4
Average	2051.2	2171.9	1346.4
Std. Dev.	520.2	618.7	405.0
RSD	25.4%	28.5%	30.1%
Board C-AD			
N	4	4	4
Average	1730.6	1729.0	1075.2
Std. Dev.	206.5	250.8	182.0
RSD	11.9%	14.5%	16.9%
Board C-AE			
N	3	3	3
Average	2405.2	2323.8	7803.6
Std. Dev.	939.4	753.8	11584.3
RSD	39.1%	32.4%	148.4%
Board C-AH			
N	4	4	4
Average	1546.6	1561.7	941.9
Std. Dev.	155.1	186.6	78.4
RSD	10.0%	12.0%	8.3%
Board C-AI			
N	3	3	3
Average	2650.3	2709.7	1607.3
Std. Dev.	428.2	612.8	369.4
RSD	16.2%	22.6%	23.0%
Board C-AK			
N	4	4	4
Average	225.6	248.5	151.7
Std. Dev.	222.2	206.2	116.2
RSD	98.5%	83.0%	76.6%

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board C-AM			
N	4	4	4
Average	2580.4	2597.1	1527.5
Std. Dev.	207.0	181.5	194.8
RSD	8.0%	7.0%	12.8%
Board C-AN			
N	4	4	4
Average	874.1	886.8	540.6
Std. Dev.	484.3	458.3	239.0
RSD	55.4%	51.7%	44.2%
Board C-AP			
N	4	4	4
Average	2555.5	2653.5	1706.5
Std. Dev.	667.7	648.8	387.1
RSD	26.1%	24.5%	22.7%
Board C-AS			
N	4	4	4
Average	1490.2	1495.9	921.2
Std. Dev.	1261.6	1233.2	733.4
RSD	84.7%	82.4%	79.6%
Board C-BE			
N	4	4	4
Average	2784.7	2649.8	1612.9
Std. Dev.	314.3	251.9	160.1
RSD	11.3%	9.5%	9.9%
Board C-BI			
N	2	2	2
Average	1279.4	1203.1	688.3
Std. Dev.	114.0	182.6	125.7
RSD	8.9%	15.2%	18.3%
Board C-BJ			
N	3	3	3
Average	2037.8	1995.6	1260.2
Std. Dev.	727.8	745.1	534.0
RSD	35.7%	37.3%	42.4%

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board C-BL			
N	4	4	4
Average	3157.9	3162.5	1979.2
Std. Dev.	573.8	378.9	204.9
RSD	18.2%	12.0%	10.4%
Board C-BM			
N	3	3	3
Average	1463.8	1451.8	933.4
Std. Dev.	1317.7	1308.3	893.2
RSD	90.0%	90.1%	95.7%
Board C-BN			
N	1	1	1
Average	2544	2602	1648
Std. Dev.	-	-	-
RSD	-	-	-
Board C-BO			
N	4	4	4
Average	1518.7	1488.4	888.8
Std. Dev.	679.7	655.8	410.0
RSD	44.8%	44.1%	46.1%
Board C-BP			
N	3	3	3
Average	2603.7	2748.1	1722.1
Std. Dev.	680.8	881.2	555.3
RSD	26.1%	32.1%	32.2%
Board C-BR			
N	3	3	3
Average	1431.9	1380.3	809.9
Std. Dev.	149.1	142.4	113.0
RSD	10.4%	10.3%	13.9%
Board C-BT			
N	1	1	1
Average	1386	1367	831
Std. Dev.	-	-	-
RSD	-	-	-

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board C-BU			
N	3	3	3
Average	2855.0	3128.9	1867.3
Std. Dev.	588.9	684.7	395.2
RSD	20.6%	21.9%	21.2%
Board C-BW			
N	3	3	3
Average	562.0	571.1	347.5
Std. Dev.	293.5	304.6	151.6
RSD	52.2%	53.3%	43.6%
Board C-BX			
N	4	4	4
Average	2301.4	2309.6	1469.8
Std. Dev.	993.6	991.5	626.1
RSD	43.2%	42.9%	42.6%
Board C-BY			
N	3	3	3
Average	2507.9	2578.5	1790.5
Std. Dev.	528.2	459.8	312.3
RSD	21.1%	17.8%	17.4%
Board C-BZ			
N	4	4	4
Average	1343.2	1486.0	847.4
Std. Dev.	439.5	559.1	337.1
RSD	32.7%	37.6%	39.8%
Board C-CA			
N	3	3	3
Average	3171.3	3224.6	1983.8
Std. Dev.	581.7	490.2	287.8
RSD	18.3%	15.2%	14.5%
Board C-CC			
N	2	2	2
Average	1435.9	1356.5	807.2
Std. Dev.	12.7	32.2	2.0
RSD	0.9%	2.4%	0.2%

Statistical Parameter	Wood Core As (mg/kg)	Wood Core Cr (mg/kg)	Wood Core Cu (mg/kg)
Board C-CD			
N	4	4	4
Average	1194.1	1162.8	671.2
Std. Dev.	798.9	777.0	449.8
RSD	66.9%	66.8%	67.0%
Board C-CE			
N	2	2	2
Average	2425.5	2425.5	1520.8
Std. Dev.	435.9	435.9	284.8
RSD	18.0%	18.0%	18.7%
Board C-E			
N	3	3	3
Average	2946.3	2832.7	1627.9
Std. Dev.	1236.1	1330.9	451.5
RSD	42.0%	47.0%	27.7%
Board C-N			
N	3	3	3
Average	2988.3	2966.6	1832.1
Std. Dev.	549.8	618.7	465.0
RSD	18.4%	20.9%	25.4%
Board C-S			
N	4	4	4
Average	3675.9	3736.5	2173.5
Std. Dev.	1047.1	840.9	310.8
RSD	28.5%	22.5%	14.3%
ALL C Boards			
N	107	107	107
Average	2074.2	2095.8	1465.0
Std. Dev.	990.1	997.4	2016.1
RSD	48.9%	48.8%	138.6%
Min	65	96	57
Max	4624	4624	21179

AWPA standards allow the actives composition of CCA-C – the formulation used to treat the wood used in this study – to vary between 44.5 – 50.5% for CrO_3, 17.0 –

21.0% for CuO, and 30.0 – 38.0% for As_2O_5 in a specific assay zone, the outer 0.6 in (15 mm) (Lebow, 1996). Knowing that the source wood for this project was treated to target retentions of 0.40 pounds per cubic foot (pcf), hypothetical, ideal actives composition (analyte concentrations) can be calculated for each CCA analyte: 0.190 pcf (86.1 g/cf) CrO_3, 0.074 pcf (33.6 g/cf) CuO, and 0.136 pcf (61.7 g/cf) As_2O_5. Furthermore, the average dry, pretreatment density of SYP is 32 pcf, or 14.5 kg/cf. Thus, predicted levels of CCA analytes in the study wood core samples can be approximated as:

CrO_3	(86.1 g/cf) / (14.5 kg/cf) x (1000 mg/g) = **5,938 mg/kg**
CuO	(33.6 g/cf) / (14.5 kg/cf) x (1000 mg/g) = **2,317 mg/kg**
As_2O_5	(61.7 g/cf) / (14.5 kg/cf) x (1000 mg/g) = **4,255 mg/kg**

The overall average results in Tables 4.3 and 4.4 (note that these are reported as elemental solid-phase concentrations) compare favorably with expected ratio of concentrations of CCA analytes, although there are some wood core sample datapoints that are clear outliers and overall variability is relatively high at about 50% RSD. Note that these RSDs listed should not be interpreted as indicators of data quality, but rather as indicators of the natural variability in wood core CCA concentrations within and between boards. Additionally, because of the way that boards are cut from the tree, taking core samples from the wide face – as done in this study – increases the likelihood that heartwood will be sampled. If the narrow faces had been sampled, sapwood would have more consistently been sampled and the values would have likely been more consistently high and less variable. A summary of the nominal (ideal), source A, and source C CCA actives composition is provided in Table 4.5.

Table 4.5 Comparison of Nominal, Source A, and Source C CCA Actives Composition

	Nominal CCA	Source A	Source C
As (mg/kg)		1,645	2,075
As as As_2O_5 (mg/kg)	4,255	2,522	3,182
As_2O_5 (%)	34.0 (30.0 – 38.0)	31.7	35.2
Cr (mg/kg)		2,045	2,095
Cr as CrO_3 (mg/kg)	5,938	3,933	4,029
CrO_3 (%)	47.5 (44.5–50.5)	49.4	44.5
Cu (mg/kg)		1,203	1,465
Cu as CuO (mg/kg)	2,317	1,506	1,834

CuO (%)	18.5 (17.0–21.0)	18.9	20.3

4.4 Baseline Wipe Sample Data

Each source board used in the construction of the minidecks had at least two baseline wipe samples taken from it prior to coating. These samples were digested, and analyzed for CCA content. The baseline wipe sample results were used to establish baseline DA concentrations for the PSAs on the minidecks and then to assess coating efficacy (via calculation methods 1 and 2, as described in Section 3.1.2) by calculating percent reduction in DA post-coat, at various time (sampling) intervals. However, it is also instructive to look at the baseline data on its own, to assess the variability of DA across each board (intraboard) and between boards (interboard) and source decks. Table 4-6 (for source A) and Table 4-7 (for source C) provide summary statistics for each board and each source deck. The full dataset showing the individual specimen baseline values is provided in Appendix K. The tables show averages, standard deviations, and relative standard deviation (RSD) for each board and include summary statistics at the end of each table for each source (A and C). As with the wood core sample results, RSDs should not be interpreted as indicators of data quality, but rather as indicators of natural variability within and between boards.

Like the wood core sample data, overall baseline wipe sample variability is relatively high (around 50% RSD). Intraboard variability (that is, variability between sampling area DAs along a given board) likewise varies: some are relatively low (5-20% RSD) while others are quite high (>50% RSD). While its overall (interboard) variability was relatively high, the newer C deck appears to have significantly lower intraboard variability than the A source deck. For reference, research by Stilwell (2003a) showed an intraboard variability (RSD) of 17% versus an interboard (between-board) variability of 39%.

Figures 4-2 through 4-7 provide simple distribution and box plots of the baseline data. Similar plots are provided, grouped by board instead of coating, in Appendix L. The figures are grouped by analyte and source, and plot coating on the x-axis versus baseline DA on the y-axis. The top plot in each figure plots simple data distribution, showing all of the baseline data points, sorted by coating. The bottom plot in each figure is a box plot which provides an excellent visual summary of many important aspects of the distribution. The box stretches from the lower hinge (defined as the 25th percentile) to the upper hinge (defined as the 75th percentile) and therefore contains the middle half of the scores in the distribution. The median is shown as a line across the box. Therefore, ¼ of the distribution is between this line and the top of the box and ¼ of the distribution is between this line and the bottom of the box.

The plus symbol (+) shows the mean. In these plots, the bars on either side of the box define the minimum and maximum.

Table 4-6. Baseline Wipe Sample Summary for Source Deck A

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board A-AC			
N	5	5	5
Average	1.63	1.62	0.74
Std. Dev.	0.41	0.28	0.25
RSD	24.9%	17.0%	34.0%
Board A-AD			
N	5	5	5
Average	2.79	3.05	1.43
Std. Dev.	0.60	0.44	0.45
RSD	21.4%	14.4%	31.4%
Board A-AE			
N	5	5	5
Average	1.36	1.87	1.01
Std. Dev.	0.29	1.11	0.30
RSD	21.2%	59.4%	30.0%
Board A-AF			
N	2	2	2
Average	1.58	1.48	0.83
Std. Dev.	0.94	0.83	0.56
RSD	59.3%	56.1%	67.4%
Board A-AG			
N	6	6	6
Average	1.42	1.50	0.65
Std. Dev.	0.63	0.66	0.16
RSD	44.5%	43.7%	24.6%
Board A-AH			
N	6	6	6
Average	0.70	0.72	0.46
Std. Dev.	0.29	0.24	0.15
RSD	41.2%	33.8%	33.1%

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board A-AJ			
N	6	6	6
Average	1.76	1.93	0.86
Std. Dev.	0.20	0.21	0.13
RSD	11.4%	10.9%	14.9%
Board A-AN			
N	5	5	5
Average	3.89	4.94	0.63
Std. Dev.	1.26	1.86	0.14
RSD	32.4%	37.6%	22.6%
Board A-AR			
N	5	5	5
Average	1.73	1.68	0.91
Std. Dev.	1.17	1.30	0.64
RSD	67.6%	77.5%	70.0%
Board A-AT			
N	5	5	5
Average	1.32	1.57	0.75
Std. Dev.	0.28	0.40	0.13
RSD	20.9%	25.2%	16.7%
Board A-BC			
N	5	5	5
Average	1.57	1.84	0.72
Std. Dev.	0.41	0.41	0.08
RSD	26.2%	22.5%	10.5%
Board A-BG			
N	6	6	6
Average	1.54	1.50	0.73
Std. Dev.	0.27	0.35	0.12
RSD	17.3%	23.0%	16.9%

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board A-BM			
N	3	3	3
Average	1.42	1.68	0.51
Std. Dev.	0.51	0.54	0.17
RSD	35.7%	32.2%	32.8%
Board A-BW			
N	6	6	6
Average	0.81	0.71	0.50
Std. Dev.	0.28	0.25	0.17
RSD	34.3%	35.2%	34.3%
Board A-BY			
N	5	5	5
Average	1.53	1.57	0.91
Std. Dev.	0.51	0.51	0.30
RSD	33.5%	32.6%	33.0%
Board A-I			
N	5	5	5
Average	1.74	2.16	0.76
Std. Dev.	0.51	0.36	0.15
RSD	29.1%	16.7%	19.5%
Board A-L			
N	5	5	5
Average	0.75	0.85	0.45
Std. Dev.	0.20	0.20	0.07
RSD	26.3%	23.5%	15.4%
Board A-O			
N	5	5	5
Average	2.17	2.38	0.95
Std. Dev.	0.69	0.81	0.26
RSD	31.6%	34.3%	27.0%

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board A-P			
N	5	5	5
Average	2.12	1.73	1.12
Std. Dev.	1.09	1.00	0.25
RSD	51.5%	57.8%	22.3%
Board A-Q			
N	5	5	5
Average	2.70	2.80	1.10
Std. Dev.	1.05	1.19	0.35
RSD	38.9%	42.6%	31.8%
Board A-T			
N	5	5	5
Average	2.19	2.17	1.18
Std. Dev.	0.60	0.57	0.41
RSD	27.3%	26.4%	34.5%
Board A-U			
N	5	5	5
Average	0.95	1.11	0.54
Std. Dev.	0.41	0.52	0.16
RSD	42.9%	47.0%	29.0%
Board A-V			
N	5	5	5
Average	1.60	1.70	0.67
Std. Dev.	0.66	0.62	0.23
RSD	41.1%	36.1%	33.9%
Board A-X			
N	5	5	5
Average	1.75	1.66	0.66
Std. Dev.	0.50	0.49	0.18
RSD	28.4%	29.4%	27.0%
Board A-Y			
N	5	5	5
Average	3.95	4.33	1.33
Std. Dev.	1.75	1.53	0.47
RSD	44.2%	35.3%	35.2%

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board A-Z			
N	5	5	5
Average	2.34	2.61	0.96
Std. Dev.	0.29	0.40	0.14
RSD	12.3%	15.4%	14.7%
All A Boards			
N	130	130	130
Average	1.81	1.96	0.82
Std. Dev.	1.02	1.19	0.36
RSD	43.4%	39.3%	56.5%
Min	0.38	0.31	0.24
Max	5.85	7.38	2.19

Table 4-7. Baseline Wipe Sample Summary for Source Deck C

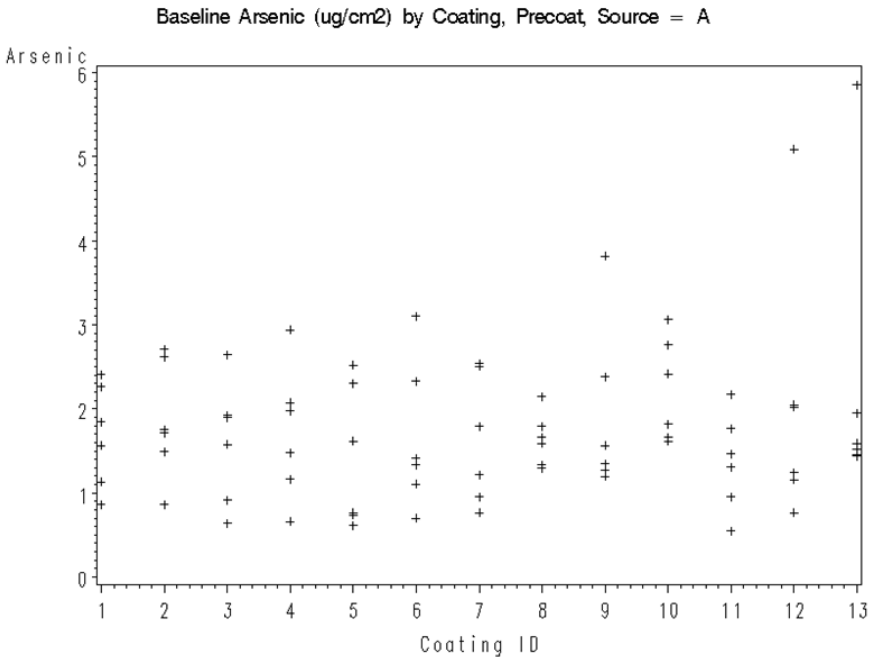
Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board C-AA			
N	5	5	5
Average	0.63	0.84	0.31
Std. Dev.	0.17	0.20	0.07
RSD	27.4%	23.5%	22.2%
Board C-AC			
N	6	6	6
Average	0.85	1.17	0.44
Std. Dev.	0.10	0.14	0.04
RSD	11.8%	11.7%	10.1%
Board C-AD			
N	7	7	7
Average	0.68	0.91	0.34
Std. Dev.	0.16	0.17	0.07
RSD	23.8%	18.6%	21.3%
Board C-AE			
N	6	6	6
Average	1.67	2.29	0.62
Std. Dev.	0.30	0.31	0.09
RSD	18.1%	13.7%	15.2%

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board C-AI			
N	5	5	5
Average	0.95	1.30	0.49
Std. Dev.	0.15	0.12	0.05
RSD	15.7%	8.9%	10.0%
Board C-AJ			
N	5	5	5
Average	1.39	1.85	0.75
Std. Dev.	0.08	0.15	0.09
RSD	5.7%	8.2%	12.2%
Board C-AK			
N	2	2	2
Average	0.59	0.88	0.48
Std. Dev.	0.07	0.05	0.04
RSD	12.3%	6.1%	7.4%
Board C-AM			
N	6	6	6
Average	1.06	1.45	0.55
Std. Dev.	0.20	0.28	0.06
RSD	18.5%	19.2%	10.9%
Board C-AN			
N	5	5	5
Average	1.24	1.36	0.54
Std. Dev.	0.31	0.72	0.09
RSD	24.9%	53.0%	16.7%
Board C-AP			
N	5	5	5
Average	0.53	0.83	0.41
Std. Dev.	0.15	0.19	0.13
RSD	28.6%	23.2%	30.9%
Board C-BE			
N	5	5	5
Average	1.39	1.73	0.83
Std. Dev.	0.19	0.29	0.49
RSD	14.0%	16.8%	58.7%

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board C-BI			
N	5	5	5
Average	0.81	1.09	0.63
Std. Dev.	0.17	0.21	0.15
RSD	21.0%	19.0%	23.6%
Board C-BJ			
N	5	5	5
Average	2.32	2.77	1.38
Std. Dev.	0.61	0.53	0.37
RSD	26.5%	19.3%	26.7%
Board C-BM			
N	7	7	7
Average	0.67	0.98	0.33
Std. Dev.	0.16	0.22	0.07
RSD	24.7%	22.7%	19.7%
Board C-BO			
N	4	4	4
Average	0.70	1.01	0.40
Std. Dev.	0.05	0.11	0.07
RSD	7.6%	11.3%	17.5%
Board C-BP			
N	5	5	5
Average	0.73	1.02	0.32
Std. Dev.	0.22	0.31	0.07
RSD	30.1%	30.3%	22.1%
Board C-BT			
N	6	6	6
Average	0.53	0.74	0.35
Std. Dev.	0.08	0.12	0.08
RSD	15.6%	15.9%	23.7%
Board C-BU			
N	3	3	3
Average	0.92	1.29	0.56
Std. Dev.	0.26	0.32	0.24
RSD	28.9%	25.0%	43.4%

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board C-BW			
N	3	3	3
Average	0.48	0.64	0.32
Std. Dev.	0.20	0.18	0.03
RSD	42.1%	28.0%	9.1%
Board C-BX			
N	5	5	5
Average	0.94	1.31	0.44
Std. Dev.	0.31	0.45	0.14
RSD	33.4%	34.7%	32.2%
Board C-BY			
N	3	3	3
Average	0.65	0.96	0.36
Std. Dev.	0.05	0.06	0.03
RSD	8.1%	6.7%	7.1%
Board C-BZ			
N	7	7	7
Average	0.71	1.06	0.46
Std. Dev.	0.30	0.40	0.14
RSD	42.2%	37.2%	31.4%
Board C-CA			
N	3	3	3
Average	0.67	0.96	0.47
Std. Dev.	0.21	0.24	0.05
RSD	30.7%	25.5%	11.4%
Board C-CC			
N	4	4	4
Average	0.80	1.11	0.55
Std. Dev.	0.14	0.17	0.05
RSD	18.0%	15.1%	8.9%
Board C-CD			
N	5	5	5
Average	1.40	1.79	1.02
Std. Dev.	0.47	0.56	0.34
RSD	33.9%	31.2%	33.5%

Statistical Parameter	DAs (µg/cm^2)	DCr (µg/cm^2)	DCu (µg/cm^2)
Board C-CE			
N	3	3	3
Average	1.38	1.87	1.14
Std. Dev.	0.26	0.30	0.23
RSD	18.5%	15.9%	20.4%
Board C-E			
N	5	5	5
Average	1.44	1.72	0.52
Std. Dev.	0.28	0.28	0.06
RSD	19.3%	16.1%	11.3%
Board C-N			
N	5	5	5
Average	1.25	1.51	0.38
Std. Dev.	0.18	0.17	0.05
RSD	14.3%	11.2%	12.5%
Board C-S			
N	5	5	5
Average	1.34	1.75	0.40
Std. Dev.	0.59	0.72	0.11
RSD	44.2%	41.0%	27.2%
All C Boards			
N	140	140	140
Average	1.00	1.33	0.54
Std. Dev.	0.48	0.57	0.29
RSD	51.7%	57.1%	46.2%
Min	0.28	0.20	0.21
Max	3.05	3.56	1.96



