Research Report
KTC-03-03/SPR 224-01-1F

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ENVIRONMENTAL IMPACTS OF BRIDGE CLEANING OPERATIONS

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176 Raymond Building
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(859) 257-4513
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1-800-432-0719
www.engr.uky.edu/ktc
ktc@engr.uky.edu

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ENVIRONMENTAL IMPACTS

OF

BRIDGE CLEANING OPERATIONS

By

Theodore Hopwood II
Associate Engineer III, Research

Sudhir Palle
Associate Engineer II, Research

And

Rick Younce
Senior Engineer Technician, Research

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, Kentucky

in cooperation with

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16. Abstract

Cleaning (washing) operations of existing leaded paints on bridges were studied to determine the level of lead contamination in the resulting wastewater. Twelve experimental overcoating projects were let on bridges with various types of existing paint in varying states of deterioration. The projects employed different washing pressures ranging from 2500 psi to 10000 psi and various wash nozzles (fan and 0^{o} spinner tips). KYTC standard filtration was used on 10 projects and 2 projects used an experimental filtration unit having a sand filter and two types of chemical filter media.

Prior to painting, the existing paint was analyzed for thickness, adhesion, and lead content. Wastewater generated during maintenance painting operations (potable, unfiltered and filtered) was sampled and analyzed for lead content (total and dissolved), total suspended solids and pH. No clear correlations were obtained between lead in the wastewater, wash pressures, nozzle type, or any of the existing paint parameters tested. The sand filter and chemical filter media of the experimental filtration unit provided significant removal of lead from wastewater.

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TABLE OF CONTENTS

LIST OF FIGURES

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EXECUTIVE SUMMARY

Background

Kentucky Transportation Cabinet (KYTC) overcoating of bridges uses pressure washing to clean the existing steel prior to painting. Typically, the existing paint being washed contains lead. Consequently, the wastewater generated is contaminated with a small amount of lead paint debris. Current KYTC specifications require contractors to use a 430 micron geotextile fabric to filter the wastewater prior to its release. That filtration is capable of removing large paint particles, but its effectiveness in removing suspended fines or dissolved metal ions had not been investigated prior to this study.

Officials of the KYTC Project Design Team wished to assess the composition of wastewater; both unfiltered and filtered, and to determine the amounts and dispositions of both particulate and dissolved lead generated by pressure washing. As part of this study, KYTC let 12 experimental overcoating projects in 2002. In the special notes for cleaning, the wash pressure was varied among the projects from 2500 psi to 10000 psi. As the mechanical washing action also affected the degree of cleaning, 0^{o} spinner tips were used on some projects and 30^{o} fan tips were used on others. On 10 of the projects, standard KYTC mechanical filtration was used wherein the wastewater was passed through a 430 μ (10^{-6}m) apparent opening size geotextile fabric before being discharged. On two projects, an experimental filtration unit from the Georgia Tech Research Institute was used to filter the wastewater. That unit was comprised of a sand filter for initial cleaning and one of two different filter media that chemically filtered the wastewater.

Prior to contractor work on projects, KTC researchers measured thickness and adhesion of the existing coatings and took samples for subsequent lead content measurements. During the contractor cleaning operations, KTC researchers took samples of potable water, unfiltered wastewater and filtered wastewater. Those samples were tested for total and dissolved lead, total suspended solids and pH. Wastewater samples from projects using standard KYTC mechanical filtration were tested at the Microbac Laboratories in Louisville. Some samples of wastewater from the projects employing chemical filtration were tested for total lead by the University of Kentucky Center for Applied Energy Research (CAER) in Lexington.

Wastewater Test Results

Most samples of potable water used for pressure washing the bridges had total (and dissolved) lead contents below the Microbac level of test reporting set at 0.1 mg/l or 100 ppb (Tables 1 and 2). The chemical filter unit was employed on those projects and higher limits of test resolution were sought (down to 0.001 mg/l). The potable water lead concentration results (both total and dissolved) from those projects obtained by CAER ranged from 0.002 to 0.004 mg/l (Tables 10 and 11). The suspended solids in the potable water were very low with all samples being below 10 mg/l (Tables 3, 10 and 11).

The test results for total lead in the unfiltered wastewater varied from 2.3 to 130 mg/l (ppm) on all the projects (Table 4, 10 and 11). The dissolved lead in the unfiltered water varied from below the limit of test resolution (i.e. <0.1 mg/l) on four projects to a maximum value of 5.5 mg/l. The total suspended solids varied from 79 mg/l to 8930 mg/l. The amounts of total lead in the unfiltered wastewater did not correlate with the amounts of dissolved lead for all the samples taken.

Also, the amount of total lead did not correlate with the amount of suspended solids for all the samples taken. The relative frequencies of the test values for the unfiltered wastewater are provided in Figures 18-20.

The test results for total lead in the conventionally filtered wastewater (using the KYTC specified 430 micron geotextile) varied from 2 mg/l to 220 mg/l (ppm) over on all the projects (Table 7). The dissolved lead in the filtered water varied from below the limit of test resolution (i.e. <0.1 mg/l) to 4.1 mg/. The total suspended solids were reduced somewhat by filtering (from an average of 1,679 mg/l in unfiltered to 1,325 mg/l in filtered). The relative frequencies of the test values for the unfiltered wastewater are provided in Figures 21-23.

For individual samples, the concentrations of total lead in the filtered wastewater did not correlate with the concentrations of dissolved lead for all the samples taken. Also, the concentrations of total lead in the filtered wastewater did not correlate with the amount of total suspended solids for all the samples taken. The total lead concentrations in the unfiltered wastewater did correlate with those in the filtered wastewater (the highest filtered tests being greater than the unfiltered tests). The dissolved lead concentrations in the filtered wastewater were slightly lower than those in the unfiltered wastewater. However, the test values for specific projects did not correlate well between the two wastewater states (i.e. unfiltered and filtered).

The variation in lead concentrations between the unfiltered and filtered states indicates that the difference was probably due to the disposition of the solids in wastewater during or prior to sampling. That variation was the result of problems in obtaining consistent unfiltered and filtered wastewater samples.

Tests of the GTRI chemical filtration unit were conducted at the Daviess Co. project from June 26-July 8, 2002 and at the Trigg Co. project on July 16, 2002. During that time the chemical filtration unit was used to filter a total of about 3,000 gallons of wastewater generated on the two projects. The test data for those projects is provided in Tables 10 and 11.