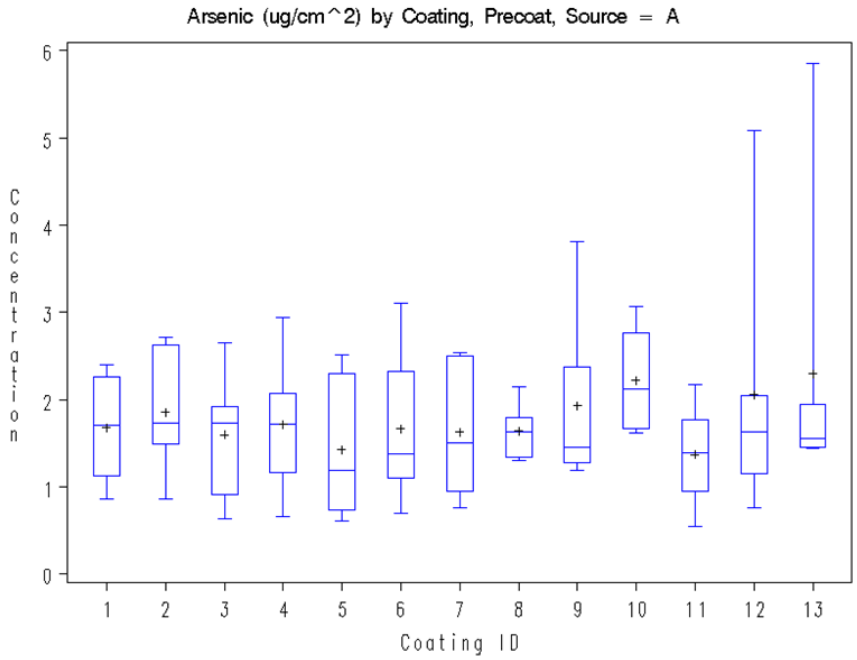
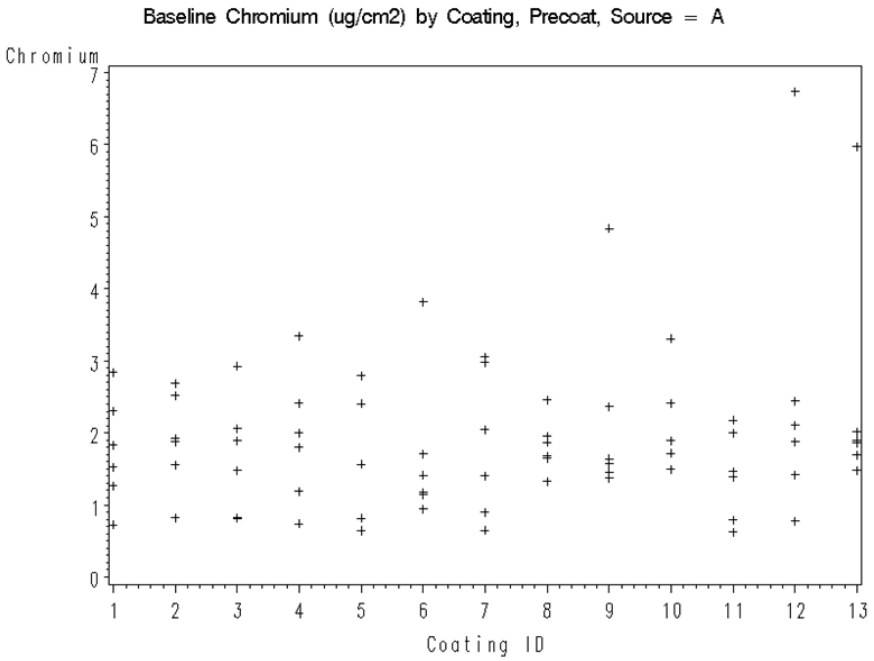


Figure 4-2. Distribution (top) and box (bottom) plot, baseline DAs, by Coating, Source A



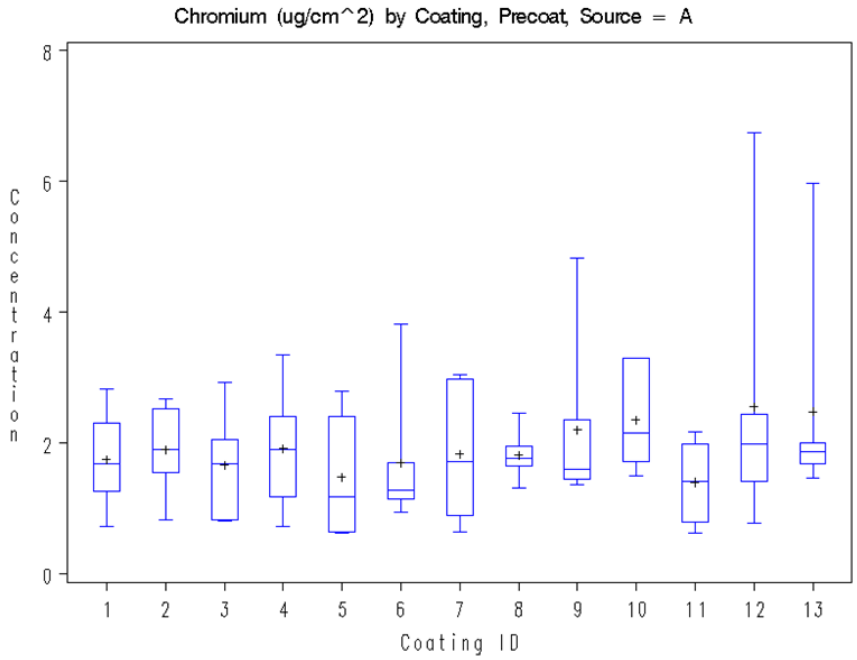
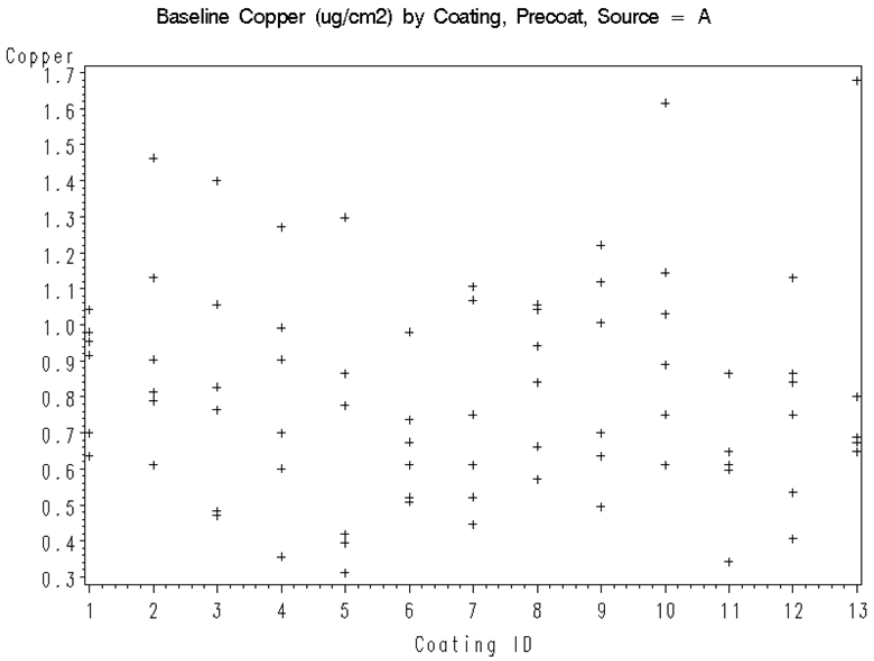


Figure 4-3. Distribution (top) and box (bottom) plot, baseline DCr, by Coating, Source A



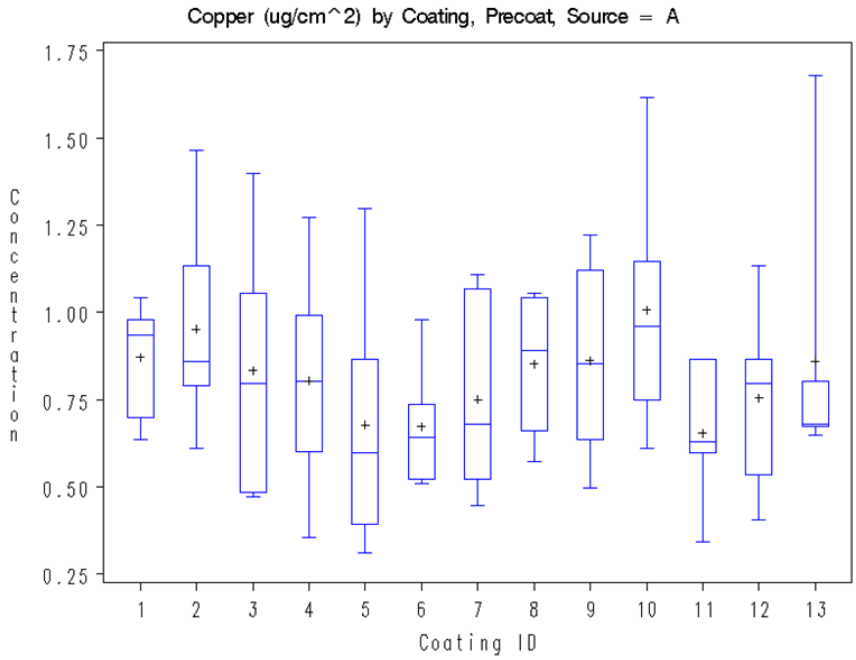
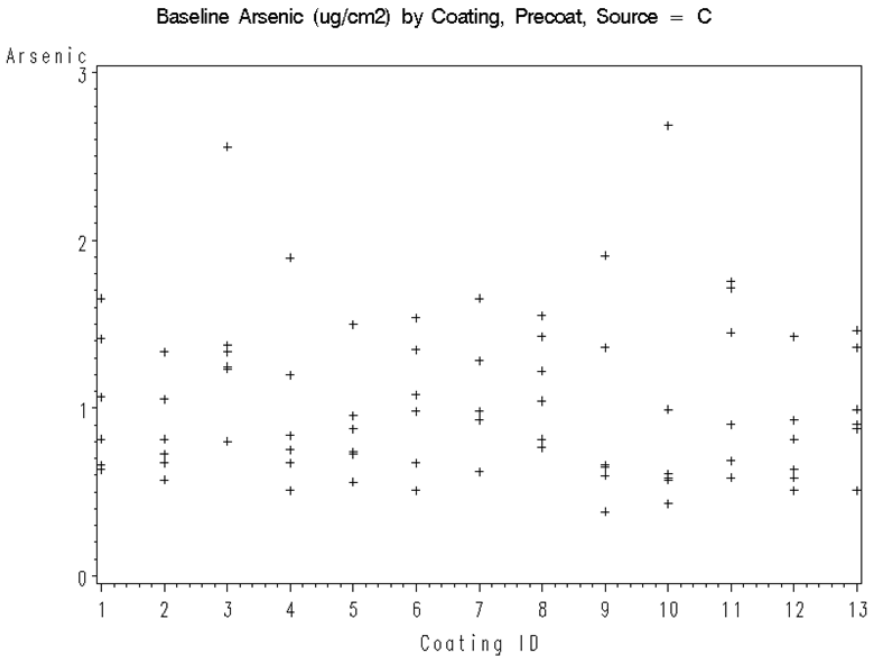


Figure 4-4. Distribution (top) and box (bottom) plot, baseline DCu, by Coating, Source A



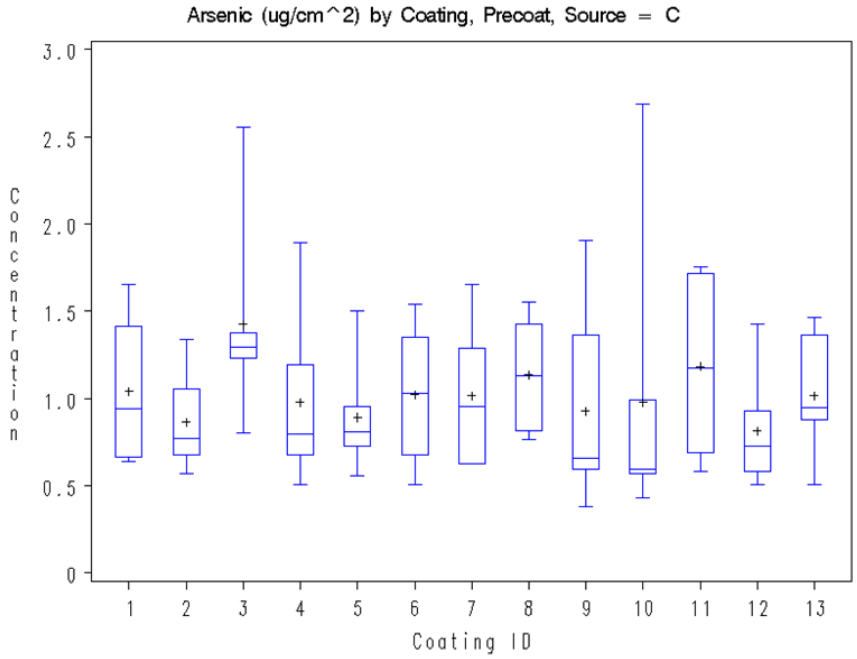
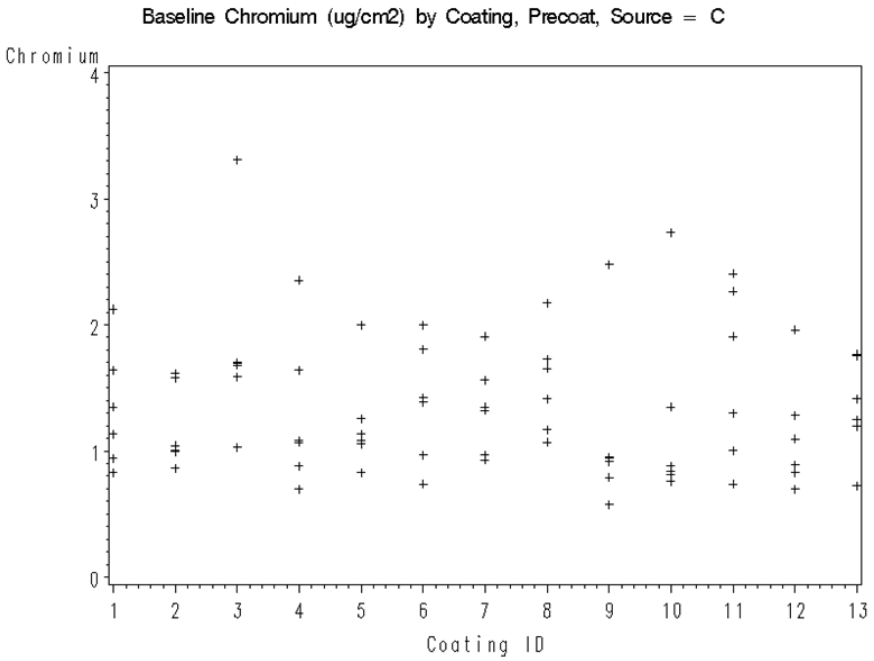


Figure 4-5. Distribution (Top) and Box (Bottom) Plot, Baseline DAs, by Coating, Source C



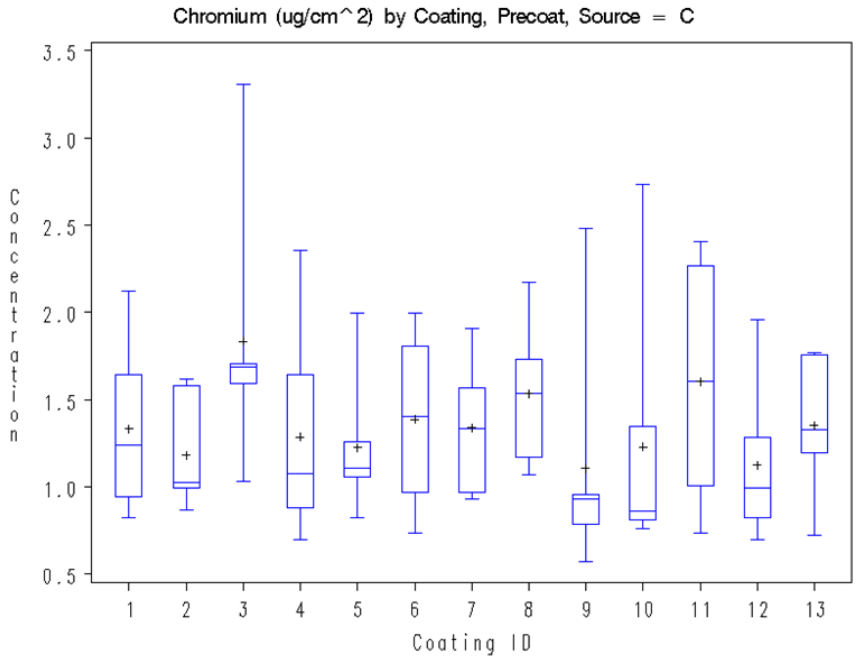
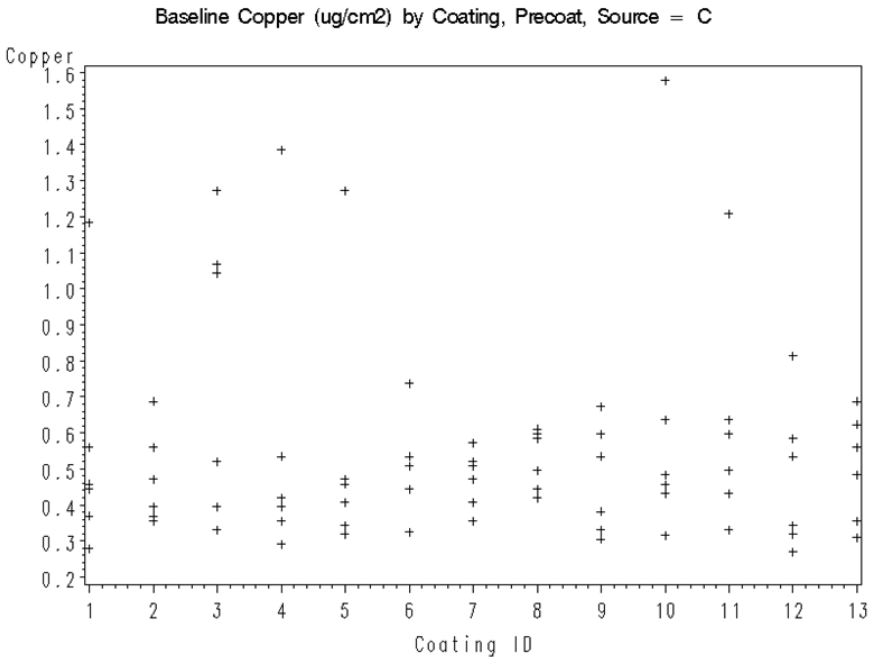


Figure 4-6. Distribution (Top) and Box (Bottom) Plot, Baseline DCr, by Coating, Source C



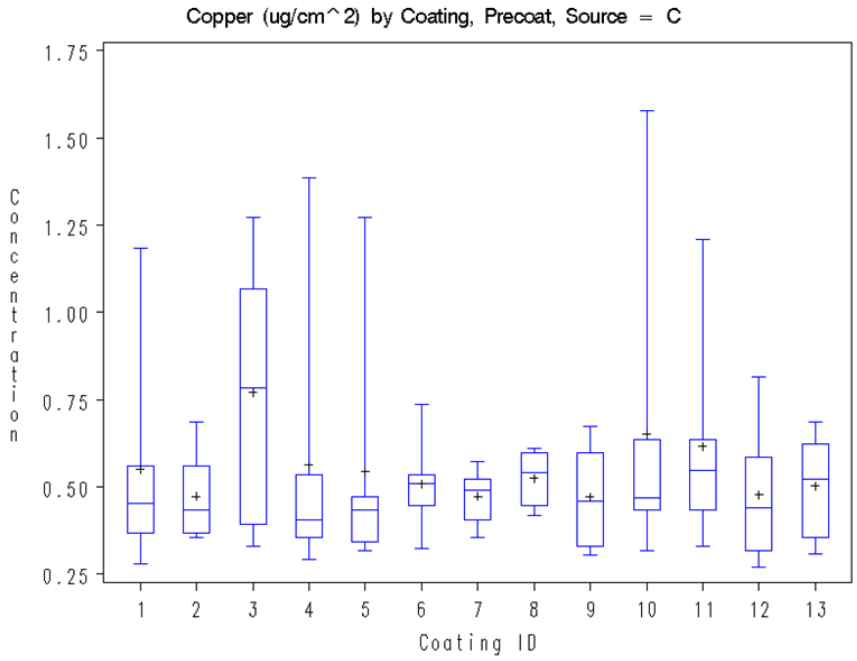


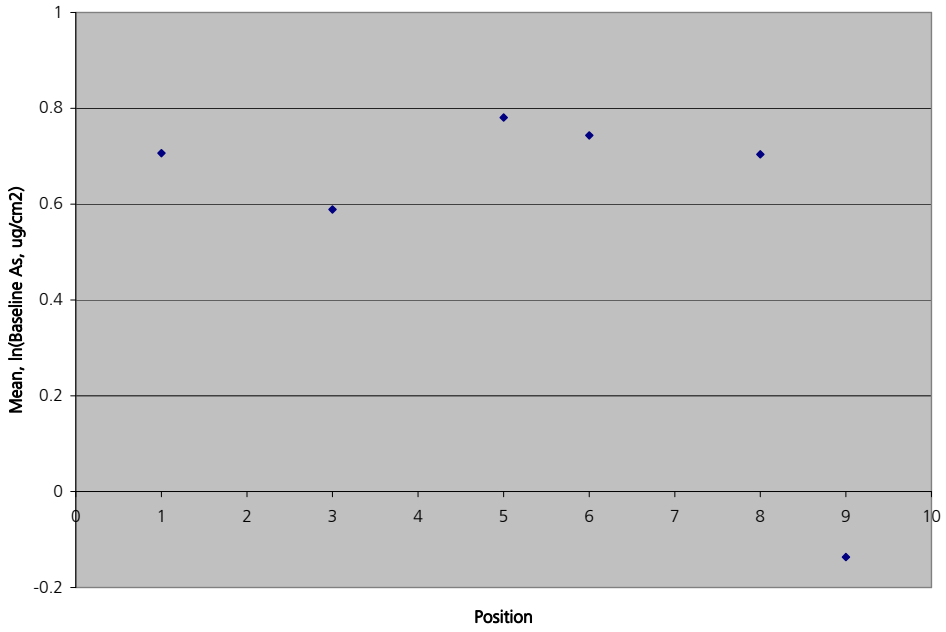
Figure 4-7. Distribution (Top) and Box (Bottom) Plot, Baseline DCu, by Coating, Source C

4.4.1 Baseline Sample Proximity Analysis

An analysis was conducted to shed light on the method by which precoat baseline values were determined for this study. That is, to determine whether there was a stronger DA correlation between sampling areas closer on a board then between those further apart. The results are graphically summarized in Figures 4-8 through 4-13. In summary, such a trend was not discovered. In other words, there is no statistical evidence that surfaces closer to one another on a given board are more strongly correlated than those surfaces that are further apart. This finding would tend to suggest that using a simple board-specific average baseline could be as appropriate as the method that was utilized in the study (averaging adjacent sampling areas).

Figures 4-8 through 4-13 each contain two plots and are grouped by source and CCA analyte. The top plot shows the mean of the natural logarithms of baseline DA (y-axis) versus position on the x-axis, where position is measured sequentially from the far end of a given board. The first position (1) would be between the first two sets of nailholes, position 2 would be between the second and third sets of nailholes, and so on. Note that there is much less data for calculating the means the further along a board, since some boards are shorter than others. Therefore, means at positions 8 and 9 for example should be viewed considering that they may have been calculated using only a few data points.

The bottom plot in each figure shows the mean of the squared differences between DA measured at each of the sampling areas along each board. Distance, on the x-axis, is calculated as the number of "positions" between each set of pairwise samples. So, a distance of 1, for example would be for sampling areas that were adjacent to one another, while a distance of 4 would be for sampling areas separated by three other possible sampling area segments (four sets of nailholes). If there had been a better correlation between DA from sampling areas closer together, then we would see lower MSDs corresponding to lower distances. Instead, we see very weak or no trends in this regard.



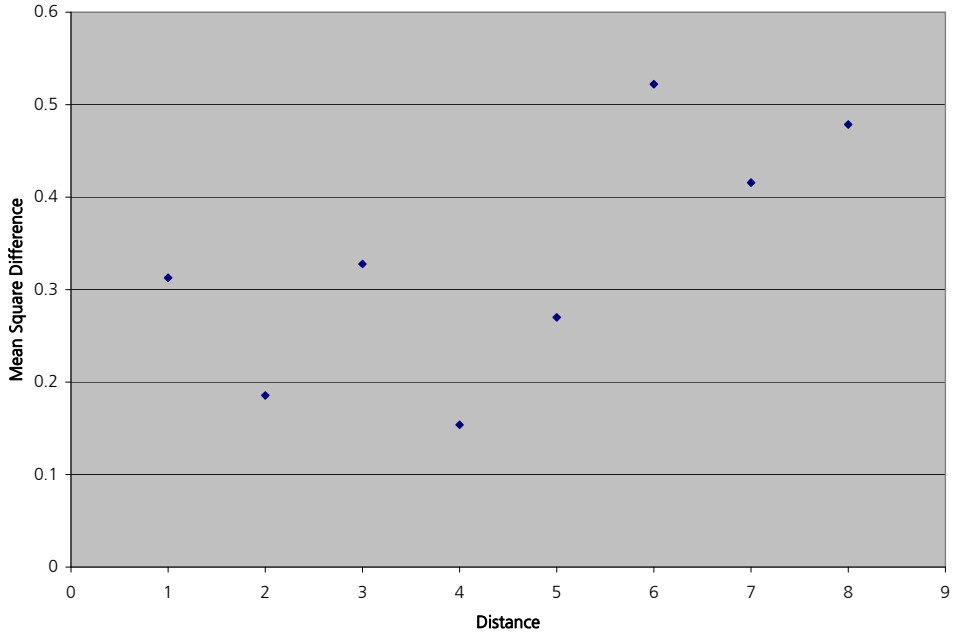


Figure 4-8. Mean vs Position and MSD vs Distance for Source A DAs Baseline

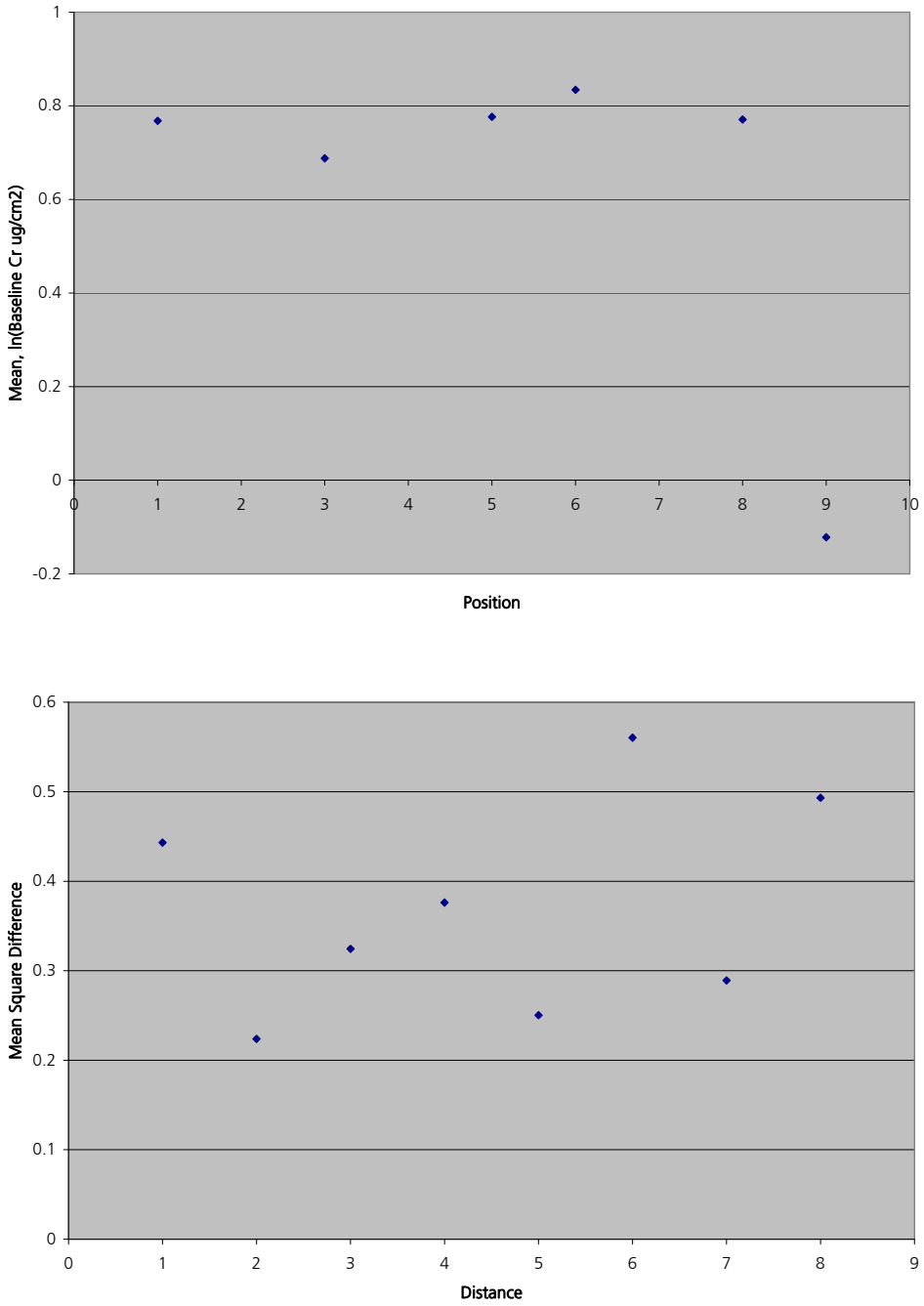


Figure 4-9. Mean vs Position and MSD vs Distance for Source A DCr Baseline

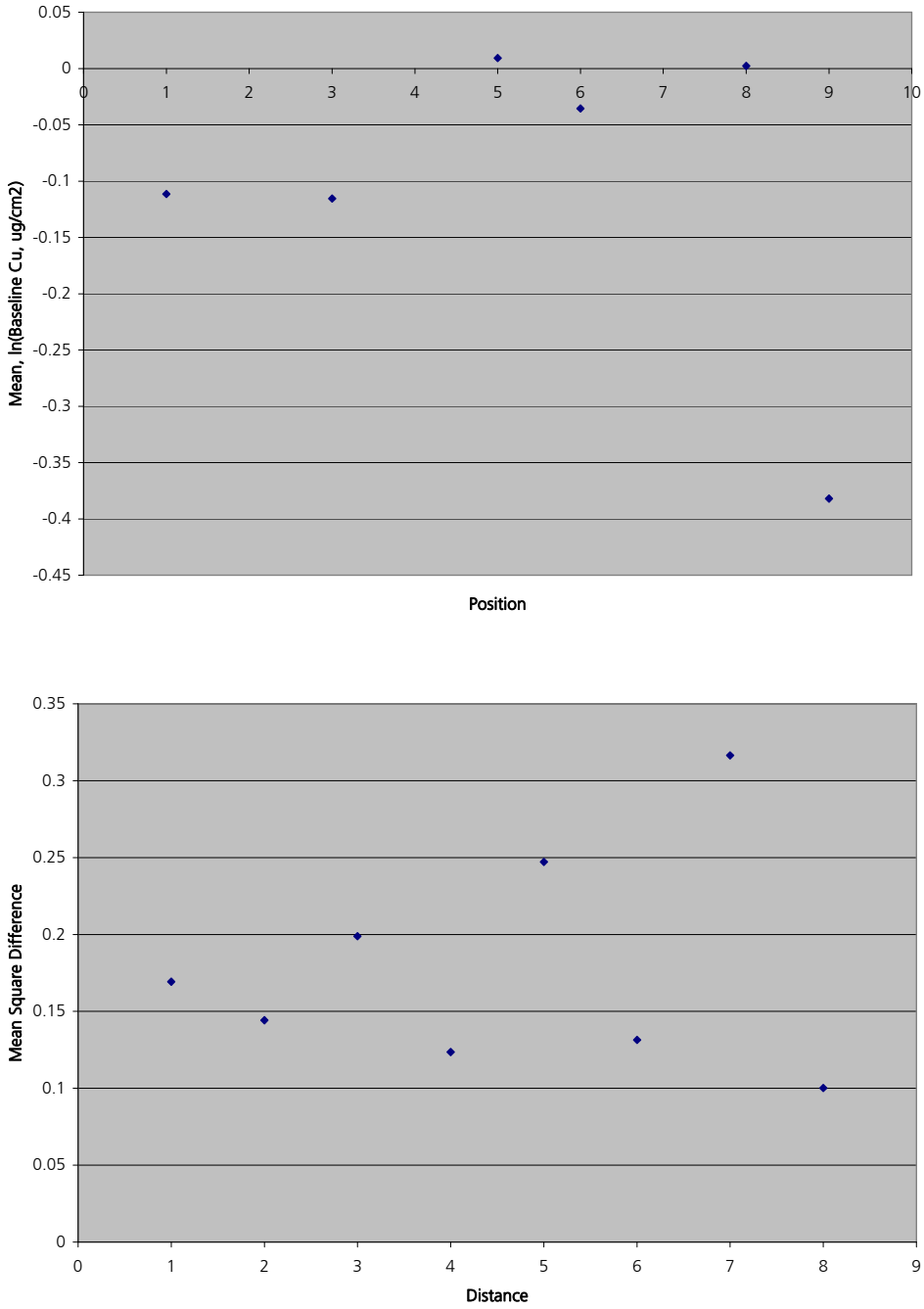


Figure 4-10. Mean vs Position and MSD vs Distance for Source A DCu Baseline

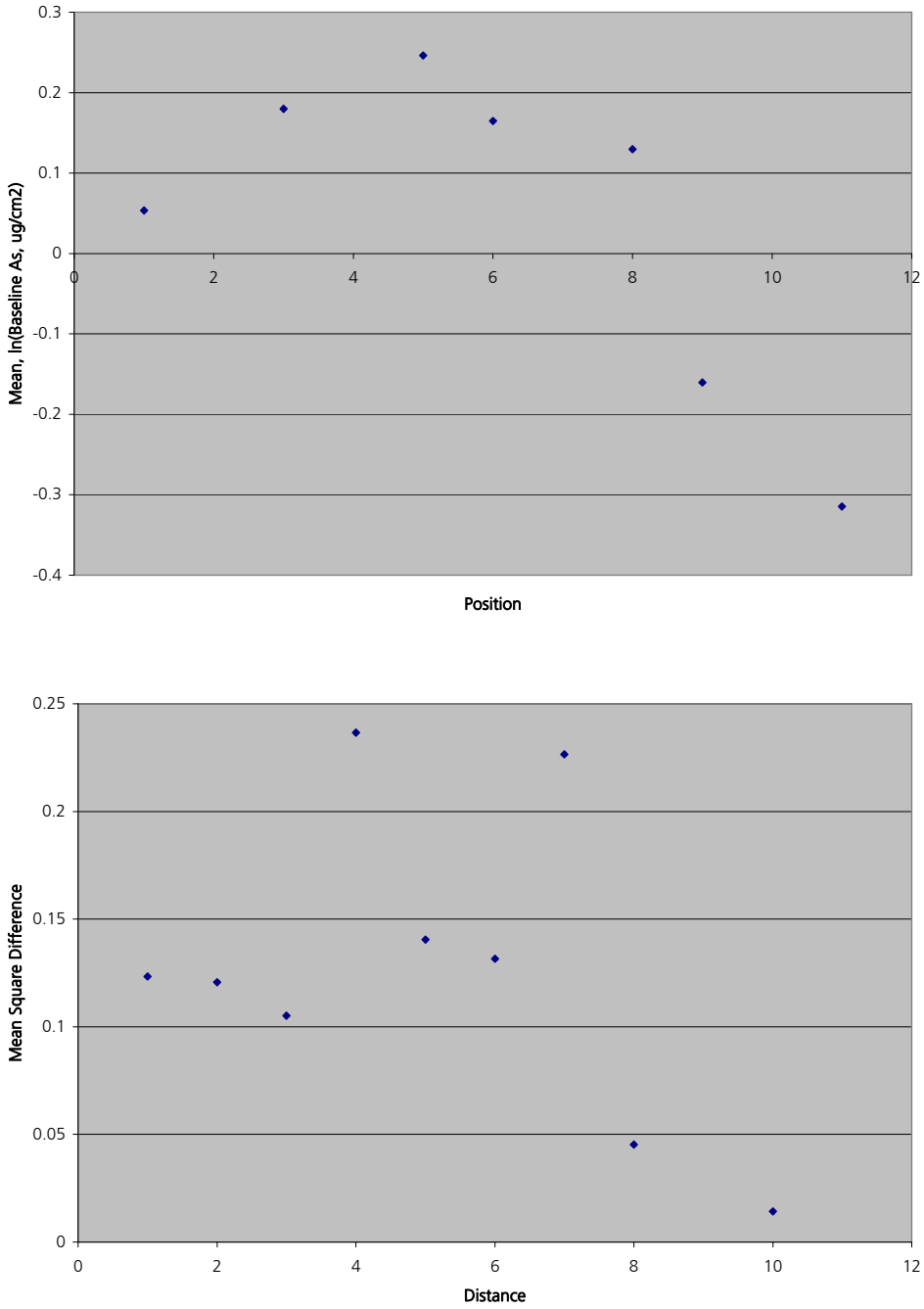


Figure 4-11. Mean vs Position and MSD vs distance for Source C DAs Baseline

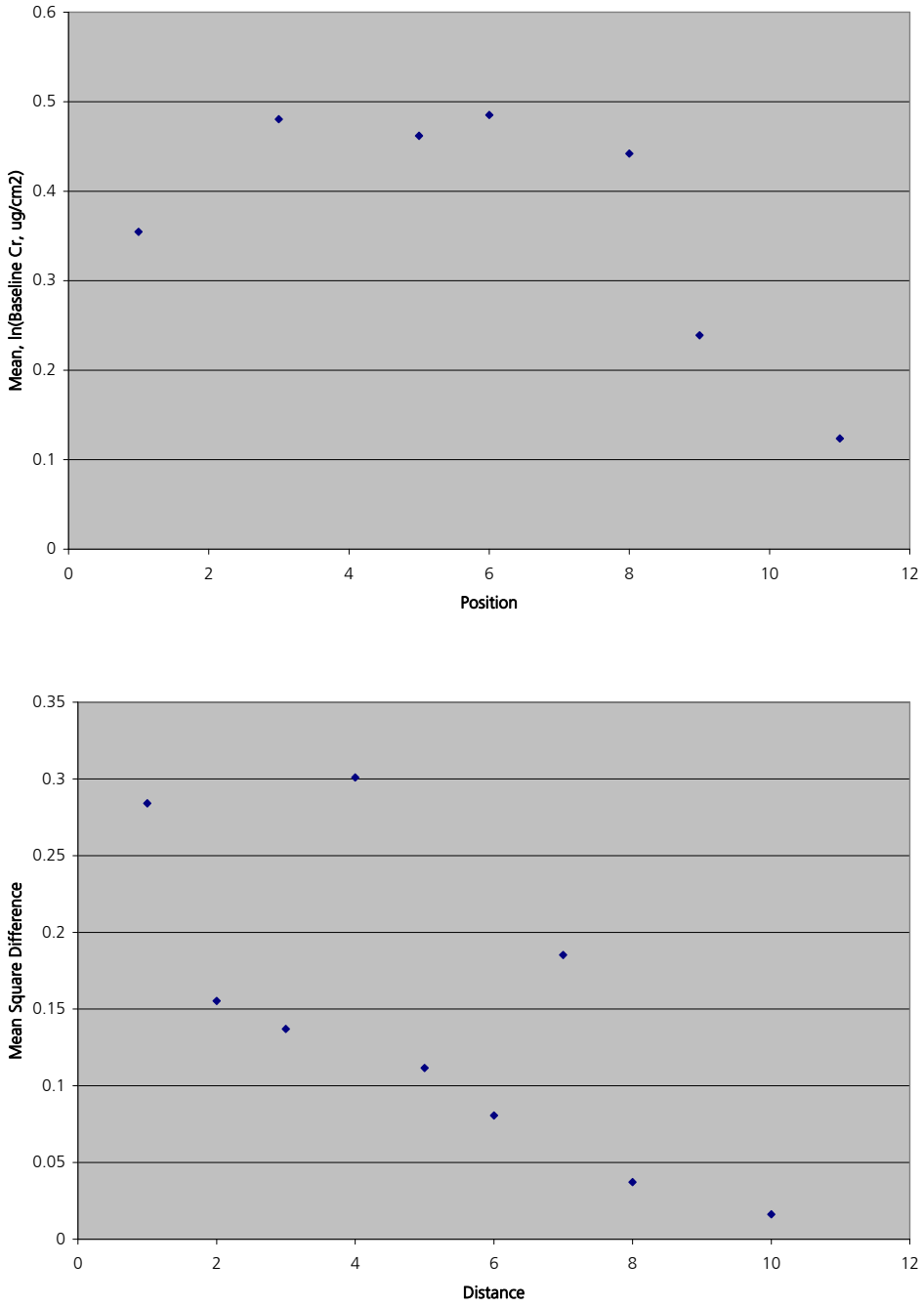


Figure 4-12. Mean vs Position and MSD vs Distance for Source C DCr Baseline

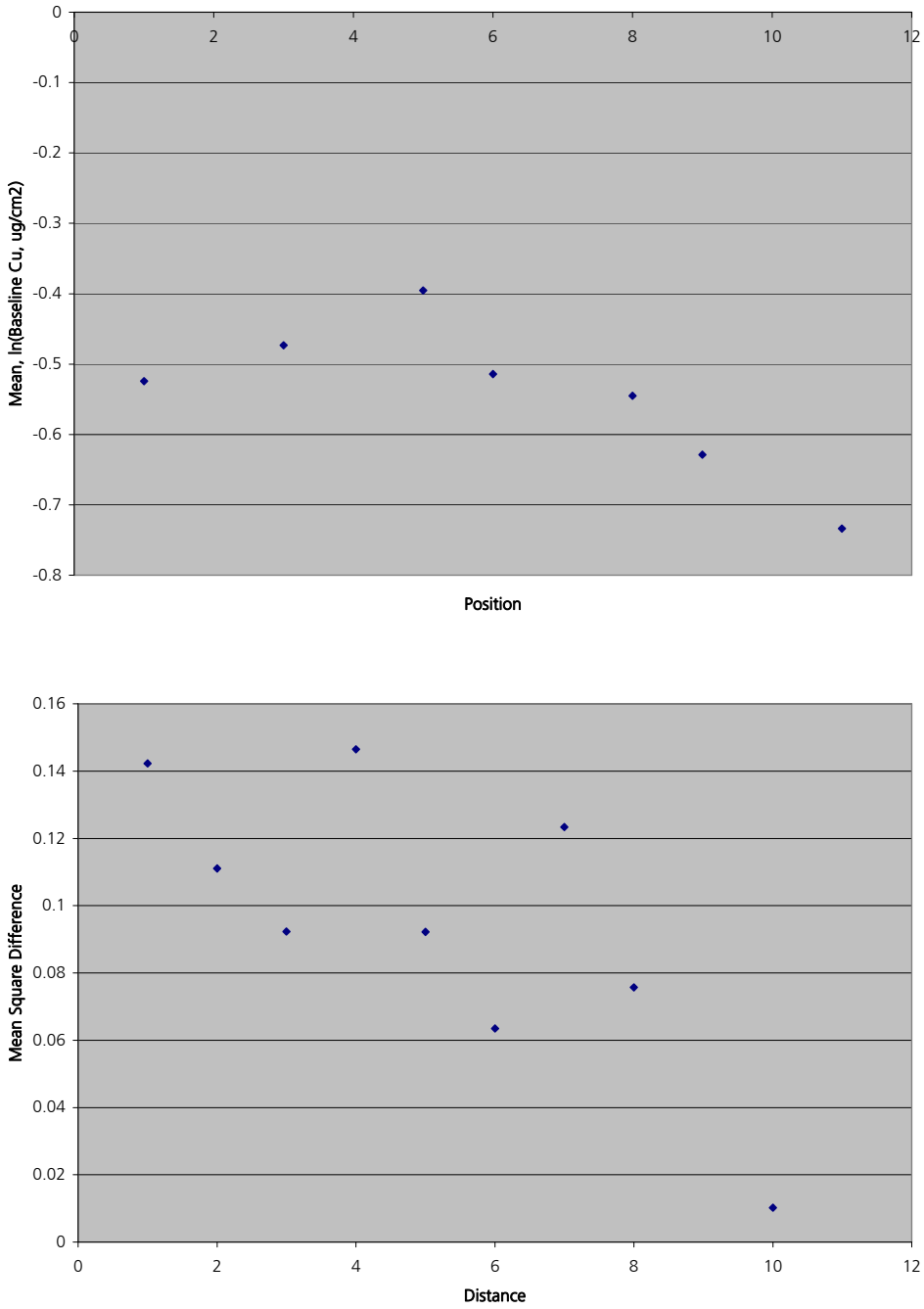


Figure 4-13. Mean vs Position and MSD vs Distance for Source C DCu Baseline

4.4.2 Core Sample-Baseline DA Correlation Analysis

Average DA versus average wood core sample concentration has been plotted for each board for which averages were available. The plots are presented as Figures 4-14 and 4-15 below for the A and C source boards, respectively. It appears that there is some correlation between high DA and high core concentrations, particularly at the higher concentrations and for source A. Note that CCA analyte concentrations are plotted as elemental concentrations in Figures 4-14 and 4-15.