Tests of the GTRI chemical filtration device were conducted over a range of high washing pressures for the Daviess Co. project (7000 to 9000 psi using 0^{o} spinner tips). The test resolution for most samples was improved in anticipation of the low lead concentrations in the filtered wastewater. The potable water lead values were tested by both CAER and Microbac. Two CAER provided identical potable water lead concentration values of 0.002 mg/l. Tests of total lead concentration in the unfiltered wastewater generated at 7000 psi washing pressure were in the range of 9-10 mg/l. Tests of total lead concentration in the unfiltered wastewater generated at 9000 psi washing pressure were in the range of 9-62 mg/l. Tests of dissolved lead concentration in the unfiltered wastewater provided values ranging from 2.0 mg/l to 2.3 mg/l for Microbac tests of both 7000 psi and 9000 psi generated wastewater. Wastewater samples were taken after pre-filtering using a sand filter bed. Tests on those samples generated at 7000 psi and 9000 psi produced total lead concentration values of 0.5 mg/l and 0.4 mg/l respectively. The sand filter provided a reduction in total lead concentrations of about 20:1 for the 7000 psi wastewater and about 150:1 for the 9000 psi wastewater.

The total suspended solids concentration in the potable water for this project was <5 mg/l. After pressure washing at 7000 psi and 9000 psi, the total suspended solids concentrations increased to 43 mg/l and 603 mg/l respectively. Tests of wastewater passed through the sand filter had total suspended solids concentrations of 65 mg/l and 14 mg/l respectively. The initial high value of total suspended solids for the 7000 psi test may have been the result of wastewater from the initial test washing the sand in the filter for the first use. Thereafter, for the 9000 psi test at Daviess Co. and the tests at Trigg Co., the total suspended solids concentration values were reduced below levels obtained in the unfiltered wastewater.

The GTRI device pumped the wastewater from the sand filter through one of two chemical filter columns. One filter material was a proprietary chemical material, a phosphate (Filter Media 1) and the second was a commercial grade of xeolite, an aluminum silicate (Filter Media 2). Tests for total lead concentrations in filtered wastewater performed by CAER from Filter Media 1 were all below the drinking water regulatory limit ranging from 0.003 mg/l to 0.005 mg/l. The Microbac tests for total and dissolved lead concentrations in wastewater passed through Filter Media 1 provided limit of test resolution results of <0.1 mg/l which were in conformance with the CAER results. Tests for total lead concentrations in filtered wastewater performed by CAER from Filter Media 2 ranged from 0.011 mg/l (below the drinking water limit) to 0.170 mg/l. The Microbac ICP-AES tests for total and dissolved lead concentrations in the wastewater passed through Filter Media 2 provided limit of test resolution results of <0.1 mg/l which were conformed with the CAER results.

At the Trigg Co. project, the cleaning operation was conducted at a single wash pressure of 3800 psi. The water used for the filtration tests was pumped into a 500 gallon holding tank. Two CAER tests for total lead concentrations in potable water gave values below the drinking water limit (003 mg/l and 0.005 mg/l). Several test runs were conducted on July 16 using the GTRI chemical filtration unit. For the morning test run, two CAER tests for the concentration of total lead in the unfiltered wastewater provided values of 20.8 mg/l and 23.2 mg/l. A Microbac test for total lead concentration in the unfiltered wastewater provided a value of 25.0 mg/l. CAER tests for concentration of total lead concentration in the sand filtered wastewater provided values of 0.60 mg/l and 1.04 mg/l. Microbac tests for concentration of dissolved lead in the sand filtered wastewater provided values of 1.1 mg/l (unfiltered) and 0.4 mg/l (sand filtered). Microbac tests of total suspended solids concentrations provided values of 637 mg/l (unfiltered). Sand filtering reduced the total suspended solids by about 30:1 down to 26 mg/l. Three CAER tests for total lead concentration in the filtered wastewater processed by Filter Media 1 were below the safe drinking water limit (all at 0.003 mg/l). CAER test values for total lead concentration in filtered wastewater processed by Filter Media 2 were also very consistent ranging from 0.017 mg/l to 0.20 mg/l.

For the afternoon test run, two CAER tests for the lead concentration in the unfiltered wastewater provided values of 26.7 mg/l and 23.0 mg/l. Those were in good agreement with the Microbac test value of 25.0 mg/l. The Microbac tests for dissolved lead test value of 1.2 mg/l (unfiltered) and 1.2 mg/l (sand filtered). The Microbac test of total lead concentration in the wastewater after sand filtering was 2.20 mg/l. This is in relatively close correlation with similar CAER test values of 1.85 and 2.08 mg/l. The Microbac test value for the concentration of total suspended solids was only 8.6 mg/l (unfiltered) and 7.0 mg/l (filtered). Tests for total lead of filtered wastewater (by CAER) processed by Filter Media 1 were all above the safe drinking water limit (0.050 mg/l, 0.052 mg/l and 0.063 mg/l). Test values for total lead of filtered wastewater (by CAER) processed by Filter Media 2 remained relatively unchanged from the morning tests ranging from 0.17 mg/l to 0.19 mg/l.

Related Test Results

Field tests and measurements were performed on the existing coatings on eight of the initial bridges. Those data are provided in Table 12. The coatings types represented included inorganic zinc/vinyl systems (low lead content), lead-pigmented alkyd systems (high lead content) and the basic lead silico-chromate/aluminum alkyd systems (intermediate lead content) that represent the coatings on a majority of KYTC steel bridges. The total coating thicknesses ranged from 2.0 mils to 6.0 mils. Tape adhesion tests provide a visual/descriptive 5-point scale for assessing coating adhesion, and in effect, coating brittleness. The bridges tested ran the gamut of potential values (1 to 5) with 1 indicating poor adhesion and 5 indicating good adhesion. Tensile adhesion tests also provide a measure of coating stability. The test values obtained for those bridges ranged from 100 psi (low adhesion) to 900 psi (very good adhesion).

Scatter diagrams were prepared for wastewater test values of total lead, dissolved lead, and total suspended solids in both the unfiltered and filtered states and were correlated with washing pressure (Figures 24-29). Total lead and dissolved lead tests of wastewater in the unfiltered and filtered states were also compared with coating thicknesses, tape adhesion, and tensile adhesion (Figures 30-35). No clear correlations were obtained for those single-parameter data comparisons.