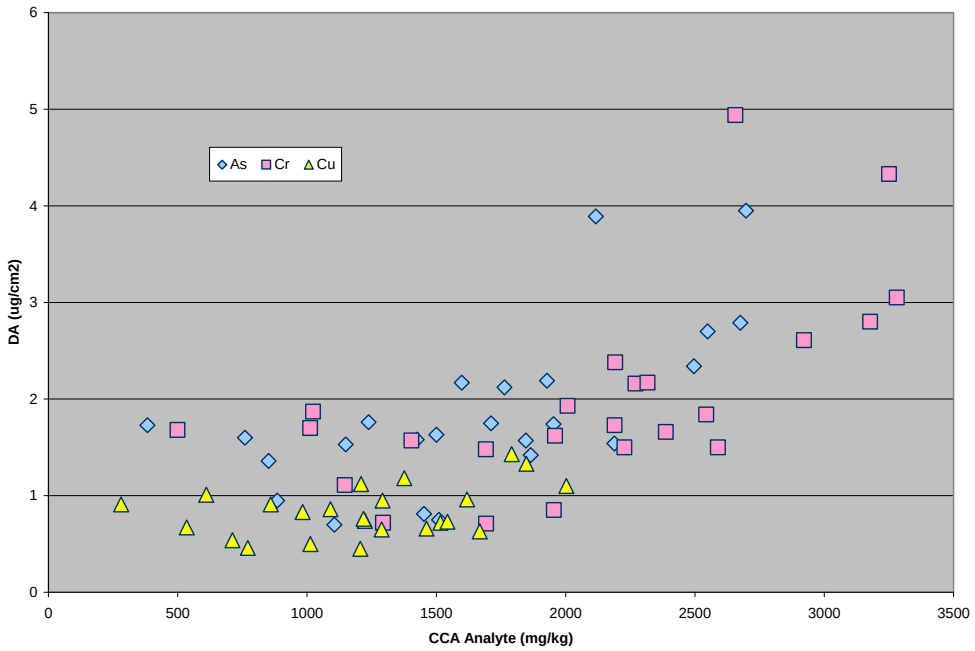


Figure 4-14. Wood Core Concentration versus Baseline DA for Source A Boards

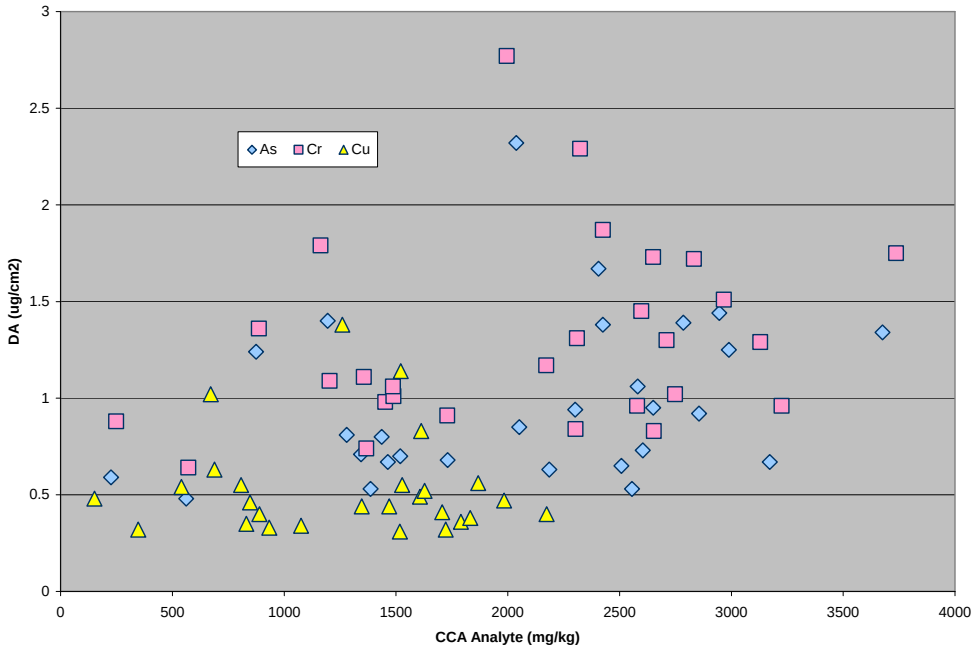


Figure 4-15. Wood Core Concentration versus Baseline DA for Source C Boards

4.5 Weather Data

A number of climatological measurements have been made at 30-minute intervals during this study, as described in Section 2.8. The most relevant parameters in terms of coating performance and sampling are: Solar Radiation (in Watts per square meter), UV Index, Rainfall (in inches), Temperature (in degrees F), and Relative Humidity (in %). Figures 4-16 through 4-20 plot daily average and running cumulative totals for each parameter versus time, with the exception of the rainfall plot (Figure 4-18) which shows daily total precipitation and cumulative total versus time. On all plots, the dates of the sampling events are superimposed for reference. Complete weather data collected through month 11 post-coating are provided in Appendix M.

UV Index is an intensity measurement first defined by Environment Canada and since adopted by the World Meteorological Organization. UV Index assigns a number between 0 and 16 to the current UV intensity. The U.S. EPA categorizes the

Index values as shown in Table 4-8. The lower the number, the lower the danger of sunburn. The index values recorded by the Vantage ProPlus are the result of real time measurements. In Figure 4-17, daily average values are presented graphically versus time.

Table 4-8. UV Index and Exposure Category

Index Values	Exposure Category
0-2	Minimal
3-4	Low
5-6	Moderate
7-9	High
10+	Very High

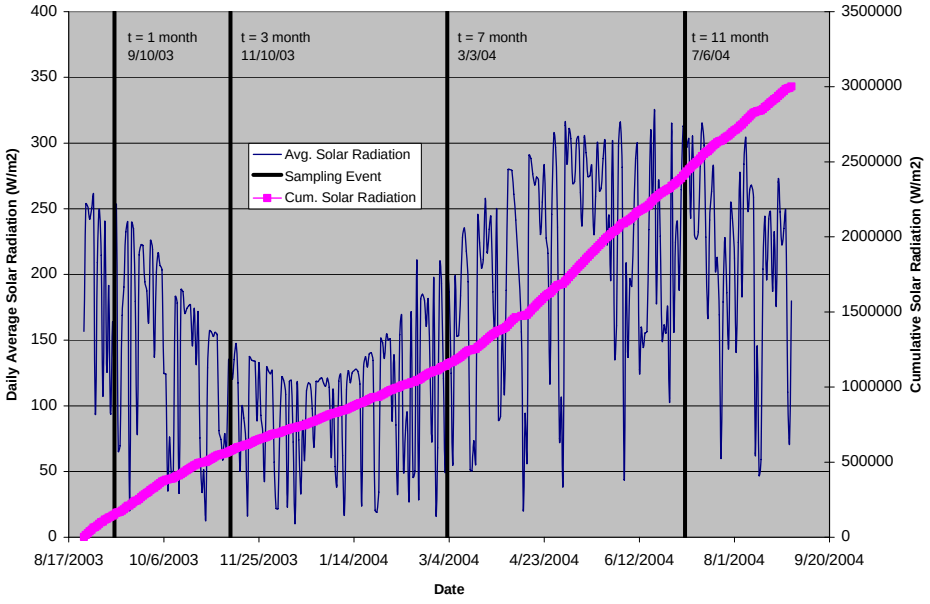


Figure 4-16. Solar Radiation Data Summary

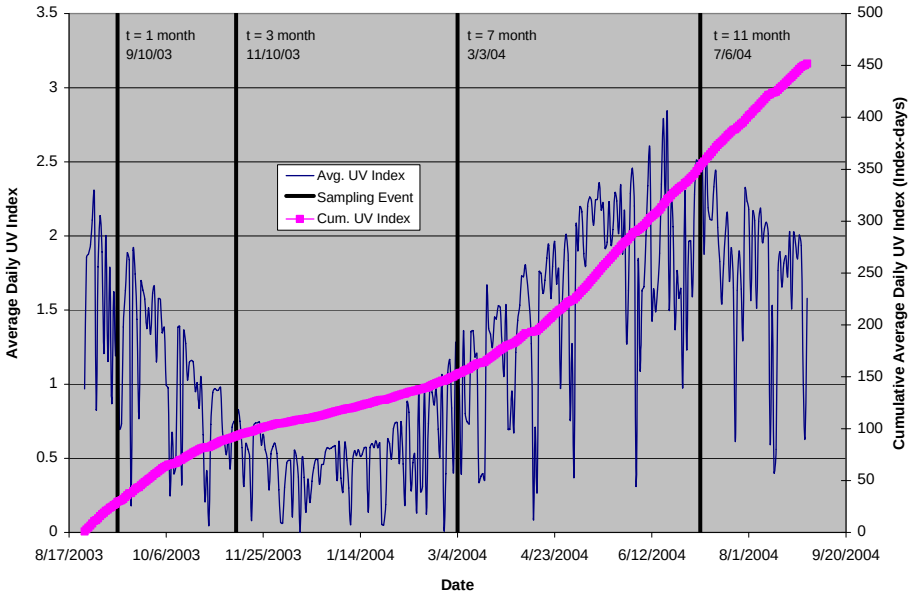


Figure 4-17. UV Index Data Summary

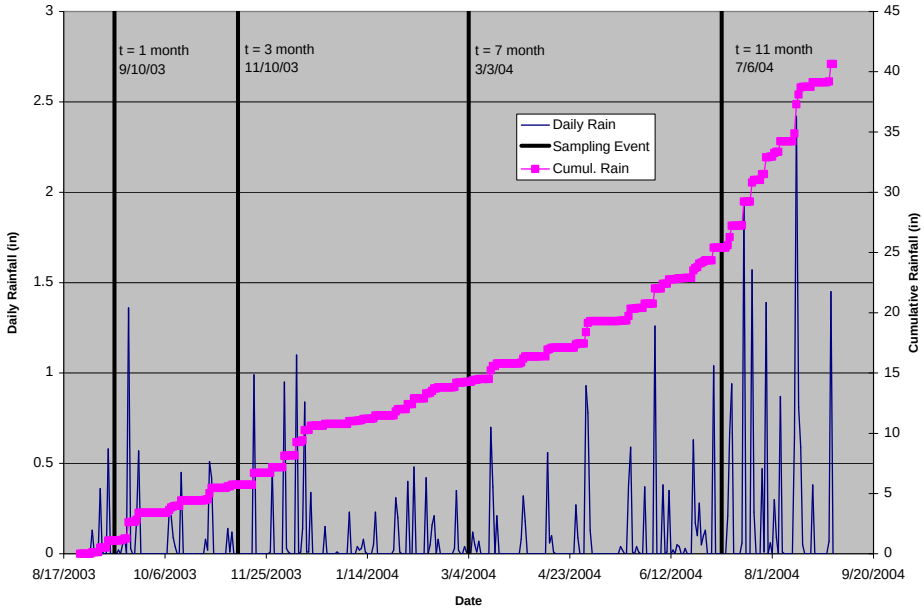


Figure 4-18. Rainfall Data Summary

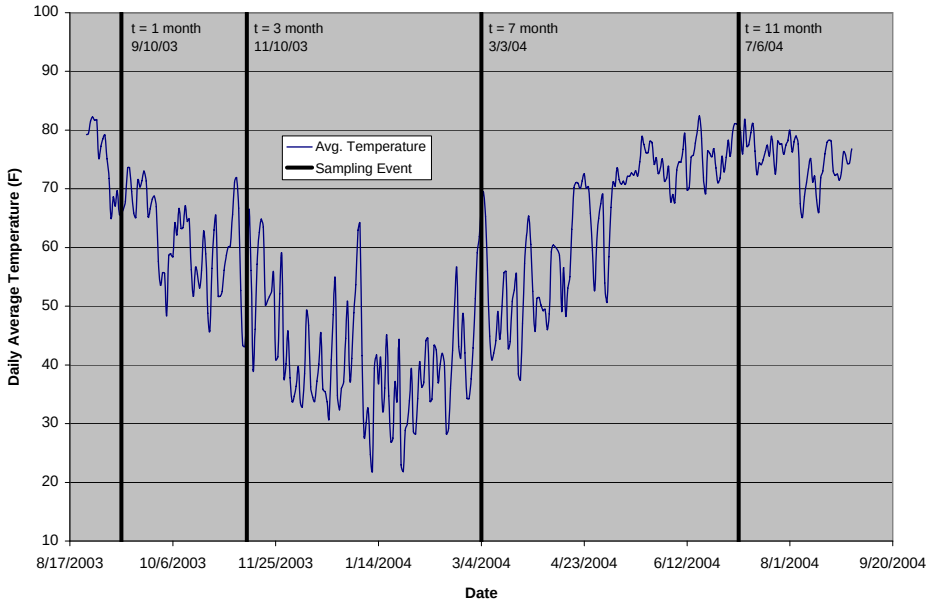


Figure 4-19. Temperature Data Summary

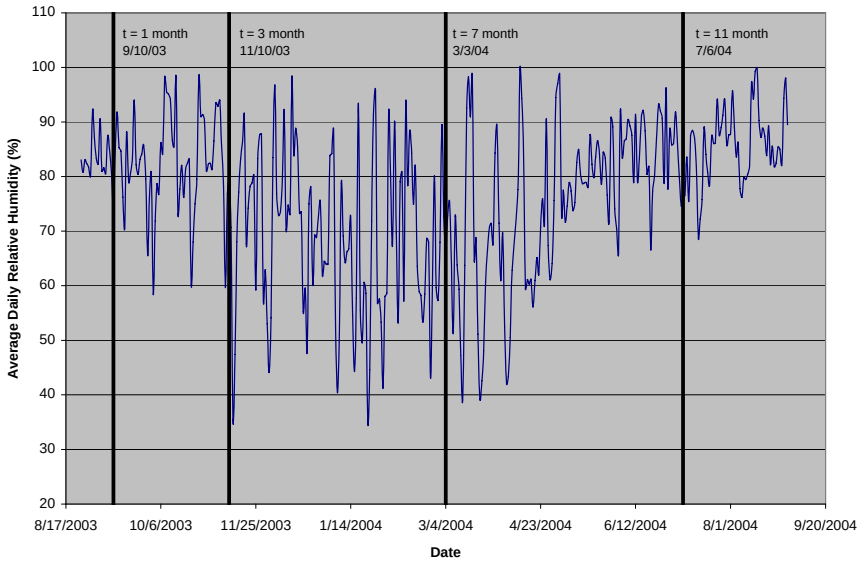


Figure 4-20. Humidity Data Summary

4.6 Coating Performance Data

Table 2-2 is recreated here as Table 4-9 for convenience in reviewing this section. A complete set of wipe sampling data, including data for both the PSA (M) samples and baseline (BL) samples at each sampling event, is provided in Appendix N.

4.6.1 Coating Performance (DA vs Time)

Baseline and time series DA values for each CCA analyte, sorted by coating, and averaged over the combined A and C sources are summarized in Tables 4-10 through 4-12. These data are shown graphically in Figures 4-21 through 4-23. Several very general things can be said of the data as a whole. First, each coating, as well as the positive controls (uncoated minidecks), show a significant decrease in DA between baseline (precoat) and samples taken 1 month after coating. This shows a clear impact on DA from rinsing or washing the minidecks. Second, the coated minidecks all have lower DA than the positive controls, which indicates that coating (using any of the coatings tested) mitigates DA to some degree. Third, DA goes up with time after coating, most likely due to the effects of weathering and possibly abrasion on the coating, although it should be noted that the uncoated positive controls show similar, though generally less pronounced, trends.

The comparative performance of the coatings is discussed in detail in Section 4.6.2.

4.6.2 Statistical Analysis and Coating Rankings

The statistical methods used to obtain the results in this section are described in Section 3.4.

Table 4-9. Coating IDs and Descriptions

#	Product Type	Base	Cover	Main Ingredients	Comments
1	Sealant	Oil	Semi		“Cedar” with UV blocker
2	Sealant	Oil	Clear	Acrylic, alkyd, urethane	“Clear”
3	Stain	Oil	Clear	Acrylic	“Deep tone base”
4	Stain	Oil	Clear	Alkyd	“Clear stain”
5	Sealant	Water	Clear		“Clear”
6	Sealant	Water	Clear	Acrylic, alkyd	“Clear”
7	Stain	Water	Semi	Alkyd	“Cedar” with UV blocker

#	Product Type	Base	Cover	Main Ingredients	Comments
8	Stain	Water	Clear	Acrylic	"Tint base, solid" with no tint added*
9	Paint	Water	Opaque	Acrylic	"Gray". Latex, designed for porches and floors
10	Paint	Oil	Opaque	Alkyd, polyurethane	"Gray". Designed for porches and floors
11	Other		Clear	Elastic vinyl	Designed for CCA encapsulation
12	Other		Clear	Polymer	Designed for CCA encapsulation
13	No coating				Uncoated control minidecks

* note that this product's labeling specifically states that it must be tinted before use.

An analysis of variance mixed model, similar to a split plot model in space and time, was fit to the data for the purpose of identifying major sources of variation and ultimately for comparing coating effectiveness after baseline adjustment, averaged over the four time periods. The objective of the analysis with regard to coatings was to identify groups of coatings exhibiting statistically distinguishable or indistinguishable performance. The response variable analyzed was $Y = \ln(DA/DA_{BL})$ where DA is, as defined earlier, the compound of interest (As, Cr, Cu) measured in the longitudinal study, and DA_{BL} is the corresponding baseline measurement. For efficacious coatings, DA should be small relative to DA_{BL}, and thus small values of Y on average indicate better coating performance. The split-plot analysis of variance model included fixed effects: coating (1-13), source deck (A, C), board face (up, down), time period (1, 2, 3, 4), and their interactions of all orders. There were three replicate minidecks for each whole-plot treatment (coating). Error terms for the split plot model were obtained from the nested effects: minideck(coating), minideck*sourcedeck*boardface*(coat1), and minideck(time), and the interaction term, mdeck*coat1*time. The model was chosen to enable comparison of coatings averaged over time. To this end, pairwise comparisons of coatings were performed and the results are displayed in Figures 4-24 through 4-29. The graphical displays were constructed by first ordering the coatings by their average performance.

Then all possible pairs of coatings were tested for statistical significance at the 0.05 level of significance, adjusted using Tukey's multiple comparison procedure. Pairs of coatings sharing a common underline are not significantly different, but those that do not share a common underline are significantly different. The analysis was done twice for all three CCA analytes, once using the data from all time periods (Figures 4-24, 4-26, and 4-28), and again using the data from only the fourth time period (Figures 4-25, 4-27, 4-29).

Evaluation of the Effectiveness of Coatings in Reducing Dislodgeable Arsenic, Chromium, and Copper from CCA Treated Wood

Interim Data Report

EPA Report EPA/600/R-05/050
9 May 2005

Table 4-10. Average DAs (µg/cm^2) vs Sampling Interval

Coating	Baseline	1 Month	3 Months	7 Months	11 Months
Coating 1	1.360	0.060	0.034	0.058	0.117
Coating 2	1.361	0.136	0.053	0.067	0.245
Coating 3	1.408	0.026	0.014	0.044	0.089
Coating 4	1.346	0.100	0.051	0.077	0.185
Coating 5	1.159	0.176	0.126	0.144	0.485
Coating 6	1.343	0.102	0.051	0.112	0.162
Coating 7	1.323	0.094	0.070	0.069	0.254
Coating 8	1.388	0.053	0.016	0.023	0.061
Coating 9	1.428	0.009	0.009	0.020	0.032
Coating 10	1.602	0.009	0.008	0.023	0.038
Coating 11	1.276	0.005	0.009	0.034	0.056
Coating 12	1.435	0.077	0.061	0.123	0.336
Coating 13	1.658	0.474	0.321	0.391	0.889

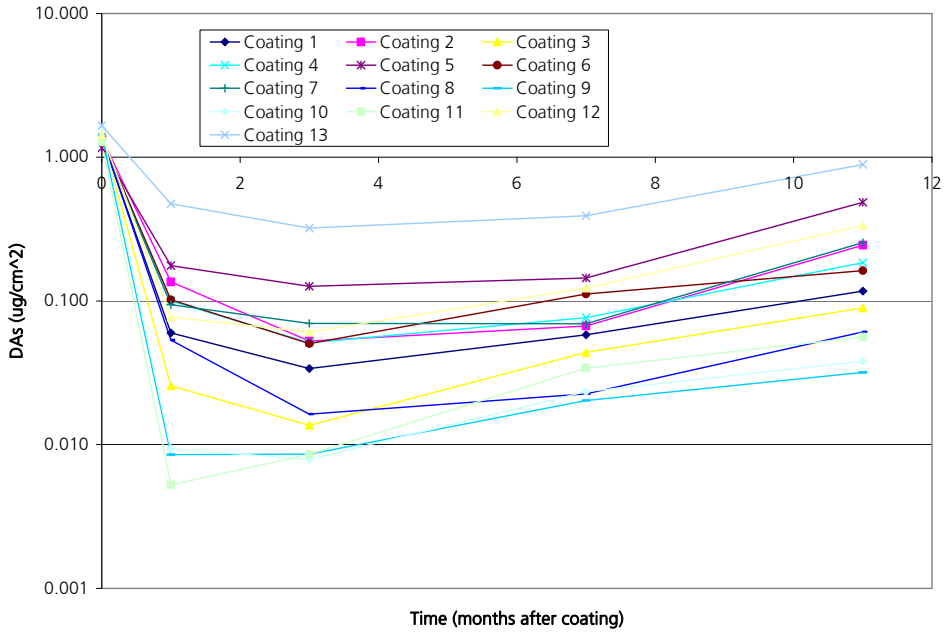


Figure 4-21. Average DAs vs Time for All Coatings

Table 4-11. Average DCr (µg/cm^2) vs Sampling Interval

Coating	Baseline	1 Month	3 Months	7 Months	11 Months
Coating 1	1.542	0.079	0.060	0.095	0.256
Coating 2	1.540	0.235	0.092	0.097	0.434
Coating 3	1.606	0.007	0.005	0.021	0.126
Coating 4	1.601	0.175	0.087	0.102	0.399
Coating 5	1.352	0.344	0.255	0.238	0.890
Coating 6	1.542	0.143	0.064	0.124	0.226
Coating 7	1.589	0.147	0.112	0.092	0.381
Coating 8	1.679	0.040	0.015	0.024	0.090
Coating 9	1.658	0.002	0.002	0.006	0.021
Coating 10	1.794	0.004	0.006	0.012	0.043
Coating 11	1.504	0.002	0.005	0.026	0.091
Coating 12	1.845	0.131	0.103	0.176	0.544
Coating 13	1.918	0.721	0.503	0.498	1.262

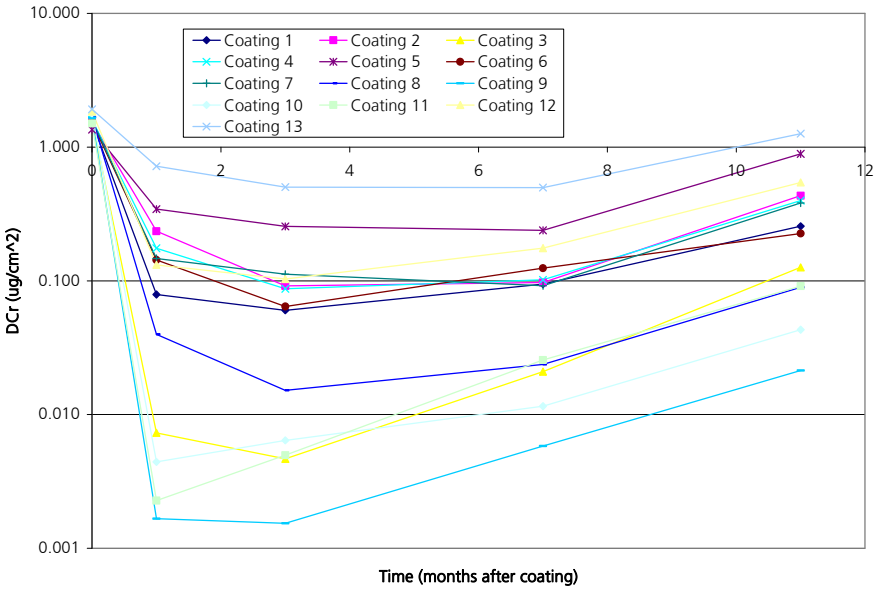


Figure 4-22. Average DCr vs Time for All Coatings

Table 4-12. Average DCu (µg/cm^2) vs Sampling Interval

Coating	Baseline	1 Month	3 Months	7 Months	11 Months
Coating 1	0.710	0.041	0.061	0.058	0.185
Coating 2	0.712	0.098	0.062	0.056	0.280
Coating 3	0.747	0.026	0.037	0.041	0.173
Coating 4	0.684	0.059	0.051	0.053	0.279
Coating 5	0.611	0.079	0.112	0.084	0.370
Coating 6	0.591	0.063	0.050	0.055	0.139
Coating 7	0.612	0.071	0.080	0.055	0.203
Coating 8	0.689	0.033	0.049	0.031	0.070
Coating 9	0.667	0.011	0.023	0.013	0.021
Coating 10	0.829	0.013	0.041	0.027	0.073
Coating 11	0.636	0.018	0.043	0.030	0.076
Coating 12	0.616	0.038	0.048	0.061	0.245
Coating 13	0.682	0.226	0.190	0.164	0.402

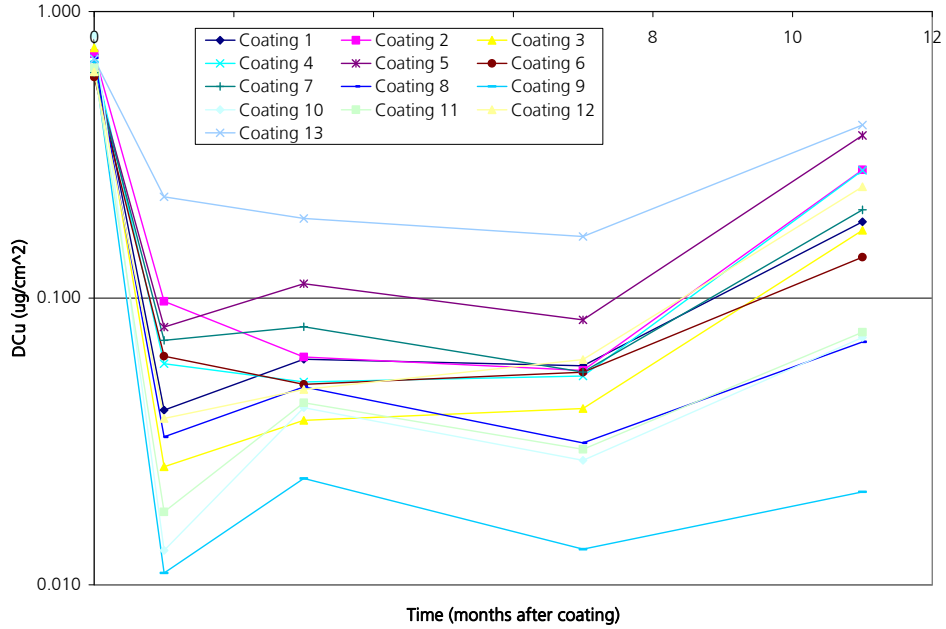


Figure 4-23. Average DCu vs time for All Coatings

For example, for As using data for all time periods, the IDs of the coatings ranked in order from lowest mean DA (best performing) to highest mean DA (worst performing) appear in Figure 4-24. Thus coating #9 performed best. However, it is not possible to statistically distinguish the performance of coating #9 from that of coatings #10 and #11 (all three share a common underline), and it is inappropriate to claim that #9 is better than #10 or #11; however, coating #9 performed significantly better than all other coatings (#9 does not a share a common underline with any coatings other than #10 and #11). Note that coatings #1, #6, #2, #4, #12, and #7 share a common underline and thus their performances are statistically indistinguishable.