During the tests, pH measurement were taken to provide data that might prove beneficial in developing new filtration methods or evaluating existing ones. The data was gathered for potable water, unfiltered wastewater and filtered wastewater on eight of the original ten bridges (Table 13). Multiple pH tests were conducted by both Microbac and KTC researchers on wastewater samples. The values for those tests of potable water ranged from 6.84 to 8.17 with an average of 7.70 (with an 8.60 value being measured on a sample from the Daviess Co. project by Microbac). The pH values of the unfiltered wastewater were slightly lower ranging from 6.10 to 8.54 with an average of 7.31. The pH values of the filtered wastewater were slightly lower than the unfiltered wastewater varying from 5.81 to 8.45 with an average of 7.18. It is interesting to note that Filter Media 2 of the GTRI chemical filter unit provided filtered wastewater with pH values that ranged from 9.07 to 9.20.

Wash water consumption rates were measured on four small single-bridge projects and a large twin-bridge Ohio River crossing (Table 14). The wash water consumption rate varied between 3.5 ft^2/gal and 7.5 ft^2/gal. The larger Ohio River project had a total water consumption rate of 12.0 ft^2/gal. That range of results correlates well with earlier data from the US 25 Clay Wade Bailey Bridge over the Ohio River at Covington (1999) wherein measurements provided wash water consumption rates between 1.2 ft^2/gal and 11.6 ft^2/gal. That variation is due to access, structure geometry, cleanliness and the disposition of the existing coating.

The scraping samples of the existing bridge coating were analyzed in September 2003 by the CAER. CAER was not provided with a proper coating key for the samples and the bridges from which the scrapings were taken could not be identified. The lead content in the paints tested ranged from 0.0003 percent by weight of the total coating in one sample (probably from an inorganic zinc/vinyl coating system) to a high of 6.44 percent by weight (probably from a lead-pigmented alkyd coating system).

Conclusions and Recommendations

The current KYTC filtration method using the 430 μ apparent opening size geotextile apparently is ineffective in removing fine particles of matter suspended in the wastewater. Its benefit in removing lead paint particles larger than 430 μ is believed greater than indicated by lead concentrations (unfiltered and filtered) taken during field sampling.

The testing conducted under this study provided considerable information of use to KYTC officials for planning future overcoating projects. Beyond extending the knowledge base, this work provided a potential low-cost/low-tech method for improving removal of heavy metals from wastewater by passing it through a sand filter. This should limit the lead content to below 1 mg/l. Chemical filtration using the phosphate material (Filter Media 1) has the potential of treating wastewater to meet safe drinking water standards allowing it to be readily discharged in any foreseeable situation.

The following recommendations are provided to further implement the findings of this study:

1) Conduct further monitoring of wastewater from future projects to identify the potential presence of other heavy metals (e.g. chromium, selenium and arsenic),

2) Investigate the use of sand filters as a low-cost method of supplementing or replacing the current KYTC filter media, and

3) Conduct further tests of chemical and other advanced filtration methods to assess their effectiveness and cost impacts.

INTRODUCTION

Bridge Maintenance Painting

The Kentucky Transportation Cabinet (KYTC) utilizes both total removal and overcoating methods for the maintenance painting of steel bridges (1, 2). Total removal provides more durable projects than overcoating, but is usually much more expensive from both the first cost and life cycle cost perspectives. Due to limited KYTC funds for bridge maintenance painting and a large backlog of structures needing it, the bulk of KYTC maintenance painting has been performed by overcoating.

Both methods of maintenance painting employ cleaning of the existing steel to provide substrates suitable for paint application. Total removal uses a dry cleaning method, abrasive blasting, on 100 percent of the exposed steel surface. It strips away all existing paint, detritus and mill scale and provides a uniformly abraded steel surface for subsequent painting. Overcoating entails two cleaning steps – pressure washing, a wet method and mechanical surface preparation, a dry method. Pressure washing is the preliminary overcoating cleaning step used on 100 percent of the exposed steel surface to remove weakly bonded paint and other detritus. Thereafter, mechanical surface preparation is employed as needed to feather edges of existing paint and to remove any exposed rust with hand or power tools (e.g. wire brushes, roto-peens and needle guns). Together, pressure washing and mechanical surface preparation provide a viable substrate for subsequent painting with surface tolerant coatings.

The existing paint on many KYTC bridges contains lead. Cleaning operations involving leaded paints generate undesirable lead-containing waste products in the form of dry particulate debris and dust (total removal) and wastewater (overcoating).

KYTC Filtering of Wastewater Generated During Bridge Cleaning Operations

On overcoating projects, KYTC usually specifies washing pressures in the range of 3,000 to 10,000 psi in conjunction with 0^{o} spinner tips (also called rotating columnar spray nozzles or "turbo-tips"). Potable (drinking quality) water is specified as the wash media to eliminate the possibility of contaminating washed surfaces with harmful materials contained in the wash water. On specific projects, KYTC may specify the use of low washing pressures and fan nozzles to limit lead paint contamination in the wastewater. The wash water impinges on the existing paint and exposed steel surfaces, removing weakly bonded materials which are carried off by the effluent (wastewater).

KYTC specifies the use of containment for both types of maintenance painting. The overcoating cleaning procedures are relatively non-invasive to the existing coatings compared to those used for total removal. Containment enclosures used for overcoating do not have to address the severe dust problems encountered in total removal due to the abrasive blasting process. Pressure washing does not produce much airborne dust – generally, suppressing it. The mechanical surface preparation commonly used, hand tool cleaning or power tool cleaning with vacuum shrouds, also limits airborne dust generation. As a consequence, containment enclosures used in overcoating are typically less elaborate.

KYTC typically requires the painting contractor to mechanically filter the wastewater to remove paint debris. The filtration specified is a non-woven geotextile with a 430 μ (10^{-6}m) apparent opening size. Typically, contractors design their overcoating containment with the geotextile laid over porous belly tarpaulins (typically 80 or 90 percent wind screens) of the containment. Effluent from the pressure washing operation drains down from the steel onto the textile filter/tarpaulin. It is gravity fed through the filtering materials and is subsequently released into the environment – the receiving waters, the ground, or, in a few cases, sanitary sewers. This filtering step is able to separate large paint chips and other large solid debris from the waste water. However, it is anticipated that particles significantly smaller than the apparent opening size would not be effectively filtered by the geotextile

The paint particle size that is trapped on the geotextile filter is dependent on the apparent pore size and condition of the filter and the processes used to wash the bridge. If pressure washers are directed to a filter that has trapped solids, some of the solids will be forced through the filter. This practice is not permitted by KYTC special notes. Daily cleaning of the filter by vacuuming reduces the amount of paint solids that are released to receiving waters.

Study Background

For several years, KYTC Project Design Team officials have discussed the need to obtain better data on the composition of wastewater; both unfiltered and filtered, to assess the amounts and dispositions of particulate (sedimentary and suspended) and dissolved wastes contained therein that were generated by pressure washing. Mechanical filtration was observed to be effective in trapping large particles of paint preventing their release into the environment. In research to investigate water jetting (at 10-20,000 psi washing pressure); KYTC officials found that the mechanical filtration routinely employed would not entirely eliminate lead in wastewater though the experimental washing tests probably generated an unusual amount of fine lead-paint particles (3).

KYTC officials wished to use that data to guide in the development of cost-effective means of further limiting or eliminating lead and other heavy metal constituents from overcoating wastewater.

The KYTC Project Design Team proposed this study to investigate: 1) the concentration of lead in wastewater from typical KYTC overcoating projects, 2) the impact of pressure washing process variables in lead generation, 3) the efficacy of the current KYTC mechanical filtration method, and 4) potential enhancements that could be made to the current filtration process that would not significantly impact overcoating costs.

Wastewater generated on typical KYTC overcoating projects (filtered and unfiltered) was to be analyzed to determine the level of heavy metal elimination from effluents provided by the current KYTC filtration method. This data was to serve as a baseline for evaluating other treatment options. Analysis was also to characterize the unfiltered and filtered wastewater in regards to dissolved lead, metallic lead, total solids and pH. Those findings were to serve as a guide for subsequent research on wastewater treatment.

Objectives of This Study

KYTC contracted with KTC to perform this study under KYSPR 02-224, *Environmental Impacts of Bridge Cleaning Operations.* The intent of this study was to focus on pressure washing effluent or wastewater. Study objectives included:

- Review of literature pertinent to existing technologies for the filtration and chemical treatment of heavy metals in water,
- Analysis of lead concentrations generated by current pressure washing/treatment practices and characterization of the existing paint to determine its potential for release of lead into the wastewater,
- Testing of advanced water treatment techniques/systems to determine the amount of lead reduction achieved,
- Evaluation of the costs for advanced filtration systems and development of specifications for field evaluation on experimental overcoating projects. Monitoring of those projects and evaluation of the effectiveness of the filtration systems in treating the waste water for lead.

Options for the advanced filtration system proposed for evaluation under this study included: 1) mechanical filtration using sequential filters of increasingly finer opening sizes, 2) chemical filtration using a column filled with a dry chemical that reacts with lead in the wastewater and binds it in unleachable compounds, and 3) a combination of mechanical and chemical filtration.

In support of this study, officials from the KYTC Project Design Team officials let 12 bridge overcoating projects in 2001-2002 incorporating a variety of specified washing pressures and nozzle types (0^o spinner and 30^o fan). KTC researchers focused on conducting the necessary field testing, providing field samples of potable water & effluent to test laboratories for analysis, and obtaining & reviewing the resulting data. They did not contact many sources of potentially viable treatment equipment in time for incorporation into experimental overcoating projects under this study. The study objectives were modified to identifying sources of those technologies with the intent of conducting field trials to evaluate them on experimental overcoating projects in a follow-on research study.

One advanced filtration system was field evaluated. At the onset of this study, KTC researchers were cooperating with Georgia Tech Research Institute (GTRI) researchers to develop a chemical filtration system for treating overcoating effluents. That work was funded under a Transportation Research Board (TRB) Innovations Deserving Exploratory Analysis (IDEA) Program grant. GTRI researchers conducted laboratory work in early 2002 using artificial wastewater with significant total and dissolved lead contents. The chemical filtration method produced promising laboratory results and GTRI committed to develop a corresponding field chemical filtering unit to assess this method on experimental KYTC overcoating projects as part of this study and the TRB grant. The unit was tested for filtering wastewater from several KYTC overcoating projects.

PRELIMINARY INFORMATION GATHERING

Literature Search

A literature search was conducted on issues related to wastewater from bridge washing operations, wastewater treatment to remove heavy metals and regulations impacting the disposal of wastewater using the NTIS and TRIS databases. Over 12,000 titles were reviewed and only 25 were found relevant to this study. Those are summarized in Appendix 1. KTC researchers contacted other state highway agencies and coatings consultants to identify any information they might possess related to the content of heavy metals in wastewater from past bridge washing operations. Data was obtained from Caltrans and KYTC and are discussed below. KTC researchers also contacted several firms/agencies manufacturing water filtration devices to assess the suitability of their technologies. Those technologies are described in Appendix 2.

Past Use of Lead-Based Coatings on Bridges

Up until the 1980s, lead was a major constituent in coatings (primarily long-oil and alkyd paints) used in painting steel structures. Nationwide, about 80 percent of all U.S. bridges have existing paint that contains lead or other heavy metals (4). Review of past Kentucky Transportation Cabinet specifications revealed the use of several types of lead-based coatings in the past that comprised those existing on KYTC bridges (5, 6). Long-oil coatings were used through the early 1970s with their gradual replacement by the Federal Type 615D basic lead silico-chromate alkyd primer and aluminum-pigmented cover coats used through the mid-1980s. Thereafter, Kentucky bridge painting employed open abrasive blasting and the use of what were termed "high-performance" coatings (e.g. inorganic zinc/vynils and epoxies). In those coatings, the use of lead was eliminated or significantly reduced serving only as a color stabilizer.

The long oil lead-based coatings systems specified up through the 1970s contained lead in both the primer and topcoat paints. Typically, KYTC employed three-coat systems for new projects and two-coat systems for maintenance painting (by overcoating). This early form of overcoating typically involved adding a spot or full coat of red lead primer and a full coat of lead-pigmented topcoat. Some bridges with multiple overcoats had/have upwards of 30 mils of existing paint. The weight of lead (in oxide form) in those bridge coatings has been estimated to meet or exceed 0.20 lb/ft^2. The lead-alkyd system used by KYTC in later years had a greatly reduced lead content in the range of about 0.05 lb/ft^2 unless repaired by overcoating. In some cases, bridges that were to have been abrasive blasted during maintenance painting operations in the 1980s have contained significant amount of existing lead primers indicating that they were improperly maintenance painted.