When interpreting the results in Figures 4-24 through 4-29, it should be kept in mind that statistical significance depends to a great extent on the sample size. Consequently, fewer statistically significant results are to be expected from the analyses that used only data from the fourth time period. This manifests with bigger groups having greater overlap (longer, overlapping lines). In light of this sample-size effect, the results for all time periods and the fourth time period only are in good agreement. Furthermore, the coating performances are reasonably consistent across compounds as well (e.g., coatings #9 and #10 are the top two performers for all compounds, except copper at 11 months after coating, where coating #9 leads the pack, but coating #8 finishes just above coating #10).

4.6.3 Inter- and Intra-Coating Comparisons

Summaries of coating performance, expressed both in terms of percent reduction, as well as in absolute measurement for each CCA analyte are provided in this section. As described in Section 3.1.2, four different techniques were used to calculate efficacy or percent reduction in DA or rank coatings by efficacy. These results obtained by each of these methods are presented in the following subsections.

Distribution and box plots, sorted by coating, and grouped by sampling event and source are provided in Appendix O to compliment the efficacy and ranking data presented in this section. These allow one to visually assess the variability in the time sequence data.

```
 9    10    11     3     8     1     6     2     4    12     7     5    13

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```

Figure 4-24. Arsenic Reduction Efficacy Line Plot by Coating – All Time Periods

```
 9    10     8    11     3     1     6     4     2     7    12     5    13

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```

Figure 4-25. Arsenic Reduction Efficacy Line Plot by Coating – at Time = 11 Months

```
 9    10    11     3     8     1     6     7    12     4     2     5    13

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```

Figure 4-26. Chromium Reduction Efficacy Line Plot by Coating – All Time Periods

```
 9    10     8    11     3     6     1     7     4     2    12     5    13

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```

Figure 4-27. Chromium Reduction Efficacy Line Plot by Coating – at Time = 11 Months

```
 9    10     8    11     3     1     6    12     4     2     7     5    13

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```

Figure 4-28. Copper Reduction Efficacy Line Plot by Coating – All Time Periods

```
 9     8    10    11     3     6     1     7    12     2     4    13     5

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```

Figure 4-29. Copper Reduction Efficacy Line Plot by Coating – at Time = 11 Months

4.6.3.1 Method 1. Using Unique Single Baselines for Each PSA

The efficacy results using method 1 are summarized in Table 4-13, grouped first by Sampling Interval, then by Coating ID, then by Source. Figures 4-30 and 4-31 show graphically the efficacy data generated for DAs by this method, grouped by Source A and C, respectively. Similar plots are provided for DCr and DCu analytes in Appendix P.

Table 4-13. DA Reduction using Method 1

Source	Interval (month)	Coating ID	Average %DAs Red.	Average %DCr Red.	Average %Cu Red.
A	1	1	96.7	96.8	95.8
C	1	1	94.0	92.3	91.3
A	1	2	93.8	89.5	90.5
C	1	2	79.1	74.0	74.9
A	1	3	97.1	99.2	96.7
C	1	3	99.5	99.7	95.4
A	1	4	92.7	87.8	90.9
C	1	4	88.9	84.8	86.2
A	1	5	88.1	77.0	85.6
C	1	5	76.6	64.5	84.8
A	1	6	93.2	91.3	90.8
C	1	6	92.7	92.5	86.1
A	1	7	94.6	89.2	88.3
C	1	7	89.7	89.2	85.3
A	1	8	95.9	98.2	96.0
C	1	8	96.1	96.9	93.9
A	1	9	99.0	99.9	98.6
C	1	9	99.6	99.8	97.3
A	1	10	99.2	99.7	98.5
C	1	10	99.8	99.7	97.6
A	1	11	99.3	99.8	97.4
C	1	11	99.8	99.8	96.0
A	1	12	95.7	93.8	93.6
C	1	12	94.0	91.8	92.8
A	1	13	64.5	55.7	63.1
C	1	13	68.7	57.0	63.4
A	3	1	97.9	96.9	93.2
C	3	1	96.9	94.8	87.4

Source	Interval (month)	Coating ID	Average %DAs Red.	Average %DCr Red.	Average %Cu Red.
A	3	2	97.1	94.8	93.1
C	3	2	93.4	91.8	86.3
A	3	3	98.4	99.6	96.0
C	3	3	99.6	99.8	92.2
A	3	4	96.8	95.2	93.3
C	3	4	93.7	91.2	86.9
A	3	5	90.5	82.6	80.4
C	3	5	85.6	75.8	76.4
A	3	6	96.7	96.3	94.2
C	3	6	97.0	96.9	87.4
A	3	7	95.2	90.3	86.4
C	3	7	92.6	92.9	83.8
A	3	8	99.1	99.5	95.8
C	3	8	98.5	98.7	88.5
A	3	9	99.2	99.9	97.2
C	3	9	99.3	99.9	94.3
A	3	10	99.4	99.6	95.4
C	3	10	99.4	99.5	91.6
A	3	11	99.0	99.5	94.0
C	3	11	99.5	99.7	90.8
A	3	12	96.3	94.7	93.2
C	3	12	96.2	94.0	86.9
A	3	13	78.5	71.2	72.8
C	3	13	74.3	67.9	63.3
A	7	1	96.9	95.5	94.0
C	7	1	93.6	90.6	87.0
A	7	2	95.5	93.8	93.9
C	7	2	93.3	92.3	87.3
A	7	3	95.1	98.1	94.7
C	7	3	98.3	98.8	92.8
A	7	4	92.7	92.2	92.2
C	7	4	94.8	93.1	88.6
A	7	5	87.9	83.1	85.2
C	7	5	84.5	76.8	82.0
A	7	6	92.3	92.5	92.8
C	7	6	95.0	95.6	86.5
A	7	7	95.5	92.9	92.5

Source	Interval (month)	Coating ID	Average %DAs Red.	Average %DCr Red.	Average %Cu Red.
C	7	7	94.1	94.3	88.2
A	7	8	98.6	99.0	97.2
C	7	8	98.0	98.1	92.2
A	7	9	98.3	99.7	98.6
C	7	9	98.6	99.4	96.5
A	7	10	98.2	99.3	96.8
C	7	10	99.0	99.2	95.1
A	7	11	95.0	96.4	94.0
C	7	11	98.7	98.7	95.3
A	7	12	91.7	91.5	91.6
C	7	12	94.2	91.1	85.8
A	7	13	69.2	69.0	75.5
C	7	13	74.2	71.1	69.2
A	11	1	93.8	88.0	82.7
C	11	1	86.5	75.4	54.2
A	11	2	85.2	76.4	74.5
C	11	2	71.9	60.4	28.4
A	11	3	92.0	92.6	85.3
C	11	3	94.6	90.5	63.7
A	11	4	85.9	75.8	69.6
C	11	4	83.1	65.2	23.6
A	11	5	63.4	41.8	46.5
C	11	5	45.2	11.4	9.5
A	11	6	86.2	84.3	86.5
C	11	6	87.6	84.9	61.4
A	11	7	84.1	75.5	73.8
C	11	7	77.6	74.8	51.3
A	11	8	95.7	95.5	94.1
C	11	8	94.9	93.7	81.9
A	11	9	96.9	98.2	97.1
C	11	9	97.6	98.7	95.7
A	11	10	97.5	97.7	91.2
C	11	10	96.7	96.5	87.8
A	11	11	94.1	92.4	89.0
C	11	11	96.1	92.8	82.2
A	11	12	75.2	70.9	76.7
C	11	12	79.5	61.7	21.7

Source	Interval (month)	Coating ID	Average %DAs Red.	Average %DCr Red.	Average %Cu Red.
A	11	13	43.3	34.9	55.2
C	11	13	25.4	9.7	-3.6

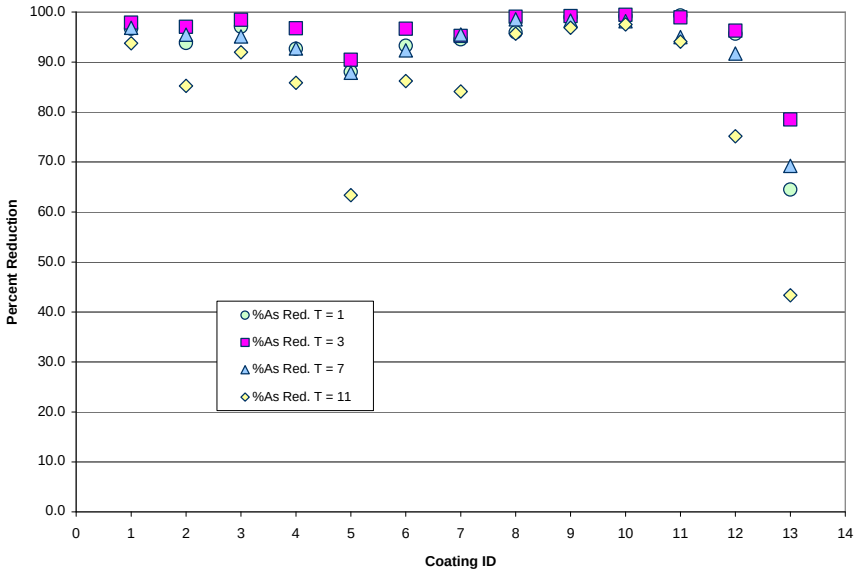

Figure 4-30. Arsenic Coating Efficacy for Source A Specimens Using Analysis Method 1

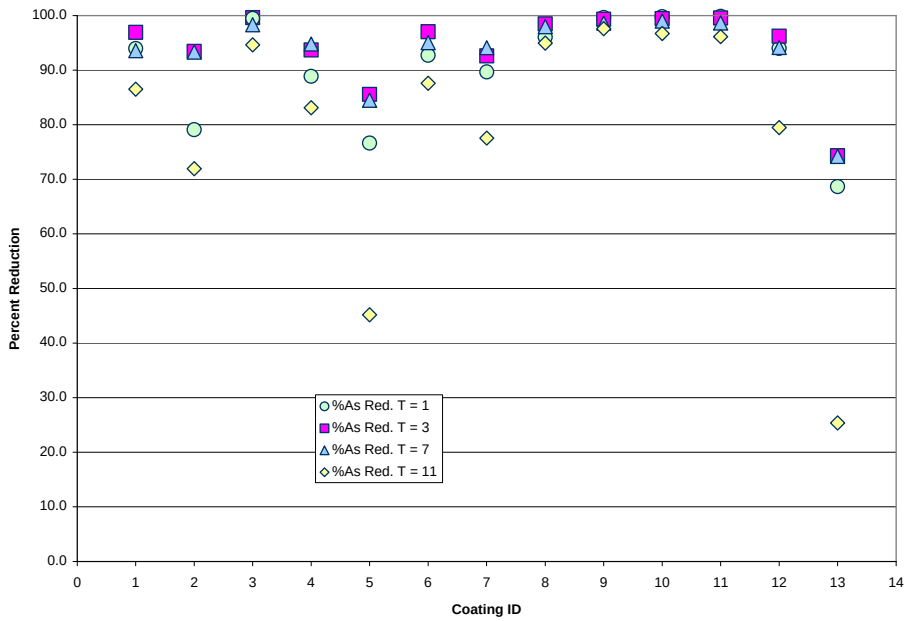

Figure 4-31. Arsenic Coating Efficacy for Source C Specimens Using Analysis Method 1

4.6.3.2 Method 2. Using Average Baseline and Sample DA Calculated for Each Grouping of Source, Sampling Interval, and Coating

The efficacy results using method 2 are summarized in Table 4-14, grouped first by Sampling Interval, then by Coating ID, then by Source. Figures 4-32 and 4-33 show graphically the efficacy data generated for DAs by this method, grouped by Source A and C, respectively. Similar plots are provided for DCr and DCu in Appendix P.

Table 4-14. DA Reduction Using Method 2

Source	Interval (month)	Coating	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
A	1	1	96.7	96.9	95.7
C	1	1	93.8	92.3	92.0
A	1	2	93.9	89.8	90.9
C	1	2	81.6	76.6	77.0
A	1	3	97.2	99.4	97.0
C	1	3	99.6	99.7	96.5
A	1	4	94.4	91.2	92.7

Source	Interval (month)	Coating	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
C	1	4	89.3	85.8	89.4
A	1	5	89.0	81.2	86.9
C	1	5	78.1	66.5	87.2
A	1	6	92.0	89.1	91.3
C	1	6	93.1	92.6	86.8
A	1	7	94.7	91.7	90.0
C	1	7	89.9	89.5	85.7
A	1	8	96.0	98.1	96.0
C	1	8	96.3	97.1	93.9
A	1	9	99.2	99.9	98.8
C	1	9	99.8	99.9	97.6
A	1	10	99.2	99.7	98.6
C	1	10	99.8	99.8	98.1
A	1	11	99.4	99.8	97.6
C	1	11	99.9	99.9	96.7
A	1	12	94.8	93.2	94.0
C	1	12	94.1	92.2	93.5
A	1	13	72.7	64.8	68.5
C	1	13	68.4	58.0	64.2
A	3	1	97.8	96.8	93.0
C	3	1	97.1	95.2	88.8
A	3	2	97.1	94.9	93.6
C	3	2	94.1	92.6	86.5
A	3	3	98.6	99.7	96.2
C	3	3	99.7	99.8	94.4
A	3	4	97.0	95.8	94.3
C	3	4	94.7	92.8	90.0
A	3	5	91.2	85.2	83.7
C	3	5	85.7	76.2	79.0
A	3	6	95.7	94.9	94.5
C	3	6	97.1	96.9	87.6

Source	Interval (month)	Coating	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
A	3	7	95.4	92.5	88.4
C	3	7	93.6	93.6	84.8
A	3	8	99.1	99.5	95.6
C	3	8	98.4	98.6	88.4
A	3	9	99.3	99.9	97.4
C	3	9	99.6	99.9	94.8
A	3	10	99.5	99.6	95.7
C	3	10	99.6	99.6	93.9
A	3	11	99.1	99.6	94.3
C	3	11	99.6	99.7	92.0
A	3	12	95.5	94.4	94.1
C	3	12	96.3	94.4	89.2
A	3	13	84.1	77.6	76.5
C	3	13	72.9	66.7	64.8
A	7	1	97.0	96.2	94.2
C	7	1	93.6	90.8	88.1
A	7	2	95.5	94.1	94.3
C	7	2	94.1	93.1	87.8
A	7	3	95.9	98.7	95.6
C	7	3	98.5	98.9	94.1
A	7	4	93.9	93.7	93.4
C	7	4	95.0	93.6	90.5
A	7	5	89.0	86.1	87.4
C	7	5	85.2	77.9	84.8
A	7	6	89.7	89.0	93.6
C	7	6	94.9	95.5	86.8
A	7	7	95.0	94.1	92.9
C	7	7	94.4	94.5	87.9
A	7	8	98.6	99.0	97.3
C	7	8	98.1	98.1	92.4
A	7	9	98.4	99.7	98.7

Source	Interval (month)	Coating	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
C	7	9	98.9	99.5	96.7
A	7	10	98.2	99.4	97.1
C	7	10	99.2	99.4	96.2
A	7	11	96.0	97.5	94.8
C	7	11	98.9	99.0	95.9
A	7	12	90.5	90.1	92.0
C	7	12	94.0	91.2	87.0
A	7	13	77.3	75.5	78.8
C	7	13	74.4	71.4	71.1
A	11	1	94.1	89.1	83.3
C	11	1	87.0	76.0	59.3
A	11	2	85.4	77.0	75.9
C	11	2	74.7	63.6	29.9
A	11	3	93.1	94.3	87.3
C	11	3	95.2	91.4	69.0
A	11	4	87.0	79.7	74.5
C	11	4	84.9	68.3	37.3
A	11	5	65.6	51.0	55.3
C	11	5	46.3	13.9	19.8
A	11	6	88.5	86.3	87.0
C	11	6	86.9	84.2	62.6
A	11	7	82.0	76.3	75.4
C	11	7	78.9	75.6	53.0
A	11	8	95.8	95.2	94.2
C	11	8	95.4	94.0	82.6
A	11	9	97.6	98.6	97.3
C	11	9	98.2	99.0	96.0
A	11	10	97.6	97.7	91.5
C	11	10	97.8	97.4	90.8
A	11	11	94.7	93.7	90.3
C	11	11	96.7	94.1	85.7

Source	Interval (month)	Coating	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
A	11	12	75.1	73.5	78.3
C	11	12	80.4	63.7	31.9
A	11	13	56.4	47.3	61.5
C	11	13	23.8	10.1	6.2

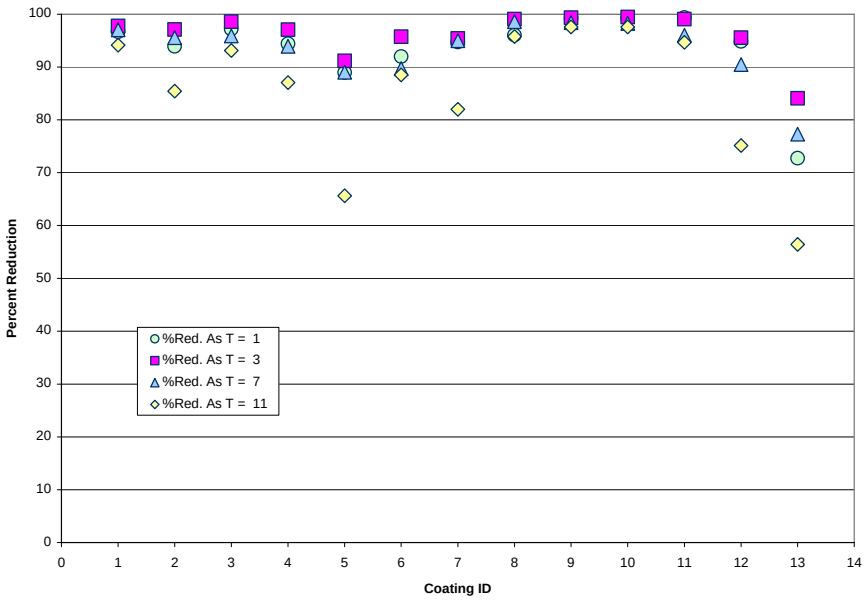

Figure 4-32. Arsenic Coating Efficacy for Source A Specimens Using Analysis Method 2

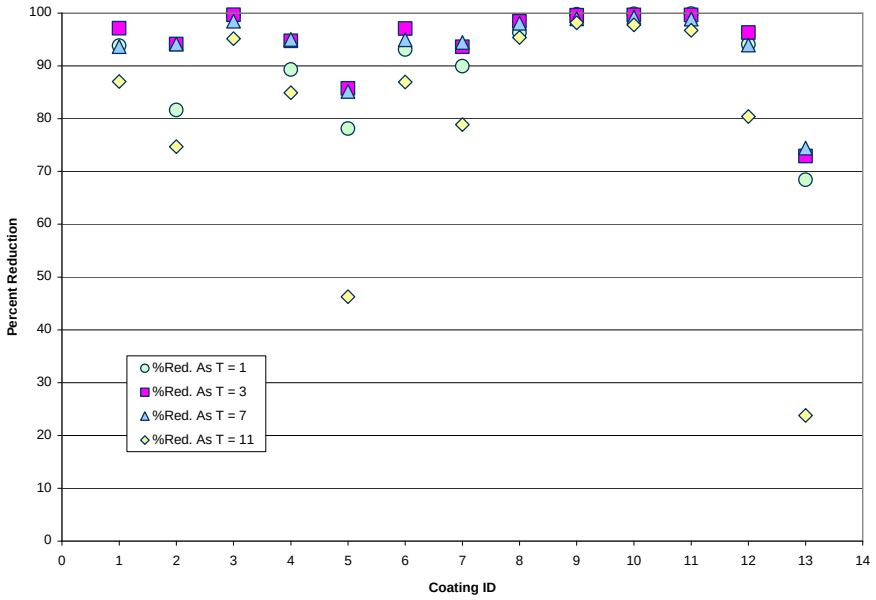

Figure 4-33. Arsenic Coating Efficacy for Source C Specimens Using Analysis Method 2

4.6.3.3 Method 3. Using the Average of the Positive Control Minideck (#13) DA Values for each Grouping of Source and Wipe Interval as Baseline

The efficacy results using method 3 are summarized in Table 4-15, grouped first by Sampling Interval, then by Coating ID, then by Source. Figures 4-34 and 4-35 show graphically the efficacy data generated for DAs by this method, grouped by Source A and C, respectively. Similar plots are provided for DCr and DCu in Appendix P.