FIELD SAMPLING AND TESTING

Potable and wastewater samples were collected from washing operations on twelve KYTC bridges overcoated during 2002 paint season. They were subsequently analyzed for the presence of lead. Typical washing pressures varied from 2500 to 10000 psi. The first nine bridges sampled were: 1) KY 551 over Green River Lake in Adair Co., 2) KY 7 over Grayson Lake Spillway in Carter Co. (Bridge 18), 3) KY 7 over Grayson Lake (Clifty Creek) in Carter Co. (Bridge 19), 4) US 62 over Cumberland River in Livingston Co., 5) KY 30 over Middle Fork of the Kentucky River in Breathitt Co., 6) I 275 Twin Bridges over Ohio River at Brent in Campbell Co., 7) KY 80 over

Cumberland Lake in Pulaski Co., 8) KY 519 over North Craney Creek in Rowan Co., 9) KY 9002 over Chaplin River (Bluegrass Parkway) in Nelson Co., and 10) KY 9002 over Chaplin River (Bluegrass Parkway) in Washington Co. (Figures 1-10).

A chemical filtration system built in cooperation between the Kentucky Transportation Cabinet, the Kentucky Transportation Center and Georgia Tech. Research Institute was used to process wastewater from 11) KY 139 over Little River in Trigg Co. and 12) US 60 over CSX Railroad in Daviess Co (Figures 11 and 12).

KTC researchers typically took samples of potable water, unfiltered wastewater and filtered waste water (Figures 13-16). However, sometimes it was collected by KYTC inspectors. The samples of effluent were collected from: 1) freshly generated wastewater falling from wash sites, 2) ponding pools of wastewater formed in solid tarpaulins draped under the structures or 3) in wastewater storage tanks. The storage tanks were used either for decanted, measured release of wastewater into receiving waters or for processing by the experimental GTRI filtration device. KTC researchers tried to get the samples to Microbac Laboratories, Inc. the same day they were taken, but normally with no more than a 24-hour delay. Field wastewater samples were placed in containers provided by Microbac Laboratories, Inc. of Louisville, Kentucky. One liter containers were used for samples to be tested for total suspended solids concentrations and pH, and 250 ml containers partially filled with a nitric acid solution were used for tests of total and dissolved lead concentrations. The latter samples needed storage in ice coolers between sampling and delivery to the Microbac Laboratory.

KTC researchers also took measurements of coating thickness (Tooke readings per ASTM 4138), coating tensile adhesion (per ASTM 2370) and tape adhesion (per ASTM 3359) on existing coatings from eight of the experimental bridges. They also took coating samples of the existing paint by taking 2-inch by 2-inch scrapings to be analyzed for lead content (Figure 17).

DATA ANALYSES

Laboratory Sample Testing

Most of the potable and wastewater samples were analyzed at Microbac Laboratories. However, some sampling of wastewater from the projects employing chemical filtration tests was performed by the University of Kentucky Center for Applied Energy Research (CAER) in Lexington. The wastewater was analyzed to determine the presence of total lead (EPA Test Method 200.7), dissolved lead (EPA Test Method 200.7) and total suspended solids (EPA Test Method 160.2) and pH (EPA Test Method 150.1). Microbac reported its total suspended solids, total lead and dissolved lead concentrations at a resolution of 0.1 mg/l or 100 ppb. Microbac used inductively coupled plasma atomic emission spectrometry testing (IPC-AES) which was capable of providing test accuracy at about 0.01 mg/l according to Microbac scientists. For the chemical filtration test work, a higher level of accuracy was required and that was provided by CAER using inductively coupled plasma mass spectrometry testing (IPC-MS) that provided a resolution for lead down to 0.001 mg/l or 1 ppb. The paint scrapings were also analyzed for lead by the CAER using inductively coupled plasma atomic emission testing.

General Test Results

Most samples of potable water used for pressure washing the bridges had total (and dissolved) lead contents below the Microbac level of test reporting set at 0.1 mg/l or 100 ppb (Tables 1 and 2). That level of accuracy was too coarse to detect lead levels at the limits mandated by the Safe Drinking Water Act and its amendments (currently .015 mg/l or 15 ppb). Three outliers were detected in discrete samples for the Livingston Co., Campbell Co., and Rowan Co. projects giving total lead values of 0.4 mg/l, 0.2 mg/l and 0.3 mg/l respectively. Successive tests on the Livingston Co. and Campbell Co. projects did not show similar high values and those may be attributable to "first flush" samples, inadvertent contamination of the samples, or erroneous test results. The tests for dissolved lead in potable water produced values below the limit of resolution of the tests for the Campbell Co. and Rowan Co. samples and a repeat value of 0.4 mg/l for the Livingston Co. sample. The Livingston Co. potable water was obtained from a rural fire hydrant located several hundred yards from the bridge and piped down to it. More accurate testing was conducted on potable water samples from the Daviess Co. and the Trigg Co. projects. The GTRI chemical filter unit was employed on those projects and higher limits of test resolution were sought (down to 0.001 mg/l). The potable water lead concentration results (both total and dissolved) from those projects obtained by CAER using IPC-MS ranged from 0.002 to 0.004 mg/l (Tables 10 and 11). Those values are well below maximum lead concentrations mandated for drinking water. The suspended solids in the potable water were very low with all samples being below 10 mg/l (Tables 3, 10 and 11).

The test results for total lead in the unfiltered wastewater varied from 2.3 to 130 mg/l (ppm) over on all the projects (Table 4, 10 and 11). The highest values (110 and 130 mg/l) were obtained on the Breathitt Co. and Washington Co. projects respectively. The dissolved lead in the unfiltered water varied from below the limit of test resolution (i.e. <0.1 mg/l) on four projects to 5.5 mg/l for Livingston Co. The total suspended solids varied from 79 mg/l to 8930 mg/l for samples from the Breathitt Co. and Carter Co. (Bridge 18). The three unfiltered wastewater samples from Breathitt Co. varied in total suspended solids from 79 mg/l to 1250 mg/l. The amounts of total lead in the unfiltered wastewater did not correlate with the amounts of dissolved lead for all the samples taken. Also, the amount of total lead did not correlate with the amount of suspended solids for all the samples taken. The relative frequencies of the test values for the unfiltered wastewater are provided in Figures 18-20.

The test results for total lead in the conventionally filtered wastewater (using the KYTC specified 430 micron geotextile) varied from 2 mg/l to 220 mg/l (ppm) over on all the projects (Table 7). The highest values were obtained on the Washington Co. (100 mg/l) and Breathitt Co. (170 and 220 mg/l) projects. The dissolved lead in the filtered water varied from below the limit of test resolution (i.e. <0.1 mg/l) to 4.1 mg/l for Breathitt Co. The total suspended solids were reduced somewhat by filtering (from an average of 1,679 mg/l in unfiltered to 1,325 mg/l in filtered). They varied from 86 mg/l to 3620 mg/l for samples from the Breathitt Co. and Carter Co. (Bridge 18). The three filtered wastewater samples from Breathitt Co. varied in total suspended solids from 86mg/l to 952 mg/l. The relative frequencies of the test values for the unfiltered wastewater are provided in Figures 21-23.

For individual samples, the concentrations of total lead in the filtered wastewater did not correlate with the concentrations of dissolved lead for all the samples taken. Also, the concentrations of total lead in the filtered wastewater did not correlate with the amount of total suspended solids for all the samples taken. The total lead concentrations in the unfiltered wastewater did correlate with those in the filtered wastewater (the highest filtered tests being greater than the unfiltered tests). The dissolved lead concentrations in the filtered wastewater were slightly lower than those in the unfiltered wastewater. However, the test values did not correlate well between the two wastewater states (i.e. unfiltered and filtered).

The variation in lead concentrations between the unfiltered and filtered states indicates that the difference was probably due to the disposition of solids in the wastewater during or prior to sampling. In some cases the wastewater was taken from pools of wastewater where it ponded in impermeable tarpaulins or had been temporarily stored in tanks for timed release. In those cases, the wastewater may have dwelled for sufficient time to allow some suspended solids to agglomerate and settle out. Also, heavy particles of paint debris rapidly sank to the bottom of collection buckets prior to sampling and could not be consistently agitated back into suspension. As a consequence, the wastewater samples, taken by dipping a ladle into the ponded wastewater or storage tank, would have not been representative of freshly generated wastewater.

Tests of the GTRI Chemical Filter Unit

Tests of the GTRI chemical filtration unit were conducted at the Daviess Co. project from June 26-July 8, 2002 and at the Trigg Co. project on July 16, 2002. During that time the chemical filtration unit was used to filter a total of about 3,000 gallons of wastewater generated on the two projects. The test data for those projects is provided in Tables 10 and 11.

Tests of the GTRI chemical filtration device were conducted over a range of high washing pressures for the Daviess Co. project (7000 to 9000 psi using 0^o spinner tips). The test resolution for most samples was improved in anticipation of the low lead concentrations in the filtered wastewater. The potable water lead values were tested by both CAER and Microbac. Two CAER ICP-MS tests provided identical potable water lead concentration values of 0.002 mg/l. Tests of total lead concentration in the unfiltered wastewater generated at 7000 psi washing pressure were in the range of 9-10 mg/l. Tests of total lead concentration in the unfiltered wastewater generated at 9000 psi washing pressure were in the range of 9-62 mg/l. Tests of dissolved lead concentration in the unfiltered wastewater provided values ranging from 2.0 mg/l to 2.3 mg/l for Microbac tests of both 7000 psi and 9000 psi generated wastewater. Wastewater samples were taken after pre-filtering using a sand filter bed. Tests on those samples generated at 7000 psi and 9000 psi produced total lead concentration values of 0.5 mg/l and 0.4 mg/l respectively. The sand filter provided a reduction in total lead concentrations of 20:1 for the 7000 psi wastewater and about 150:1 for the 9000 psi wastewater.

The total suspended solids concentration in the potable water for this project was <5 mg/l. After pressure washing at 7000 psi and 9000 psi, the total suspended solids concentrations increased to 43 mg/l and 603 mg/l respectively. Tests of wastewater passed through the sand filter had total suspended solids concentrations of 65 mg/l and 14 mg/l respectively. The initial high value of total suspended solids for the 7000 psi test may have been the result of wastewater from the initial test washing the sand in the filter for the first use. Thereafter, for the 9000 psi test at Daviess Co. and the tests at Trigg Co., the total suspended solids concentration values were reduced below levels obtained in the unfiltered wastewater.

The GTRI device pumped the wastewater from the sand filter through one of two chemical filter columns. One filter material was a proprietary chemical material, a phosphate (Filter Media 1) and the second was a commercial grade of xeolite, an aluminum silicate (Filter Media 2). Both media had been able to extract lead from aqueous solutions in laboratory tests conducted by GRTI researchers. Wastewater samples were taken from the outlet of each filter column.

Tests for total lead concentrations in filtered wastewater performed by CAER using ICP-MS from Filter Media 1 were all below the drinking water regulatory limit ranging from 0.003 mg/l to 0.005 mg/l. The Microbac ICP-AES tests for total and dissolved lead concentrations in wastewater passed through Filter Media 1 provided limit of test resolution results of <0.1 mg/l which were in conformance with the CAER results. Tests for total lead concentrations in filtered wastewater performed by CAER using ICP-MS from Filter Media 2 ranged from 0.011 mg/l (below the drinking water limit) to 0.170 mg/l. The Microbac ICP-AES tests for total and dissolved lead concentrations in the wastewater passed through Filter Media 2 provided limit of test resolution results of <0.1 mg/l which were conformed with the CAER results. The chemical filtration results did not appear to depend upon the washing pressure employed for either filter media. Approximately 2,000 gallons of water was filtered during the Daviess Co. project.

At the Trigg Co. project, the cleaning operation was conducted at a single wash pressure of 3800 psi. The contractor was washing bridge beams on a side span. He had placed impermeable tarps on the berm under the beams to catch the wastewater. At the foot of the berm, he formed the tarps into a collection pond and routed the wastewater out of the pond with a sump pump. The water used for the filtration tests was pumped into a 500 gallon holding tank. When the filtration tests were not being run, contractor pumped the wastewater into the Little River. Two CAER ICP-MS tests for total lead concentrations in potable water gave values below the drinking water limit (003 mg/l and 0.005 mg/l). For this series of tests dissolved lead and total suspended solids tests were not performed for the potable water. .

Several test runs were conducted on July 16 using the GTRI chemical filtration unit. An initial test run was performed on the morning, after the contractor's washing operation had filled a 500 gallon capacity holding tank with wastewater. The wastewater was pumped into the filtration unit and held in a surge tank. Pumps on the filtration unit routed the wastewater through a trickling sand filter for initial treatment and thereafter the flow was split into the two filter media columns for final filtering and final disposal routing into the Little River. Samples were taken from the unfiltered wastewater coming in to the unit, wastewater after preliminary filtration and wastewater after final filtration by one of the filter media. It took little more than an hour to filter all of the water in the holding tank. An afternoon test run was performed after the contractor's washing operation were resumed re-filled the holding tank. The filtration operation was used again to treat all of the water in the holding tank. During both the morning and afternoon test runs, wastewater sampling was not initiated until about one-half of the holding tank contents had been filtered.