Table 4-15. DA Reduction Using Method 3

Source	Coating ID	Interval (month)	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
A	1	1	91.1	93.7	86.2
C	1	1	80.0	81.8	75.6
A	2	1	82.0	77.9	68.2
C	2	1	50.7	51.1	39.7
A	3	1	92.8	98.9	90.9
C	3	1	98.0	99.2	85.1
A	4	1	84.7	80.7	78.5

Source	Coating ID	Interval (month)	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
C	4	1	67.5	67.9	66.9
A	5	1	74.9	68.2	67.4
C	5	1	39.3	27.7	61.2
A	6	1	78.8	78.9	78.5
C	6	1	78.1	82.0	62.6
A	7	1	86.3	82.5	72.5
C	7	1	68.2	75.2	62.4
A	8	1	89.6	96.0	87.6
C	8	1	87.0	92.1	82.3
A	9	1	97.6	99.8	96.0
C	9	1	99.3	99.8	93.8
A	10	1	97.2	99.3	94.8
C	10	1	99.5	99.5	93.3
A	11	1	98.6	99.7	94.3
C	11	1	99.5	99.6	88.6
A	12	1	83.1	80.0	83.4
C	12	1	84.9	84.5	82.7
A	1	3	89.7	90.0	69.8
C	1	3	89.1	85.6	65.3
A	2	3	85.2	82.8	69.9
C	2	3	81.5	80.5	64.1
A	3	3	93.8	99.0	84.5
C	3	3	98.3	99.2	75.4
A	4	3	86.1	85.4	77.4
C	4	3	81.3	79.2	68.3
A	5	3	65.6	60.6	45.5
C	5	3	53.8	35.1	35.3
A	6	3	80.6	84.5	81.7
C	6	3	89.1	90.6	64.4
A	7	3	79.6	75.3	57.1
C	7	3	76.5	80.8	59.3

Source	Coating ID	Interval (month)	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
A	8	3	95.9	98.3	81.6
C	8	3	93.6	95.4	65.6
A	9	3	96.4	99.7	88.9
C	9	3	98.6	99.7	86.2
A	10	3	96.7	98.5	78.8
C	10	3	98.7	99.0	77.4
A	11	3	96.6	99.0	81.7
C	11	3	98.4	99.1	72.2
A	12	3	75.0	74.4	78.0
C	12	3	89.1	85.8	70.9
A	1	7	90.4	89.0	72.2
C	1	7	74.6	68.3	55.1
A	2	7	84.1	81.5	70.4
C	2	7	80.4	78.9	60.2
A	3	7	87.4	96.4	79.8
C	3	7	91.6	94.8	68.7
A	4	7	80.0	80.1	70.8
C	4	7	81.2	78.7	63.1
A	5	7	70.0	66.3	53.3
C	5	7	49.1	29.9	43.1
A	6	7	67.1	69.3	76.4
C	6	7	80.1	84.0	53.7
A	7	7	84.3	82.1	70.7
C	7	7	78.2	80.8	60.7
A	8	7	95.6	96.9	87.6
C	8	7	91.5	92.6	72.6
A	9	7	94.2	99.0	93.8
C	9	7	96.2	98.5	89.5
A	10	7	92.5	97.5	83.8
C	10	7	97.0	98.0	82.9
A	11	7	89.5	94.3	81.3

Source	Coating ID	Interval (month)	Average %DAs Red.	Average %DCr Red.	Average %DCu Red.
C	11	7	94.8	95.7	82.7
A	12	7	62.4	58.5	67.1
C	12	7	81.1	74.5	57.3
A	1	11	90.2	85.4	56.1
C	1	11	82.6	73.6	52.6
A	2	11	73.0	66.7	30.8
C	2	11	71.8	64.5	29.8
A	3	11	89.0	92.8	68.1
C	3	11	91.1	87.0	49.3
A	4	11	77.8	70.3	38.2
C	4	11	81.0	66.4	25.1
A	5	11	51.1	44.7	8.8
C	5	11	38.1	13.1	7.4
A	6	11	80.9	82.2	73.6
C	6	11	82.8	82.0	59.6
A	7	11	70.7	66.8	44.4
C	7	11	72.3	73.0	52.9
A	8	11	93.1	93.4	85.2
C	8	11	93.2	92.4	80.6
A	9	11	95.4	97.6	93.0
C	9	11	97.8	99.1	96.0
A	10	11	94.6	95.9	74.1
C	10	11	97.2	97.4	87.3
A	11	11	92.7	93.2	80.8
C	11	11	95.0	92.2	81.2
A	12	11	49.0	48.1	50.6
C	12	11	79.4	66.4	31.0

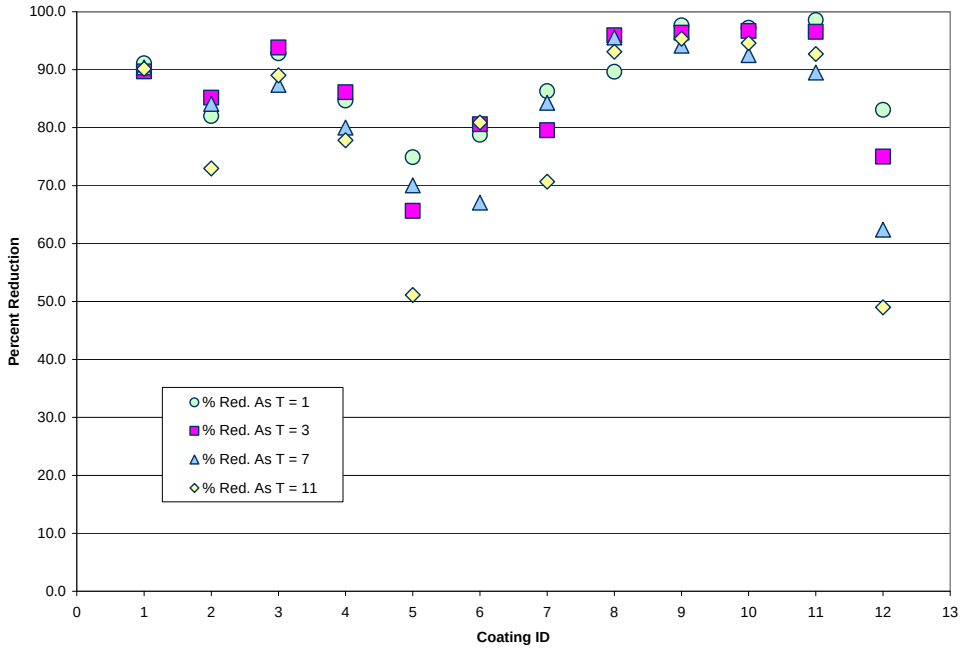

Figure 4-34. Arsenic Coating Efficacy for Source A Specimens Using Analysis Method 3

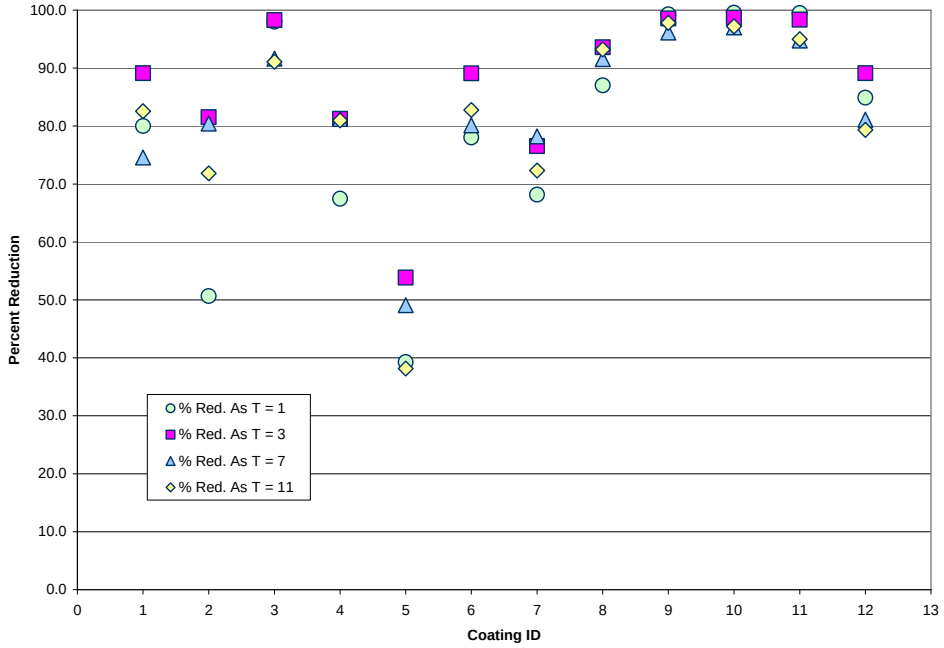

Figure 4-35. Arsenic Coating Efficacy for Source C Specimens Using Analysis Method 3

4.6.3.4 Method 4. Estimating Coating Efficacy Relative to Deck 13 Calculated Using the Analysis of Variance Model That Was Used to Compare Coatings

Method 4 utilizes a more rigorous statistical model than do the other methods. As such, the results are summarized in a somewhat different fashion than for the other methods. Specifically, a series of tables, Tables 4-16 through 4-19, are provided, which show results composited over all four sampling intervals. Each reported efficacy is bound by its upper and lower univariate confidence limits (CL), at 95% confidence. Two tables, one for each wood source, are provided for DAs reduction efficacy, while only one, combined for both wood sources, are provided for DCr and DCu reduction efficacy. All tables show the coatings ordered by ranking with respect to efficacy, with the best performers at the top of the table and the poorest performers at the bottom.

Table 4-16. Composite DAs Reduction Efficiencies for Source A, per Method 4, with 95% CL

	DAs Reduction Efficacy		
Coating	**Lower**	**Mean**	**Upper**
10	93.5%	96.4%	98.0%
9	92.6%	95.9%	97.7%
11	88.0%	93.2%	96.2%
8	87.4%	92.9%	96.0%
1	79.6%	88.5%	93.5%
3	77.7%	87.5%	92.9%
2	68.4%	82.2%	90.0%
6	61.7%	78.5%	87.9%
4	61.1%	78.2%	87.7%
7	59.9%	77.4%	87.3%
12	55.4%	74.9%	85.9%
5	19.3%	54.6%	74.4%

Table 4-17. Composite DAs Reduction Efficiencies for Source C, per Method 4, with 95% CL

	DAs Reduction Efficacy		
Coating	**Lower**	**Mean**	**Upper**
10	96.5%	98.1%	98.9%
11	96.4%	98.0%	98.9%
9	96.2%	97.9%	98.8%
3	94.6%	97.0%	98.4%
8	85.8%	92.2%	95.7%
1	70.6%	83.7%	91.0%
6	68.7%	82.7%	90.4%
12	64.3%	80.3%	89.1%
4	56.8%	76.1%	86.8%
7	52.8%	73.9%	85.6%
2	40.9%	67.3%	81.9%
5	-18.6%	34.4%	63.7%

Table 4-18. Composite DCr Reduction Efficiencies, for Both Sources Combined, per Method 4, with 95% CL

	DCr Reduction Efficacy		
Coating	**Lower**	**Mean**	**Upper**
9	99.2%	99.4%	99.6%
10	97.9%	98.5%	98.9%
11	96.9%	97.8%	98.4%
3	96.3%	97.4%	98.1%
8	93.6%	95.5%	96.8%
1	77.8%	84.2%	88.7%
6	75.6%	82.8%	87.9%
7	63.8%	74.5%	82.0%
12	62.4%	73.9%	81.8%
4	62.6%	73.7%	81.5%
2	61.8%	73.4%	81.5%
5	-1.3%	28.7%	49.8%

Table 4-19. Composite DCu Reduction Efficiencies, for Both Sources Combined, per Method 4, with 95% CL

	DCu Reduction Efficacy		
Coating	**Lower**	**Mean**	**Upper**
9	89.7%	92.5%	94.5%
10	84.6%	88.4%	91.2%
8	78.1%	83.5%	87.5%
11	78.2%	83.4%	87.4%
3	74.8%	80.8%	85.4%
1	61.7%	70.8%	77.8%
6	56.6%	67.3%	75.3%
12	51.0%	63.4%	72.7%
4	50.8%	62.9%	72.1%
2	45.2%	59.1%	69.4%
7	44.5%	58.1%	68.4%
5	14.0%	35.2%	51.1%

4.6.3.5 Summary and Comparison of Efficacy Calculations

Tables 4-20 (Source A) and 4-21 (Source C) summarize calculated efficacies and rankings for each coating using the three sampling interval-specific efficacy calculation methods (methods 1, 2, and 3) at each sampling event. The tables are sorted first by interval, then by coating rank. Appendix Q includes three-dimensional plots showing coating ranking, sorted by sampling event, source, and calculation method (for methods 1, 2, and 3 only).

Table 4-20. Comparison of DAs Efficacy Calculation Methods, Methods 1, 2, and 3, Source A

		Method 1		Method 2		Method 3	
Interval	Rank	Coating	% DAs Red.	Coating	% DAs Red.	Coating	% DAs Red.
One-month sampling event (t = 1 month)							
1	1	11	99.3	11	99.4	11	98.6
1	2	10	99.2	9	99.2	9	97.6
1	3	9	99.0	10	99.2	10	97.2
1	4	3	97.1	3	97.2	3	92.8
1	5	1	96.7	1	96.7	1	91.1
1	6	8	95.9	8	96.0	8	89.6
1	7	12	95.7	12	94.8	7	86.3
1	8	7	94.6	7	94.7	4	84.7
1	9	2	93.8	4	94.4	12	83.1
1	10	6	93.2	2	93.9	2	82.0
1	11	4	92.7	6	92.0	6	78.8
1	12	5	88.1	5	89.0	5	74.9
1	13	13	64.5	13	72.7	--	--
Three-month sampling event (t = 3 month)							
3	1	10	99.4	10	99.5	10	96.7
3	2	9	99.2	9	99.3	11	96.6
3	3	8	99.1	8	99.1	9	96.4
3	4	11	99.0	11	99.1	8	95.9
3	5	3	98.4	3	98.6	3	93.8
3	6	1	97.9	1	97.8	1	89.7

		Method 1		Method 2		Method 3	
Interval	**Rank**	**Coating**	**% DAs Red.**	**Coating**	**% DAs Red.**	**Coating**	**% DAs Red.**
3	7	2	97.1	2	97.1	4	86.1
3	8	4	96.8	4	97.0	2	85.2
3	9	6	96.7	6	95.7	6	80.6
3	10	12	96.3	12	95.5	7	79.6
3	11	7	95.2	7	95.4	12	75.0
3	12	5	90.5	5	91.2	5	65.6
3	13	13	78.5	13	84.1	--	--
Seven-month sampling event (t = 7 month)							
7	1	8	98.6	8	98.6	8	95.6
7	2	9	98.3	9	98.4	9	94.2
7	3	10	98.2	10	98.2	10	92.5
7	4	1	96.9	1	97.0	1	90.4
7	5	7	95.5	11	96.0	11	89.5
7	6	2	95.5	3	95.9	3	87.4
7	7	3	95.1	2	95.5	7	84.3
7	8	11	95.0	7	95.0	2	84.1
7	9	4	92.7	4	93.9	4	80.0
7	10	6	92.3	12	90.5	5	70.0
7	11	12	91.7	6	89.7	6	67.1
7	12	5	87.9	5	89.0	12	62.4
7	13	13	69.2	13	77.3	--	--
Eleven-month sampling event (t = 11 month)							
11	1	10	97.5	9	97.6	9	95.4
11	2	9	96.9	10	97.6	10	94.6
11	3	8	95.7	8	95.8	8	93.1
11	4	11	94.1	11	94.7	11	92.7
11	5	1	93.8	1	94.1	1	90.2
11	6	3	92.0	3	93.1	3	89.0
11	7	6	86.2	6	88.5	6	80.9

		Method 1		Method 2		Method 3	
Interval	**Rank**	**Coating**	**% DAs Red.**	**Coating**	**% DAs Red.**	**Coating**	**% DAs Red.**
11	8	4	85.9	4	87.0	4	77.8
11	9	2	85.2	2	85.4	2	73.0
11	10	7	84.1	7	82.0	7	70.7
11	11	12	75.2	12	75.1	5	51.1
11	12	5	63.4	5	65.6	12	49.0
11	13	13	43.3	13	56.4	--	--

Table 4-21. Comparison of DAs Efficacy Calculation Methods, Methods 1, 2, and 3, Source C

		Method 1		Method 2		Method 3	
Interval	Rank	Coating	% DAs Red.	Coating	% DAs Red.	Coating	% DAs Red.
One-month sampling event (t = 1 month)							
1	1	11	99.8	11	99.9	10	99.5
1	2	10	99.8	10	99.8	11	99.5
1	3	9	99.6	9	99.8	9	99.3
1	4	3	99.5	3	99.6	3	98.0
1	5	8	96.1	8	96.3	8	87.0
1	6	12	94.0	12	94.1	12	84.9
1	7	1	94.0	1	93.8	1	80.0
1	8	6	92.7	6	93.1	6	78.1
1	9	7	89.7	7	89.9	7	68.2
1	10	4	88.9	4	89.3	4	67.5
1	11	2	79.1	2	81.6	2	50.7
1	12	5	76.6	5	78.1	5	39.3
1	13	13	68.7	13	68.4	--	--
Three-month sampling event (t = 3 month)							
3	1	3	99.6	3	99.7	10	98.7
3	2	11	99.5	10	99.6	9	98.6
3	3	10	99.4	11	99.6	11	98.4
3	4	9	99.3	9	99.6	3	98.3
3	5	8	98.5	8	98.4	8	93.6
3	6	6	97.0	1	97.1	1	89.1
3	7	1	96.9	6	97.1	12	89.1
3	8	12	96.2	12	96.3	6	89.1
3	9	4	93.7	4	94.7	2	81.5
3	10	2	93.4	2	94.1	4	81.3
3	11	7	92.6	7	93.6	7	76.5
3	12	5	85.6	5	85.7	5	53.8
3	13	13	74.3	13	72.9	--	--

		Method 1		Method 2		Method 3	
Interval	**Rank**	**Coating**	**% DAs Red.**	**Coating**	**% DAs Red.**	**Coating**	**% DAs Red.**
Seven-month sampling event (t = 7 month)							
7	1	10	99.0	10	99.2	10	97.0
7	2	11	98.7	9	98.9	9	96.2
7	3	9	98.6	11	98.9	11	94.8
7	4	3	98.3	3	98.5	3	91.6
7	5	8	98.0	8	98.1	8	91.5
7	6	6	95.0	4	95.0	4	81.2
7	7	4	94.8	6	94.9	12	81.1
7	8	12	94.2	7	94.4	2	80.4
7	9	7	94.1	2	94.1	6	80.1
7	10	1	93.6	12	94.0	7	78.2
7	11	2	93.3	1	93.6	1	74.6
7	12	5	84.5	5	85.2	5	49.1
7	13	13	74.2	13	74.4	--	--
Eleven-month sampling event (t = 11 month)							
11	1	9	97.6	9	98.2	9	97.8
11	2	10	96.7	10	97.8	10	97.2
11	3	11	96.1	11	96.7	11	95.0
11	4	8	94.9	8	95.4	8	93.2
11	5	3	94.6	3	95.2	3	91.1
11	6	6	87.6	1	87.0	6	82.8
11	7	1	86.5	6	86.9	1	82.6
11	8	4	83.1	4	84.9	4	81.0
11	9	12	79.5	12	80.4	12	79.4
11	10	7	77.6	7	78.9	7	72.3
11	11	2	71.9	2	74.7	2	71.8
11	12	5	45.2	5	46.3	5	38.1
11	13	13	25.4	13	23.8	--	--

Table 4-22 provides a similar comparison, showing DA reduction efficacies for all three CCA analytes, for all four calculation methods at the 11-month sampling event (method 4 was reapplied to be specific to the 11-month event, rather than composited over time). In these calculations, results from the two sources of wood are combined.

Table 4-22. Comparison of Efficacy Calculation Methods, for Arsenic at 11 Months, Both Sources Combined

	Method 1	Method 2	Method 3	Method 4
Coating	**% Reduction**	**% Reduction**	**% Reduction**	**% Reduction**
DAs Reduction (%)				
1	90.14	90.57	86.36	86.31
2	78.59	80.06	72.40	77.62
3	93.28	94.15	90.08	93.83
4	84.49	85.98	79.41	77.33
5	54.27	55.94	44.63	45.59
6	86.90	87.72	81.84	79.32
7	80.83	80.43	71.50	75.35
8	95.30	95.58	93.17	92.81
9	97.21	97.87	96.58	97.53
10	97.13	97.67	95.89	97.32
11	95.10	95.69	93.84	96.31
12	77.33	77.76	64.18	76.69
13	34.35	40.11	--	--
DCr Reduction (%)				
1	81.70	82.54	79.50	84.17
2	68.41	70.29	65.59	73.40
3	91.55	92.86	89.89	97.36
4	70.55	73.99	68.33	73.67
5	26.62	32.45	28.88	28.67
6	84.62	85.26	82.10	82.78
7	75.15	75.94	69.89	74.48
8	94.61	94.61	92.88	95.50
9	98.47	98.78	98.33	99.44

	Method 1	Method 2	Method 3	Method 4
Coating	**% Reduction**	**% Reduction**	**% Reduction**	**% Reduction**
10	97.06	97.55	96.61	98.51
11	92.58	93.91	92.73	97.80
12	66.30	68.61	57.22	73.87
13	22.27	28.72	--	--
DCu Reduction (%)				
1	68.44	71.27	54.33	70.85
2	51.45	52.91	30.30	59.06
3	74.47	78.15	58.69	80.84
4	46.59	55.89	31.62	62.92
5	28.01	37.58	8.10	35.16
6	73.93	74.78	66.60	67.26
7	62.59	64.23	48.67	58.13
8	88.01	88.40	82.89	83.48
9	96.41	96.65	94.48	92.49
10	89.50	91.12	80.70	88.38
11	85.59	87.97	81.03	83.40
12	49.22	55.08	40.83	63.45
13	25.81	33.85	--	--

With regards to the choice of method to use to calculate efficacy, Table 4-22 indicates that, particularly for coatings with high efficacies (percent reductions), the variability among calculation methods is low. For the lower performing coatings, the variability is greater. However, these poorer performing coatings are of relatively low interest since they do not provide acceptable levels of mitigation. As such, it appears that the specific method used to calculate efficacy is relatively unimportant. Method 4 may be the most useful since it is most inclusive of the factors considered potentially important in determining coating performance.

To summarize the efficacy results, every coating mitigated DA when compared with the positive control, although the difference between coating #5 and the positive control (coating #13) was consistently insignificant. In general, coatings, when ranked with

respect to efficacy, can be assigned into three broad performance tiers: good performers (high), average performers (mid), and mediocre performers (low).

The best performers were generally coatings #9, #10, and #11, and, to a somewhat lesser extent, #3 and #8. These coatings generally reduced DAs by about 90% or greater (depending on analytical method used to compute DAs reduction) after 11 months (see Table 4-22). The middle tier performers included coatings #1, #4, and #6; these generally reduced DAs by about 75% or greater at 11 months. The lower tier performers included coatings #2, #5, #7, and #12. These generally reduced DAs by about 75% or less at 11 months. Coating #5, the poorest performer tested, achieved only about 50% reduction at 11 months, considerably less that other coatings in this grouping and generally not statistically significantly different from the positive control minideck.

While the top two performers were film-forming coatings – the only two paints tested (coatings #9 and #10) – several other, more typical deck treatment products performed almost as well. The painted minidecks show significant weathering, with an oil-based paint seeming to resist chipping better than a water-based paint. However, there are significant concerns about the applicability of using paints as coatings for exposed outdoor surfaces subject to abrasion. Weathered paints can have a noticeably poor appearance, necessitating frequent recoating. Additionally, the chipping of paints and surface preparation techniques for recoating, which typically include sanding, can generate dust which may make inhalation of CCA-contaminated particles a serious health risk.

Another film-former, an elastic vinyl product designed to encapsulate CCA wood (coating #11), performed very well initially, but appeared to fall off slightly in comparison to other high-performing products over time. This product additionally exhibited significant biological growth and associated discoloration.

Within the remaining coatings, no clear trends with respect to product type or characteristics are immediately evident. For example, tinted stains and sealants do not appear to consistently perform significantly better than untinted ones, although it must be pointed out that this experiment did not control specifically for pigmentation. In other words, the same coating was not tested with and without pigmentation; rather, all twelve products tested were different from one another. In a related study being conducted by CPSC staff, one coating was tested with and without pigmentation and the same coating with pigmentation performed significantly better than without (CPSC staff 2005).

The best non-film-forming products were identified as coatings #1, #3, and #8. Coating #1 is an oil-based semitransparent sealant in cedar tone. Coating #3 is a clear, oil-based, acrylic, deep tone base stain to which no pigment had been added prior to application. Coating #8 is a clear, water-based, acrylic, tint base, solid stain to which no pigment had been added prior to application.