For the morning test run, two CAER ICP-MS tests for the concentration of total lead in the unfiltered wastewater provided values of 20.8 mg/l and 23.2 mg/l. A Microbac ICP-AES test for total lead concentration in the unfiltered wastewater provided a value of 25.0 mg/l. CAER tests for concentration of total lead concentration in the sand filtered wastewater provided values of 0.60 mg/l and 1.04 mg/l. Microbac tests for concentration of dissolved lead in the sand filtered wastewater provided values of 1.1 mg/l (unfiltered) and 0.4 mg/l (sand filtered). Microbac tests of total suspended solids concentrations provided values of 637 mg/l (unfiltered). Sand filtering reduced the total suspended solids by about 30:1 down to 26 mg/l. Three CAER ICP-MS tests for total lead concentration in the filtered wastewater processed by Filter Media 1 were below the safe drinking water limit (all at 0.003 mg/l). CAER test values for total lead concentration in filtered wastewater processed by Filter Media 2 were also very consistent ranging from 0.017 mg/l to 0.20 mg/l.

For the afternoon test run, two CAER tests for the lead concentration in the unfiltered wastewater provided values of 26.7 mg/l and 23.0 mg/l. Those were in good agreement with the Microbac test value of 25.0 mg/l. The Microbac tests for dissolved lead test value of 1.2 mg/l (unfiltered) and 1.2 mg/l (sand filtered). The Microbac test of total lead concentration in the wastewater after sand filtering was 2.20 mg/l. This is in relatively close correlation with similar CAER test values of 1.85 and 2.08 mg/l. The Microbac test value for the concentration of total suspended solids was only 8.6 mg/l (unfiltered) and 7.0 mg/l (filtered). Tests for total lead of filtered wastewater (by CAER) processed by Filter Media 1 were all above the safe drinking water limit (0.050 mg/l, 0.052 mg/l and 0.063 mg/l). Test values for total lead of filtered wastewater (by CAER) processed by Filter Media 2 remained relatively unchanged from the morning tests ranging from 0.17 mg/l to 0.19 mg/l.

Related Tests

Field tests and measurements were performed on the existing coatings on eight of the initial bridges. Those data are provided in Table 12. The coatings types represented included inorganic zinc/vinyl systems (low lead content), lead-pigmented alkyd systems (high lead content) and the basic lead silico-chromate/aluminum alkyd systems (intermediate lead content) that represent the coatings on a majority of KYTC steel bridges. For the most part, the systems were not excessively built-up by previous overcoating. The total coating thicknesses ranged from 2.0 mils to 6.0 mils. Tape adhesion tests provide a visual/descriptive 5-point scale for assessing coating adhesion, and in effect, coating brittleness. The bridges tested ran the gamut of potential values (1 to 5) with 1 indicating poor adhesion and 5 indicating good adhesion. Tensile adhesion tests also provide a measure of coating stability. The test values obtained for those bridges ranged from 100 psi (low adhesion) to 900 psi (very good adhesion). These bridges provided a good variety of various conditions to obtain correlations between coatings types and properties that could impact the lead content in wastewater and allow KYTC officials to anticipate when high lead levels could be expected from cleaning operations. Scatter diagrams were prepared for wastewater test values of total lead, dissolved lead, and total suspended solids in both the unfiltered and filtered states and were correlated with washing pressure (Figures 24-29). Total lead and dissolved lead tests of wastewater in the unfiltered and filtered states were also compared with coating thicknesses, tape adhesion, and tensile adhesion (Figures 30-35). No clear correlations were obtained for those single-parameter data comparisons.

During the tests, pH measurement were taken to provide data that might prove beneficial in developing new filtration methods or evaluating existing ones. The data was gathered for potable water, unfiltered wastewater and filtered wastewater on eight of the original ten bridges (Table 13). Multiple pH tests were conducted by both Microbac and KTC researchers on wastewater samples. The values for those tests of potable water ranged from 6.84 to 8.17 with an average of 7.70 (with an 8.60 value being measured on a sample from the Daviess Co. project by Microbac). The pH values of the unfiltered wastewater were slightly lower ranging from 6.10 to 8.54 with an average of 7.31. The pH values of the filtered wastewater were slightly lower than the unfiltered wastewater varying from 5.81 to 8.45 with an average of 7.18. It is interesting to note that Filter Media 2 of the GTRI chemical filter unit provided filtered wastewater with pH values that ranged from 9.07 to 9.20.

Wash water consumption rates were measured on four small single-bridge projects and a large twin-bridge Ohio River crossing (Table 14). The wash water consumption rate varied from 3.5 ft^2/gal to 7.5 ft^2/gal. The larger Ohio River project had a total water consumption rate of 12.0 ft^2/gal. That range of results correlates well with earlier data from the US 25 Clay Wade Bailey Bridge over the Ohio River at Covington (1999) wherein measurements provided wash water consumption rates from 1.2 ft^2/gal to 11.6 ft^2/gal. That variation is due to access, structure geometry, cleanliness and the disposition of the existing coating.

The scraping samples of the existing bridge coating were analyzed in September 2003 by the CAER. CAER was not provided with a proper coating key for the samples and the bridges from which the scrapings were taken could not be identified. The lead content in the paints tested ranged from 0.0003 percent by weight of the total coating in one sample (probably from an inorganic zinc/vinyl coating system) to a high of 6.44 percent by weight (probably from a lead-pigmented alkyd coating system).

CONCLUSIONS

The current KYTC filtration method using the 430 µ apparent opening size geotextile apparently is ineffective in removing fine particles of matter suspended in the wastewater. Its benefit in removing lead paint particles larger than 430 µ is believed greater than indicated by lead concentrations (unfiltered and filtered) taken during field sampling. As previously noted, it was difficult to obtain representative samples of wastewater. The filtered sample tests did reveal what the current KYTC filtration could be expected to achieve in terms of lead concentrations in wastewater discharged into the environment.

The testing conducted under this study provided considerable information of use to KYTC officials for planning future overcoating projects. Beyond extending the knowledge base, this work provided a potential low-cost/low-tech method for improving removal of heavy metals from wastewater by passing it through a sand filter. This should limit the lead content to below 1 mg/l. Chemical filtration using the phosphate material (Filter Media 1) has the potential of treating wastewater to meet safe drinking water standards allowing it to be readily discharged in any foreseeable situation. Additional work needs to be done to evaluate the efficacy of that approach. Other potential filtration systems listed in Appendix 2 also warrant evaluation. Those methods appear to be more cost effective than collection and disposal by TSD facilities.