4.6.4 Coating Appearance

The coating appearance after weathering was qualitatively assessed in person and by viewing photographs of each minideck at each sampling event, that is, precoat, after 1 month, 3 months, 7 months, and 11 months of weathering. The photos can be viewed in Appendix R. In general, the two cedar stains and sealants (coatings #1 and #7) retained their appearance well over the first year of service. The paints (coatings #9 and #10) generally also held their overall appearance, though substantial chipping is evident. Coating #11 also held its overall appearance as a smooth, semi-transparent surface layer over the boards, though it too is showing signs of wear and chipping as well as biological growth. Other notable observations are summarized in Table 4-23. It is important to note again that no targeted abrasion component was included in this study. It is likely that some, if not all, coatings – and particularly the film-formers – would have shown more extensive wear patterns if they had been subjected to abrasion in addition to weathering.

4.7 Abrasion and Rewipe Analysis

Statistical methods used to analyze wipe sample data for abrasion and rewipe effects are described in Section 3.4.3. As stated there, the analysis used all of the M and BL sample data to determine whether TTPW or NOPW had an effect on predicting DA.

The statistical analysis indicates that there are no significant trends with the time (months) since the previous wipe (TTPW), but that there is evidence of a downward trend with the number of previous wipes (NOPW). That is, the greater the NOPW, the lower the DA level (data not presented). The direction of the trend is opposite what would be expected if wiping had abraded coatings and reduced their effectiveness (i.e., the hypothesis that more wiping would wear down the coating and allow more CCA analytes to permeate the worn-down, thinner coating).

Table 4-23. Summary of Visual Observations of Minidecks

#	Product Type	Base	Cover	Pigmentation	Main Ingredients	Summary of Visual Observations
Coating 1	Sealant	Oil	Semi	"Cedar"		Deep red coloration. Some wear-through where wiped.
Coating 2	Sealant	Oil	Clear	"Clear"	Acrylic, alkyd, urethane	No visible signs of coating. Relatively light and bright wood appearance.
Coating 3	Stain	Oil	Clear	"Deep Tone Base" (no pigment added)	Acrylic	Extensive black mold or mildew on untreated boards. Varying amounts, from slight to extensive, on treated boards. Growth appeared between 7 and 11 months after coating. Otherwise, no visible signs of coating, though with fresh coating the wood appearance was significantly darkened.
Coating 4	Stain	Oil	Clear	"Clear Stain"	Alkyd	No visible signs of coating. Mold or mildew on untreated boards.
Coating 5	Sealant	Water	Clear	"Clear"		No visible signs of coating. Relatively dark (gray) wood appearance.
Coating 6	Sealant	Water	Clear	"Clear"	Acrylic, alkyd	Slightly yellow tint to treated boards. Some wear-through where wiped.
Coating 7	Stain	Water	Semi	"Cedar"	Alkyd	Lighter red coloration. Wear-through where wiped.
Coating 8	Stain	Water	Clear	"Tint base, solid" (no pigment added)	Acrylic	Very slight tint on treated boards, but generally no visible signs of coating. Relatively light and bright wood appearance.
Coating 9	Paint	Water	Opaque	Gray	Acrylic	Retained gray paint coloration, but moderate-to-extensive chipping, especially at cracks, starting around 7 months.
Coating 10	Paint	Oil	Opaque	Gray	Alkyd, polyurethane	Retained gray paint coloration, slight-to-moderate chipping at cracks. Some black mold or mildew on untreated boards.
Coating 11	Other		Clear	Clear	Elastic vinyl	Extensive black mold or mildew on untreated boards. Varying amounts, from none to moderate, on treated boards. Growth appeared between 7 and 11 months after coating. Seems to visually perform better on A source than C source. Some limited chipping and peeling at large cracks. General appearance is slick and waxy, with an amber coloration that has held well on treated boards.
Coating 12	Other		Clear	Clear	Polymer	No visible signs of coating.
Coating 13	No coating					No visible signs of coating. Some mold and mildew on untreated boards.

This finding should be viewed with some skepticism. Because the experiment was not designed explicitly for assessing abrasion and wipe frequency, there is not much relevant information in the data, and it is difficult to claim with any certainty that the method of analysis is the best way to use the data available for teasing out abrasion and rewipe (from each other and from the other effects). Consequently the significant effect associated with NOPW could be due to confounding with other effects. Alternatively, it is possible that the amount of abrasion induced by rubbing the coating with a pad is negligible, but that the amount of cleaning (of "built-up" DA) is substantial. Thus the number of rewipes might be a surrogate for prior cleaning; the greater the prior cleaning, the less the measured DA.

4.8 Miscellaneous Samples

4.8.1 Brush Washwater Samples

Two types of brushes were used to apply coatings to the minidecks. They were both 2" chip brushes with either natural bristles or polyolefin bristles. Prior to coating application, both brush types were analyzed per the methods described in Section 2.7 in order to ensure that they did not contribute significant amounts of arsenic, chromium, or copper to the wood surfaces.

The results of the analyses are presented in Table 4-24. It can be seen from this table that arsenic levels are below the reporting limit (note that STL-Savannah changed their reporting limit from 0.20 µg/L at the beginning of the study to 0.10 µg/L, currently); chromium levels are also less than 1 µg/L. Although the copper levels are higher than levels of the other two metals, they are lower than levels seen from blank (untreated) boards and can therefore be considered to be insignificant.

Table 4-24. Brush Sample CCA Analyte Concentrations

		Actual Concentration (µg/L)		
Sample Number	**Bristle Type**	**As**	**Cr**	**Cu**
SS-502	Natural	<0.20	0.40	4.2
SS-503	Natural	<0.20	0.88	2.4
SS-504	Synthetic	<0.20	0.49	1.7
SS-505	Synthetic	<0.20	0.35	1.7

4.8.2 Cross Contamination and Negative Control Deck Sample Results

A series of samples were taken from the untreated specimens on each deck which are used to separate boards from one another, as described in Section 2.16. These were designed to provide a control to assess whether "splash-over" of water during precipitation events, for example, could cause cross-contamination of adjacent samples. The most effective way to assess this was to compare the cross-contamination results for the coating #13 minidecks (the uncoated controls) versus the results from the blank control minideck (the minideck whose top is constructed entirely of untreated wood). These results are summarized in Table 4-25, while the full dataset is provided in Appendix S.

The results of all of the untreated wood wipe samples for arsenic are very low in comparison with those from the treated wood specimens. While there appears to be more DAs from the cross-contamination controls versus the blank minideck controls, it is unlikely that the result is significant. Additionally, a comparison of the DCr and DCu results between the cross-contamination and blank minideck controls are inconsistent with those of the DAs results, which also suggests that the results may not be significant.

The cross-contamination data for all of the coatings are summarized in Table 4-26, while the full dataset is provided in Appendix T. Again, the results do not appear consequential; that is, no corrections for cross-contamination need to be made, though we would suggest that future studies also include a cross-contamination buffer board between treated samples. It is interesting to note that there is generally an increasing trend in DA on the control boards over time, which is particularly apparent in the results of samples taken 11 months after coating. It could be that the climatological conditions during or prior to this sampling event resulted in more cross-contamination or simply more retention of DA on the wipes.

Table 4-25. Summary of Cross-Contamination and Blank Control Minideck Results

		Arsenic		Chromium		Copper	
		(µg/L)	(µg/cm^2)	(µg/L)	(µg/cm^2)	(µg/L)	(µg/cm^2)
Cross-Contamination Control Samples (Untreated Boards from coating #13 Minidecks)							
1 month	Average	9.233	0.003	13.167	0.004	57.333	0.018
	Std Dev	5.871	0.002	7.006	0.002	12.423	0.004
	RSD	63.6%	--	53.2%	--	21.7%	--
3 months	Average	6.267	0.002	9.000	0.003	153.333	0.049
	Std Dev	4.271	0.001	5.292	0.002	50.332	0.016
	RSD	68.2%	--	58.8%	--	32.8%	--
7 months	Average	5.933	0.002	11.100	0.004	135.333	0.043
	Std Dev	1.595	0.001	3.851	0.001	65.767	0.021
	RSD	26.9%	--	34.7%	--	48.6%	--
11 months	Average	18.433	0.006	29.000	0.009	310.000	0.099
	Std Dev	11.544	0.004	15.395	0.005	80.000	0.025
	RSD	62.6%	--	53.1%	--	25.8%	--
Blank Control Minideck							
1 month	Average	7.133	0.002	38.333	0.012	71.333	0.023
	Std Dev	1.680	0.001	19.348	0.006	11.504	0.004
	RSD	23.6%	--	50.5%	--	16.1%	--
3 months	Average	2.100	0.001	9.367	0.003	140.000	0.045
	Std Dev	0.500	0.000	2.294	0.001	36.056	0.011
	RSD	23.8%	--	24.5%	--	25.8%	--
7 months	Average	2.000	0.001	5.533	0.002	62.667	0.020
	Std Dev	0.458	0.000	1.206	0.000	13.868	0.004
	RSD	22.9%	--	21.8%	--	22.1%	--
11 months	Average	2.300	0.001	7.067	0.002	126.667	0.040
	Std Dev	0.200	0.000	1.193	0.000	5.774	0.002
	RSD	8.7%	--	16.9%	--	4.6%	--

Table 4-26. Summary of Cross-Contamination Data for All Coatings.

		Time = 1 month			Time = 3 month			Time = 7 month			Time = 11 month		
Coat.		**As (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**As (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**As (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**As (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**
1	av	2.07	3.20	59.33	2.20	4.60	143.7	7.37	10.87	103.0	24.00	20.00	280.0
	Std Dev	0.32	0.53	6.03	1.15	1.54	54.50	2.00	1.96	12.12	15.59	11.36	121.6
	RSD	15.6%	16.5%	10.2%	52.4%	33.5%	37.9%	27.2%	18.1%	11.8%	65.0%	56.8%	43.4%
2	av	3.43	5.90	39.67	2.37	6.40	112.7	5.53	9.80	103.0	11.03	17.00	313.3
	Std Dev	1.42	2.14	7.23	0.32	2.21	31.64	0.78	2.31	23.52	1.95	1.00	20.82
	RSD	41.2%	36.2%	18.2%	13.6%	34.6%	28.1%	14.0%	23.5%	22.8%	17.7%	5.9%	6.6%
3	av	2.07	3.37	67.33	2.80	4.83	176.7	5.90	6.57	113.7	9.10	7.87	153.3
	Std Dev	0.60	0.61	3.51	1.11	1.59	5.77	0.87	1.98	28.29	1.77	0.42	40.41
	RSD	29.2%	18.1%	5.2%	39.8%	33.0%	3.3%	14.8%	30.1%	24.9%	19.4%	5.3%	26.4%
4	av	4.70	7.23	28.00	3.13	4.87	103.7	10.27	15.33	111.7	22.67	24.67	303.3
	Std Dev	0.66	1.76	7.81	0.85	2.24	46.69	4.27	3.21	51.23	9.07	13.50	185.6
	RSD	14.0%	24.4%	27.9%	27.1%	46.0%	45.0%	41.6%	21.0%	45.9%	40.0%	54.7%	61.2%
5	av	3.53	6.17	30.67	4.47	7.53	113.3	10.67	18.33	117.0	18.00	26.33	383.3
	Std Dev	0.50	1.84	6.66	1.42	3.00	15.28	2.52	5.03	39.96	4.00	6.81	100.7
	RSD	14.2%	29.9%	21.7%	31.7%	39.9%	13.5%	23.6%	27.5%	34.2%	22.2%	25.8%	26.3%
6	av	4.67	7.20	33.00	3.43	4.83	86.67	10.37	7.77	67.67	48.67	22.33	170.0
	Std Dev	1.93	2.80	2.65	1.07	1.48	43.50	1.10	1.24	12.01	10.26	13.65	26.46
	RSD	41.3%	38.9%	8.0%	31.1%	30.7%	50.2%	10.6%	16.0%	17.8%	21.1%	61.1%	15.6%
7	av	2.77	4.80	34.33	3.30	4.50	102.7	89.67	125.6	104.0	40.00	11.33	176.7
	Std Dev	0.32	0.95	4.73	1.08	1.31	24.68	138.9	203.0	59.09	5.57	1.53	28.87
	RSD	11.6%	19.9%	13.8%	32.8%	29.1%	24.0%	154.9%	161.7%	56.8%	13.9%	13.5%	16.3%
8	av	1.53	2.70	34.67	2.10	3.73	170.0	6.50	7.67	82.00	8.83	8.80	132.0
	Std Dev	0.25	0.46	4.04	0.35	0.95	34.64	1.35	1.86	11.27	1.20	1.93	62.39
	RSD	16.4%	17.0%	11.7%	16.5%	25.3%	20.4%	20.7%	24.2%	13.7%	13.6%	21.9%	47.3%
9	av	1.20	3.73	41.33	1.18	2.23	107.0	4.13	4.90	53.67	6.33	3.70	26.33
	Std Dev	0.10	3.02	12.58	0.20	0.29	14.73	2.05	2.52	23.46	2.31	1.39	14.47
	RSD	8.3%	80.8%	30.4%	17.1%	12.9%	13.8%	49.7%	51.5%	43.7%	36.5%	37.5%	54.9%
10	av	1.09	1.93	26.33	1.67	3.77	143.3	6.30	7.10	86.33	5.50	4.17	66.67
	Std Dev	0.12	0.45	5.86	0.51	0.92	55.08	1.95	1.67	12.34	3.25	1.46	32.53
	RSD	11.1%	23.3%	22.3%	30.8%	24.5%	38.4%	30.9%	23.5%	14.3%	59.1%	35.1%	48.8%
11	av	1.60	3.30	56.00	3.77	4.47	163.3	4.97	3.77	36.67	7.37	5.70	45.00

		Time = 1 month			Time = 3 month			Time = 7 month			Time = 11 month		
Coat.		**As (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**As (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**As (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**As (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**
	Std Dev	0.26	0.20	6.08	1.06	1.72	83.86	1.11	0.60	7.64	1.65	1.37	13.89
	RSD	16.5%	6.1%	10.9%	28.1%	38.4%	51.3%	22.3%	16.0%	20.8%	22.4%	24.1%	30.9%
12	av	4.43	6.10	35.33	4.30	10.97	102.3	6.97	8.30	66.67	12.67	19.00	233.3
	Std Dev	4.56	5.98	12.74	2.40	8.59	22.50	3.74	2.14	28.01	4.62	8.19	25.17
	RSD	102.9%	98.0%	36.1%	55.8%	78.3%	22.0%	53.8%	25.8%	42.0%	36.5%	43.1%	10.8%
13	av	9.23	13.17	57.33	6.27	9.00	153.3	5.93	11.10	135.3	18.43	29.00	310.0
	Std Dev	5.87	7.01	12.42	4.27	5.29	50.33	1.59	3.85	65.77	11.54	15.39	80.00
	RSD	63.6%	53.2%	21.7%	68.2%	58.8%	32.8%	26.9%	34.7%	48.6%	62.6%	53.1%	25.8%

5. Data Validation and Quality Assurance and Quality Control

5.1 Assessing DQI Goals

The critical measurements for the accelerated and natural weathering tests are total arsenic, total chromium, and total copper concentrations. Data quality indicator (DQI) goals for concentration in terms of accuracy, precision, and completeness, as established in the QAPP for this project, are shown in Table 5-1.

Table 5-1. Data Quality Indicator Goals for Critical Measurements

Analyte	Method	Accuracy (%Recovery)	Precision (%RSD/RPD)	Completeness (%)
Arsenic (total)	SW-846 Method 6020 (modified)	90-110	10	90
Chromium (total)	SW-846 Method 6020 (modified)	90-110	10	90
Copper (total)	SW-846 Method 6020 (modified)	90-110	10	90

After reviewing sample results, the DQI goals for precision and accuracy have been revised for concentrations <10 µg/L. Acceptance criteria of ±25% RPD for precision between duplicates and 75-125% recovery for accuracy will be used for concentrations <10 µg/L.

5.1.1 Precision

In order to evaluate the precision of a measurement, it is necessary to make at least duplicate measurements of a relatively unchanging parameter. Precision can then be expressed as the relative percent difference (RPD) of the duplicated measurement. RPD is calculated using Equation 5.1 where Y1 is the concentration of the first sample and Y2 is the concentration of the duplicate sample.

$$RPD = \frac{(Y1 - Y2)}{\overline{Y}} * 100 \qquad \text{(Equation 5.1)}$$

A large number of blind field duplicates (wipe samples split following extraction) were performed and delivered to the laboratory for analysis. These duplicates were performed at a rate of 7% of the total number of samples collected and provide an indication of the repeatability of the analytical method. The DQI goal for precision was set at ±10% RPD. For the majority of samples, agreement between field

duplicates was very good (i.e., the RSD was small). The DQI goal of ±10% was increased to ±25% for samples with concentrations <10 µg/L because smaller differences in lower concentrations have a greater effect on RPD. With the modification, there were still some cases where the DQI goal was slightly exceeded. In only one case was RPD >50%, this was the only sample set where the data was qualified as estimated "J" due to the RPD between the duplicate samples. A summary of duplicate results is shown in Table 5-2. Instances where these revised DQI goals were not met are shown in ***bold***. Completeness summaries for each metal using the revised DQI goals are shown at the bottom of the table. Achieved completeness was >80%, which did not meet the DQI goal of 90% established in the QAPP. There are no acceptance criteria given in the analytical method for agreement between duplicate samples. A DQI goal of ±15% RPD may be more realistic for these types of samples.

5.1.2 Accuracy and Bias

For this project, the accuracy of the measurement is expressed in terms of recovery of a known spike. Recovery is calculated by:

$$Percent\ Bias = \frac{R - C}{C} \times 100 \qquad \text{(Equation 5.2)}$$

Spiked samples were performed by the laboratory at 3 of 4 concentration levels with the samples from each sampling event. Those concentration levels were 10,000 µg/L, 1,000 µg/L, 50 µg/L and 1 µg/L. In addition to the laboratory spikes, ARCADIS provided 1000 µg/L spikes (in triplicate) and submitted these blind to the laboratory. Spike results are summarized in Table 5-3. Results that do not meet the DQI goals of 90-110% recovery are indicated in ***bold*** (with the exception of the 1 µg/L spikes). The DQI recovery goal for the 1 µg/L spike sample was increased to 75-125% as was done for precision. Completeness was calculated separately for each spiking level and each analyte and is shown at the end of each spike level. Bias results clearly improve as the concentration of the spike level is increased. Not enough spikes were performed at the 10,000 µg/L level to be representative of the sample set. Performance of more spikes at all levels may improve completeness results. Future sample groups should include at least one spike per 100 samples. Spikes were not performed at that rate for any of these tests.

Table 5-2. Precision of Duplicate Samples

Sample/Duplicate (Group)	As (µg/L)	%RSD	Cr (µg/L)	% RSD	Cu (µg/L)	% RSD
SS-859/626 (WIPE-05)	3.6/4.0	10.5	5.7/5.7	0	23/23	0
SS-860/633	490/490	0	690/690	0	190/190	0
SS-861/635	5.9/5.4	8.8	10/9.2	8.3	40/37	7.8
SS-862/647	300/270	***10.5***	390/370	5.3	190/180	5.4
SS-863/656	34/36	5.7	8.1/8.8	8.3	31/33	6.3
SS-864/666	73/74	1.4	17/18	5.7	40/40	0
SS-865/674	120/140	***15.4***	220/260	***16.7***	130/150	***14.3***
SS-866/687	150/150	0	260/260	0	180/180	0
SS-867/690	810/810	0	1700/1700	0	660/660	0
SS-868/700	83/83	0	120/120	0	74/73	1.4
SS-872/712 (WIPE-06)	72/81	***11.8***	120/140	***15.4***	87/98	***11.9***
SS-873/714	290/300	3.4	410/410	0	200/200	0
SS-874/718	58/56	3.5	27/26	3.8	71/69	2.9
SS-875/719	360/340	5.7	110/100	9.5	110/110	0
SS-876/720	190/190	0	210/210	0	140/150	6.9
SS-877/721	130/120	8.0	140/140	0	92/89	3.3
SS-878/724	460/440	4.4	150/150	0	160/150	6.5
SS-879/727	8.9/20	***76.8***	2.2/5.3	***82.7***	13/31	***81.8***
SS-880/730	5.1/5.1	0	5.0/5.2	3.9	59/59	0
SS-881/734	3.9/4.1	5	4.7/4.8	2.1	62/64	3.2
SS-886/837 (WIPE-07)	160/170	6.1	300/310	3.3	99/100	1.0
SS-887/849	69/69	0	46/45	2.2	73/71	2.8
SS-888/852	3/2.8	6.9	8.7/8.4	3.5	35/33	5.9
SS-885/824	1.7/1.7	0	2.6/2.6	0	51/53	3.8
SS-1274/1071 (WIPE-08)	880/890	1.1	1100/1100	0	190/190	0
SS-1275/1084	25/26	3.9	7.3/7.6	4.0	66/71	7.3
SS-1276/1090	200/200	0	240/250	4.1	110/110	0
SS-1277/1091	180/190	5.4	310/320	3.2	170/180	5.7
SS-1278/1107	150/150	0	140/140	0	220/230	4.4

Sample/Duplicate (Group)	As (µg/L)	%RSD	Cr (µg/L)	% RSD	Cu (µg/L)	% RSD
SS-1279/1116	6/5.3	12.4	11/10	9.5	150/150	0
SS-1280/1126	130/130	0	150/160	6.5	280/300	6.9
SS-1281/1131	150/150	0	350/340	2.9	250/260	3.9
SS-1282/1149	530/530	0	830/840	1.2	390/400	2.5
SS-1283/1153	700/680	2.9	1100/1100	0	490/500	2.0
SS-1284/1160	<0.5/<0.5	0	<0.5/<0.5	0	1.5/1.8	18.2
SS-1285/1161	35/33	5.9	39/37	5.3	130/130	0
SS-1286/1171	8.3/7.9	4.9	13/12	8.0	140/140	0
SS-1287/1172	2.5/2.8	11.3	2.6/2.9	10.9	110/120	8.7
SS-1288/1173	2.5/2.6	3.9	8.3/8.3	0	170/180	5.7
SS-1289/1179	210/210	0	550/570	3.6	220/250	***12.8***
SS-1290/1180	<0.5/<0.5	0	0.95/0.84	12.3	2.3/2.9	23.1
SS-1291/1181	3.7/3.6	2.7	5.7/5.7	0	120/130	8.0
SS-1292/1208	39/37	5.3	55/54	1.8	93/93	0
SS-1293/1210	30/30	0	57/58	1.7	77/82	6.3
SS-1294/1215	19/19	0	17/16	6.1	120/120	0
SS-1295/1222	3/3	0	6.2/6.6	6.2	170/170	0
SS-1296/1223	180/190	5.4	290/310	6.7	140/140	0
SS-1297/1230	370/350	5.6	740/700	5.6	300/300	0
SS-1298/1234	120/110	8.7	230/220	4.4	160/150	6.5
SS-1299/1247	41/44	7.1	41/46	***11.5***	80/87	8.4
SS-1300/1258	18/17	5.7	13/12	8.0	110/100	9.5
SS-1587/1324 (WIPE-10)	9.2/8.0	14.0	15/13	***14.3***	90/81	***10.5***
SS-1588/1333	240/240	0	440/440	0	230/220	4.4
SS-1589/1344	53/48	9.9	27/24	***11.8***	100/91	9.4
SS-1590/1348	77/72	6.7	48/44	8.7	210/190	10.0
SS-1591/1352	150/140	6.9	30/26	***14.3***	41/36	***13.0***
SS-1592/1371	92/91	1.1	14/14	0	36/33	8.7
SS-1593/1376	140/140	0	41/39	5.0	81/72	***11.8***
SS-1594/1383	2300/2300	0	2700/2600	3.8	390/360	8.0

Sample/Duplicate (Group)	As (µg/L)	%RSD	Cr (µg/L)	% RSD	Cu (µg/L)	% RSD
SS-1595/1386	12/11	8.7	11/9.2	17.8	72/67	7.2
SS-1596/1407	730/700	4.2	100/950	5.1	490/430	***13.0***
SS-1597/1415	100/98	2.0	160/160	0	140/130	7.4
SS-1598/1479	480/490	2.1	630/640	1.6	350/360	2.8
SS-1600/1487	77/73	5.3	170/160	6.1	150/140	6.9
SS-1601/1495	470/480	2.1	560/570	1.8	230/240	4.3
SS-1602/1502	450/490	8.5	1100/1260	***13.6***	420/460	9.1
SS-1603/1512	110/110	0	240/240	0	160/160	0
SS-1604/1514	31/29	6.7	87/81	7.1	190/180	5.4
SS-1605/1519	59/65	9.7	270/290	7.1	140/150	6.9
SS-1606/1529	99/100	1.0	22/22	0	32/33	3.1
SS-1607/1531	22/23	4.4	6.5/6.9	6.0	33/34	3.0
SS-1608/1534	2.6/2.4	8.0	5.3/5.0	5.8	83/82	1.2
SS-1609/1536	2.2/2.1	4.7	8.3/7.8	6.2	91/88	3.4
SS-1610/1540	<1.0/<1.0	0	<1.0/<1.0	0	2.4/3.0	22.2
SS-1611/1566	7.7/7.6	1.3	9.6/9.2	4.3	94/88	6.6
SS-1612/1568	130/120	8.0	49/43	***13.0***	140/120	***15.4***
SS-1613/1576	280/300	6.9	73/80	9.2	140/160	***13.3***
SS-1614/1578	56/54	3.6	57/56	1.8	170/160	6.1
WB-278/893 (WIPE-11)	8900/9400	5.5	8800/9100	3.4	5300/5300	0
WB-348/894	11000/9700	***12.6***	12000/9800	20.***2***	7500/6300	***17.4***
WB-353/895	6200/6000	3.3	7100/6600	7.3	4400/4000	9.5
WB-373/896	8500/8600	1.2	7800/8000	2.5	5500/5500	0
WB-383/897	8800/8600	2.3	8500/8300	2.4	4600/4400	4.4
WB-394/898	8900/10000	***11.6***	8500/9600	***12.2***	4900/5400	9.7
WB-409/899	600/600	0	680/680	0	410/380	7.6
WB-445/900	5300/5500	3.7	6700/6900	2.9	4500/4600	2.2
WB-445/901	7500/7700	2.6	7400/7700	4.0	4500/4600	2.2
WB-449/902	2200/2300	4.4	3000/3100	3.3	1600/1700	6.1
WB-443/903	11000/8400	***26.8***	11000/8100	***30.4***	7400/5400	***31.3***

Sample/Duplicate (Group)	As (µg/L)	%RSD	Cr (µg/L)	% RSD	Cu (µg/L)	% RSD
WB-437/904	1800/1200	***40.0***	1900/1200	***45.2***	1300/860	***40.7***
WB-260/905	5400/3500	***42.7***	6600/6500	1.5	3600/5500	***41.8***
WB-196/906	4000/4300	7.2	5100/5400	5.7	2700/2700	0
WB-115/907	4900/4900	0	4800/4700	2.1	2800/2600	7.4
WB-118/908	5800/5200	***10.9***	7000/6000	***15.4***	4100/3400	***18.7***
WB-149/909	6600/6700	1.5	8400/8400	0	5200/6100	***15.9***
WB-173/910	5900/6500	9.7	7200/7700	6.7	4200/4300	2.4
WB-239/911	10000/9800	2.0	11000/10000	9.5	7000/6200	***12.1***
WB-255/912	12000/11000	8.7	13000/12000	8.0	7200/6200	***14.9***
WB-146/920 (WIPE-12)	130/91	***35.3***	140/95	***38.3***	110/77	***35.3***
WB-154/921	4200/4700	***11.2***	4800/5500	***13.6***	2900/3200	9.8
WB-215/922	5900/5000	***16.5***	6600/5600	***16.4***	3500/3000	***15.4***
SS-1884/1842 (WIPE-13)	30/28	6.9	14/14	0	29/27	7.1
SS-1885/1713	33/31	6.3	30/38	***20.3***	540/480	***11.8***
SS-1886/1727	72/78	8.0	120/130	8.0	340/370	8.5
SS-1887/1815	1300/1200	8.0	2200/2100	4.7	820/780	5.0
SS-1888/1851	590/520	***12.6***	1500/1300	***14.3***	1300/1100	***16.7***
SS-1889/1797	7.5/7.6	1.3	7.3/7.4	1.4	140/140	0
SS-1890/1671	870/760	***13.5***	1800/1700	5.7	650/610	6.3
SS-1891/1653	1000/940	6.2	1760/1600	9.5	950/940	1.1
SS-1892/1624	360/3440	5.7	420/460	9.1	260/250	3.9
SS-1893/1772	4000/3700	7.8	5600/5200	7.4	2200/2100	4.7
SS-1894/1749	85/75	***12.5***	120/110	8.7	170/180	5.7
SS-1895/1869	310/350	***12.1***	230/250	8.3	330/340	3.0
SS-1896/1882	140/140	0	270/290	7.1	330/340	3.0
SS-1897/1641	14/14	0	20/21	4.9	310/290	6.7
Completeness						
Using DQI of ±10%	99/115 = 86.0%		96/115 = 83.4%		93/115 = 80.9%	
Using DQI of ±15%	109/115=94.8%		105/115=91.3%		104/115=90.4%	

Table 5-3. Spike Results

Analytical Group	Arsenic		Chromium		Copper	
	Obtained	%Recovery	Obtained	%Recovery	Obtained	%Recovery
10,000 µg/L Spike Level (DQI Goal 90-110%)						
WIPE-10	9700	97	10000	100	9700	97
WIPE-13	10000	100	12000	***120***	10000	100
Completeness		100%		***50%***		100%
1,000 µg/L Spike Level (DQI Goal 90-110%)						
WIPE-05	1100	110	1000	100	980	98
WIPE-06	1000	100	980	98	920	92
WIPE-07	1100	110	1000	100	950	95
WIPE-08	980	98	1000	100	980	98
WIPE-08*	970	97	1000	100	970	97
WIPE-08*	940	94	1000	100	950	95
WIPE-08*	980	98	1000	100	970	97
WIPE 11	1100	110	1000	100	930	93
WIPE-11 (duplicate)	1100	110	1000	100	980	98
WIPE-12	1100	110	990	99	970	97
WIPE-13	1000	100	1100	110	990	99
Completeness		100%		100%		100%
50 µg/L Spike Level (DQI Goal 90-110%)						
WIPE-05	50	100	52	104	49	98
WIPE-06	58	***116***	52	104	51	102
WIPE-07	45	90	47	94	43	114
WIPE-08	46	92	50	100	47	94
WIPE-10	52	104	49	98	48	96
WIPE 11	51	102	53	106	51	102
WIPE-11 (duplicate)	54	108	51	102	50	100
WIPE-12	54	108	52	104	50	100
WIPE-13	64	***128***	57	***114***	59	***118***

Analytical Group	Arsenic		Chromium		Copper	
	Obtained	%Recovery	Obtained	%Recovery	Obtained	%Recovery
Completeness		***77.8%***		***88.9%***		***77.8%***
1 µg/L Spike Level (DQI Goal 75-125%)						
WIPE-05	2.3	***230***	3.4	***340***	4.6	***460***
WIPE-06	0.95	95	0.9	90	1.2	120
WIPE-07	0.97	97	0.84	84	1.3	***130***
WIPE-08	1.0	100	1.0	100	1.2	120
WIPE-10	1.1	110	<1.0	100	<1.0	100
WIPE 11	1.2	120	1.1	110	1.2	120
WIPE-11 (duplicate)	0.5	***50***	0.5	50	0.5	***50***
WIPE-12	1.1	110	0.96	96	1.3	***130***
WIPE-13	1.3	130	1.0	100	1.0	100
Completeness		***66.7%***		***77.8%***		***55.6%***

5.1.3 Completeness

The ratio of the number of valid data points taken to the total number of data points planned is defined as data completeness. Completeness goals of >90% were not achieved for a number of measurements. These are summarized in Tables 5-2 and 5-3. Data results suggest that the DQI goal of ±10% for precision between duplicates may be too ambitious. There is no specific acceptance criteria given in the analytical method for precision between duplicate samples. If the DQI goal were slightly increased to 15% RPD, completeness goals would have been met for all metals. Also, the analytical method cites acceptance criteria for recovery of spiked blanks as 85-115% which is slightly higher than the DQI goal of 90-110%. Using this criteria, completeness of accuracy results would improve. DQI goals will be reviewed and may be revised as needed.

5.2 Quality Control Checks

A variety of control samples were taken as described in Section 4.1-4.4 of the QAPP (U.S. EPA 2003). Results from the checks are described in the following subsections.

5.2.1 Blanks

5.2.1.1 Wipe Blank Study

A number of blank evaluations were performed early in the project to evaluate the amounts of target compounds inherent in the extraction process and the wipes themselves. Initially, wipes directly out of the bag were placed in clean digestion vessels and approximately 40 mL of 10% nitric acid added. The samples were then heated lightly in the microwave and allowed to cool and the contents transferred to a 100 mL volumetric flask. An additional 40 mL of 10% nitric was added to the vessel and the process repeated. The vessel was then rinsed with consecutive 10 mL aliquots of 10% nitric acid and the contents transferred, bringing the volumetric to mark. It should be noted that the wipe remained wet and it was impossible to completely transfer all of the liquid to the volumetric flask. Successive extractions and rinses were used in the hopes of largely transferring all of the metals to the volumetric flask. Blank results for arsenic and chromium are shown in Table 5-4. Initial wipe blank analysis did not include an analysis for copper.

Table 5-4. Polywipe Blank Analyses

Sample Number	As (µg/L)	Cr (µg/L)
AQS-54	1.2	0.8
AQS-55	1.3	1.1

To investigate the potential to reduce the background levels of As and Cr seen in the wipe blanks, nine polywipes were pretreated by extracting them with 10% nitric acid at 60 °C for 1 hr, then rinsing thoroughly with de-ionized water, and allowing them to dry in a clean environment. Results comparing the pretreated wipe blank to the previous results are shown in Table 5-5. The pretreated polywipes were used for the subsequent tests and sampling events.

Table 5-5. Results from a September 2003 Wipe Comparison Study

Average	Ar (µg/L)	Cr (µg/L)	Cu (µg/L)
Wipe Blank (Out of Bag)	0.41	0.93	2.1
Digested Nitric Blank	<0.10	<0.50	0.3
Acid Wipe Blank	0.2	<0.50	1.3

Results for the initial out of bag wipe blanks experiments were performed using a whole 12” x 12” polywipe. The data collected from the September 2003 Wipe Comparison Study were performed using half of a wipe, thus the concentrations for the half a wipe should be lower than from a whole wipe.

5.2.1.2 Blanks During Sampling Events

During actual sampling events, two types of blank samples were submitted by ARCADIS to the laboratory for analysis. Blind field blanks were submitted at a frequency of one every 20 samples and consisted of the extraction fluid from a clean wipe (i.e., not wiped across a board). Reagent blanks were also submitted at a frequency of one per sample delivery group and consisted of an aliquot of the nitric acid reagent used for extracting samples. The majority of results from the blind field blank samples resulted in non-detects for each metal of interest. When there were detects (>1µg/L), concentrations were always < 10 µg/L and always less than the action levels. In some cases, samples with reported concentrations of the metals less than the action level associated with these field blanks were qualified as not detected and flagged “U”. These results are summarized in the individual validation reports included in Appendix U. None of the metals of interest were detected in any of the reagent blanks submitted to the laboratory for analysis. No blank corrections were performed on reported sample concentrations.

5.2.2 Initial Spike Study

A number of spike studies were done to ensure that the analytes of interest could be captured with the wipes, extracted and analyzed. In the first study, three samples were prepared by spiking known amounts of arsenic and chromium standard stock onto a clean glass plate and allowing the liquid to evaporate. Each glass plate was then wiped using the CPSC technique and the polywipes were extracted and analyzed. Recovery results are shown in Table 5-6.

Table 5-6. Results of Spiking onto Glass

	As	Cr	Units
Spiked Amount	50	49.75	µg
Sample AQS-56	33	38	µg
Sample AQS-57	41	46	µg
Sample AQS-58	41	46	µg
Average	38.3	43.3	µg
SD	4.6	4.6	µg
% recovery (av)	77%	87%	
% RSD	12%	11%	

The recoveries from the glass plate sampling have an average of 77% recovery for arsenic and 87% recovery for chromium. Less than 100% recovery of the metals could be expected due to the drying of the spike solutions on the glass. A small amount of residue was seen left on the glass after wiping with the wiping apparatus. The residue could be removed with further cleaning which indicated that the stain was metal salts and not etching.

In the next study, pretreated polywipes were directly spiked with 1 µg/L, 50 µg/L and 1000 µg/L of arsenic, chromium and copper standard. These samples were extracted and analyzed by the laboratory. Results are shown in Table 5-7.

Table 5-7. Results of Spiking Wipes Directly

Sample ID	Arsenic (µg/L)	Recovery (%)	Chromium (µg/L)	Recovery (%)	Copper (µg/L)	Recovery (%)
SS-562	1.0	100	1.0	100	1.2	120
SS-563	47	94	51	102	47	94
SS-564	1100	110	1000	100	970	97

In addition to liquid standards for arsenic, CPSC also provided ARCADIS with a standard CCA Dust Material that contained a known amount of arsenic. A known weight of this material was placed directly in to extraction vessels containing the acid rinsed polywipes and extracted and analyzed. This spiking was done in duplicate and recoveries for arsenic were 98% and 102%. As a result of the spike studies, it was

determined that arsenic, chromium and copper could be adequately recovered from wipe samples.

5.2.3 Laboratory Control Samples

A series of laboratory control samples were analyzed with each batch of samples as defined by the analytical method (EPA Method 200.8). Internal laboratory QC checks included laboratory reagent blanks at a frequency of one every 20 samples, laboratory fortified blanks at a frequency of one per batch and post-digestion spikes which were performed at a frequency of one every 10 samples. Results of laboratory control samples were summarized in the analytical reports and also in the internal validations performed by ARCADIS. Failure to meet acceptance criteria resulted in data flagged as estimated "J", or non-detects, "U".

5.3 Data Validation Summary

The subcontract laboratory was required to submit calibration and QC data along with each data package. All data packages received by ARCADIS were internally validated by a qualified staff scientist according to the QA/QC criteria set forth in the U.S. EPA *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review,* July 2002 (NFG). When parameters called out in the NFG were different from those established in the QAPP or the analytical method (EPA Method 200.8), the more stringent criteria were used. Validation reports were prepared for each sample delivery group and the reported data were qualified as appropriate. These reports are included in Appendix U.

5.4 Deviations from the QAPP

Deviations from the original QAPP and the reasons or justification for them are listed below:

- Laboratory cites use of Method 200.8-*Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma/Mass Spectrometry* instead of SW-846 Method 6020 as referenced in the QAPP. Method 200.8 is a more detailed and specific method than 6020 and there are no technical differences between the two.

- Field blanks at a rate of 5% were not included in the first two batches of samples sent to the laboratory as stated in the QAPP Section 4.4. This was a mistake by the sampling team. Subsequent batches contained the appropriate number (or more) of

field blanks. Based on the results of subsequent field blanks, it is not believed that the first batches of samples were compromised due to insufficient number for field blanks.

- Blind spiked samples were not submitted to the laboratory at the frequency described in Section 4.4 of the QAPP. Only one set of triplicate spikes at 1,000 µg/L were submitted. There are a number of laboratory control samples required by the method that are performed with each batch. It was felt that one set of blind spiked samples was sufficient.

- The laboratory performed post-digestion spikes at a 10% frequency, but did not do standard matrix spikes and matrix spike duplicates, since ARCADIS did the sample extraction and digestion.

- Two brush wash water samples were taken per brush type (four total samples) and the wash technique used was slightly different than that in the QAPP.

- Wood moisture content was not measured during each wipe event, because of concerns about damaging and compromising coatings using the wood moisture probe.

5.5 Audits

The ARCADIS QA Officer performed an internal technical systems audit on the sampling portion of this project on September 10 and 11, 2003. The following findings were reported to the ARCADIS Work Assignment (WA) Manager. All problems found during the audit were corrected the same day.

- Sampling staff were not wearing gloves on the first day of sampling. Corrective actions were taken and for all subsequent sampling the sampling staff used double gloves and changed the outer pair after each sample was taken.
- Sampling apparatus was not being decontaminated after each board. Corrective action was implemented that apparatus would be wiped down after each board using wipes wetted with DI water.
- There were some initial problems with the wipe staying on the apparatus when wiping boards with a rough surface. The corrective action taken was to orient the wipe such that corners are facing board when wiping, which helps the wipe stay in place.

In addition to the systems audit, three blind audit samples were submitted to STL for analysis. Results from these samples were presented in Table 5-7 and met all DQI goals.

An audit of data quality was performed on the information contained in the database through Sampling Event #4 (July 2004). Database data was checked for accuracy by comparing entries with raw data sheets, project notebooks and laboratory reports. The ARCADIS QA Officer performed this audit by randomly selecting samples representing approximately 10% of the total number of entries contained in the database. The following parameters were verified for 77 randomly selected specimens:

Specimen label
Board label
Minideck label
Specimen type
Date sampled
Date analyzed
Lab sample ID
Laboratory batch number
Arsenic concentration
Chromium concentration
Copper concentration
Core wood analysis results (when applicable)
Moisture content
Baseline arsenic, chromium and copper
Coating ID

In addition to the 77 samples randomly selected, 100% of the data recorded for coating volume and coating mass for each minideck was recalculated. Any discrepancies were immediately reported to the ARCADIS work assignment leader (WAL) and database manager (Krich Ratanaphruks) and corrected. An internal report was submitted to the ARCADIS WAL. The following findings were cited:

- Specimen A-BG-BL6 in database should actually be A-L-BL5. All other information related to this sample is correct.

- There is no baseline data for A-BG-M4 contained in the database.

- In the file Baseline Samples-ver5.xls for sample C-BO, there are two BL4 entries. One should be BL5.

- The concentration in the database for C-BT-M2 is an average of BL3 and Bl4 and should be an average of BL2 and BL3.

- There were discrepancies (affecting approximately 20%) in the way moisture averages were calculated. The same logic was not applied to every specimen.

- There were numerous errors made in volume (affecting approximately 30%) and weight (affecting approximately 15%) calculations for initial coating of minidecks. Errors were caused by mistakes in subtraction and difficulty reading handwriting in notebooks. For this reason, 100% of the information was recalculated using the information documented on original data sheets and in the project notebook. Corrected values were submitted to the Database Manager.

The majority of these findings were minor and corrected in the database immediately. As a result of the audit findings, a new column for moisture data for each specimen was added to the database that is an average of all measurements made for the entire board. This method of calculating moisture eliminates having to determine which two moisture measurements to use in the average to apply to each specimen. No systematic corrective actions were implemented for the coating volume and mass finding because these measurements will not be performed again unless new minidecks are prepared. In the event new coatings are evaluated, changes in how volumes and weights are recorded will be implemented.

An EPA audit was performed in November 2004 at the time of collection of the 15-month samples. Results of this audit will be reported within the final data report which will contain the results for the samples collected at the 15-month sampling period in addition to the data from each of the other sampling events.

6. Conclusions

The primary purpose of this study is to provide EPA with data needed to make and support guidance to consumers regarding mitigating health risks associated with the continued use of CCA treated wood structures, like decks. As such, the coatings that were tested were ranked based on their performance. Upper tier performers generally reduced dislodgeable arsenic (DAs) by about 90% or greater after 11 months, middle tier performers generally reduced DAs by about 75% or greater at 11 months, and lower tier performers generally reduced DAs by about 75% or less at 11 months.

While the top two performers were film-forming coatings – the only two paints tested (coatings #9 and #10) – several other, more typical deck treatment products performed almost as well. The painted minidecks show significant weathering, with an oil-based paint seeming to resist chipping better than a water-based paint. However, there are significant concerns about the applicability of using paints as coatings for exposed outdoor surfaces subject to abrasion. Weathered paints can have a noticeably poor appearance, necessitating frequent recoating. Additionally, the chipping of paints and surface preparation techniques for recoating, which typically include sanding, can generate dust which may make inhalation of CCA-contaminated particles a serious health risk.

Another film-former, an elastic vinyl product designed to encapsulate CCA wood (coating #11), performed very well initially, but appeared to fall off slightly in comparison to other high-performing products over time. This product additionally exhibited significant biological growth and associated discoloration.

Within the remaining coatings, no clear trends with respect to product type or characteristics are immediately evident. The best non-film-forming products were identified as coatings #1, #3, and #8. Coating #1 is an oil-based semitransparent sealant in cedar tone. Coating #1 additionally contains a UV blocking agent. Another coating containing a UV blocker (coating #7) did not perform as well. Coating #3 is a clear, oil-based, acrylic, deep tone base stain to which no pigment had been added prior to application. Coating #8 is a clear, water-based, acrylic, tint base, solid stain to which no pigment had been added prior to application.

Additionally, we can say that:

- Rinsing the wood surfaces reduces DA measured by wipe sampling, although it may simply relocate the CCA chemicals to other places where exposure is possible.

- Coating the wood surfaces further reduces DA over uncoated surfaces.
- Weathering reduces the effectiveness of coatings as seen by increases in DA.
- Some coatings perform better than others in terms of DA reduction but there are inconsistencies between coatings within the same classification.
- Coating product trade names are not tied to specific formulations, potentially complicating the ability to communicate results and guidance effectively with the public.

Significant findings with regards to the test protocol, include the following:

- The protocol appears robust and could be used by the coatings industry to develop coatings and to verify coating performance for CCA exposure mitigation.
- Cross-contamination does not appear to be a significant issue with respect to the study design utilized for this project.
- It appears that baseline (pre-coat) DA should be determined either for each PSA (as done in this study) or averaged over each board. Averaging over each source board may allow more flexibility from a study design logistics perspective, without sacrificing statistical power with respect to assessing coating performance via efficacy calculations. We recommend devising a way to take precoat measurements before and after doing the coating preparation (washing, rinsing, etc.) step to determine the effect of coating preparation on DA.
- The effects of abrasion – that is, the wearing down of the coating and the liberation of more DA – resulting from the wipe sampling method used for this study appear to be negligible, thus avoiding potential complications, or false positive interferences, as a result of the sampling methodology.
- As noted in other related studies, rewipe effect – that is, the reduction in DA post-sampling – may be significant. However, in this study, no significant trends were observed between DA and the elapsed time between sampling events, although there was a significant relationship between DA and the number of previous wipe samples taken. The 60-day post-sampling recovery period suggested by Stilwell (2003a) appears to be the minimum amount of time to allow DA to recover to presample levels. In this study, rebound to presampling levels (samples taken 1

month after coating, for the positive control minidecks), only occurs for several PSA samples. On average, DA reductions from the first sampling event are still observed after 4 months of no-sampling weathering, suggesting that the recovery period may need to be even greater than 4 months.

- There appears to be a relatively strong correlation between DAs, DCr, and DCu. That is, wipe areas with high DA measurements for one CCA analyte generally also have high DA measurements for the other CCA analytes.

- The method by which coating efficacies are calculated or modeled did not appear to have a large effect on the rank order of coatings. Additional work may need to be done to determine which of the methods provide the most useful data with respect to the specific mitigation goals of a project (i.e., in appropriately predicting percent reductions to use in associated risk analyses, etc.).

Finally, abrasion is considered another likely important coating performance factor. Coating protocols for testing DA mitigation should include an abrasion component in addition to weathering.

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