RECOMMENDATIONS

The following recommendations are provided to further implement the findings of this study:

4) Conduct further monitoring of wastewater from future projects to identify the potential presence of other heavy metals (e.g. chromium, selenium and arsenic),

5) Investigate the use of sand filters as a low-cost method of supplementing or replacing the current KYTC filter media, and

6) Conduct further tests of chemical and other advanced filtration methods to assess their effectiveness and cost impacts.

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Table 1. Total Lead in Potable Water

Project	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	< 0.1	< 0.1			2500	0^o Spinner
Carter18	< 0.1	< 0.1	< 0.1		2600	30^o Fan
Carter19	< 0.1	< 0.1	< 0.1		2700	30^o Fan
Livingston	0.4	< 0.1	< 0.1	< 0.1	7500	0^o Spinner
Breathitt	< 0.1	< 0.1	< 0.1		4500	0^o Spinner
Campbell	< 0.1	0.2	< 0.1		5000	0^o Spinner
Pulaski	< 0.1				10000	0^o Spinner
Rowan	0.3				4600	0^o Spinner
Nelson	< 0.1	< 0.1	< 0.1		3500	30^o Fan
Washington	< 0.1	< 0.1	< 0.1		3600	30^o Fan

Table 2. Dissolved Lead in Potable Water

Project	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	< 0.1	< 0.1			2500	0^o Spinner
Carter18	< 0.1	< 0.1	< 0.1		2600	30^o Fan
Carter19	< 0.1	< 0.1	< 0.1		2700	30^o Fan
Livingston	0.4	< 0.1	< 0.1	< 0.1	7500	0^o Spinner
Breathitt	< 0.1	< 0.1	< 0.1		4500	0^o Spinner
Campbell	< 0.1	< 0.1	< 0.1		5000	0^o Spinner
Pulaski	< 0.1				10000	0^o Spinner
Rowan	< 0.1				4600	0^o Spinner
Nelson	< 0.1	< 0.1	< 0.1		3500	30^o Fan
Washington	< 0.1	< 0.1	< 0.1		3600	30^o Fan

Table 3. Suspended Solids in Potable Water						
Project	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	3	3			2500	0^o Spinner
Carter18	5	5	3		2600	30^o Fan
Carter19	3	3	3		2700	30^o Fan
Livingston		8.2	3	3	7500	0^o Spinner
Breathitt	4	3	3		4500	0^o Spinner
Campbell	7	7	3		5000	0^o Spinner
Pulaski	7				10000	0^o Spinner
Rowan	5				4600	0^o Spinner
Nelson	3	3	3		3500	30^o Fan
Washington	3	3	3		3600	30^o Fan

Table 4. Total Lead in Unfiltered Wastewater						
	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	8.7	3.4	6.8		2500	0^o Spinner
Carter18	52.0	19.0	18.0		2600	30^o Fan
Carter19	21.0	25.0	33.0		2700	30^o Fan
Livingston	8.5	35.0	19.0	22.0	7500	0^o Spinner
Breathitt	9.8	130.0			4500	0^o Spinner
Campbell	4.4	2.3	13.0		5000	0^o Spinner
Pulaski	33.0				10000	0^o Spinner
Rowan	3.9				4600	0^o Spinner
Nelson	18.0	6.4	12.0		3500	30^o Fan
Washington	78.0	70.0	110.0		3600	30^o Fan

Table 5. Dissolved Lead in Unfiltered Wastewater						
	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	0.4	0.8	0.9		2500	0^o Spinner
Carter18	0.5	0.5	1.4		2600	30^o Fan
Carter19	2.1	1.1	0.7		2700	30^o Fan
Livingston	5.5		<0.1	0.2	7500	0^o Spinner
Breathitt	1.5	2.8	3.5		4500	0^o Spinner
Campbell	<0.1	0.2	<0.1		5000	0^o Spinner
Pulaski	<0.1				10000	0^o Spinner
Rowan	<0.1				4600	0^o Spinner
Nelson	<0.1	<0.1	0.2		3500	30^o Fan
Washington	0.2	0.5	1.1		3600	30^o Fan

Table 6. Suspended Solids in Unfiltered Wastewater						
	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	2090	95	285		2500	0^o Spinner
Carter18	8930	1740	523		2600	30^o Fan
Carter19	596	1450	1570		2700	30^o Fan
Livingston	256		1150	1990	7500	0^o Spinner
Breathitt	79	650	1250		4500	0^o Spinner
Campbell	1750	213	5460		5000	0^o Spinner
Pulaski	2390				10000	0^o Spinner
Rowan	645				4600	0^o Spinner
Nelson	1380	2850	506		3500	30^o Fan
Washington	2940	1730	1110		3600	30^o Fan

Table 7. Total Lead in Filtered Wastewater						
Project	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	15	3	5		2500	0^o Spinner
Carter18	15	16	15		2600	30^o Fan
Carter19	19	21	30		2700	30^o Fan
Livingston	7	28	14	19	7500	0^o Spinner
Breathitt	10	170	220		4500	0^o Spinner
Campbell	3	2	12		5000	0^o Spinner
Pulaski	33				10000	0^o Spinner
Rowan	4				4600	0^o Spinner
Nelson	18	29	12		3500	30^o Fan
Washington	69	78	100		3600	30^o Fan

Table 8. Dissolved Lead in Filtered Wastewater						
Project	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	0.4	0.9	0.9		2500	0^o Spinner
Carter18	0.5	0.5	1.3		2600	30^o Fan
Carter19	1.9	1.1	0.6		2700	30^o Fan
Livingston	0.6	1.8	0.2	0.2	7500	0^o Spinner
Breathitt	1.6	3.2	4.1		4500	0^o Spinner
Campbell	<0.1	0.5	<0.1		5000	0^o Spinner
Pulaski	<0.1				10000	0^o Spinner
Rowan	<0.1				4600	0^o Spinner
Nelson	<0.1	<0.1	0.2		3500	30^o Fan
Washington	0.2	0.5	1.1		3600	30^o Fan

Table 9. Suspended Solids in Filtered Wastewater

Project	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Pressure (psi)	Tip
Adair	1860	56	282		2500	0^o Spinner
Carter18	3620	2600	298		2600	30^o Fan
Carter19	462	1350	1440		2700	30^o Fan
Livingston	213	3016	1070	1160	7500	0^o Spinner
Breathitt	66	601	952		4500	0^o Spinner
Campbell	1060	190	3500		5000	0^o Spinner
Pulaski	2340				10000	0^o Spinner
Rowan	641				4600	0^o Spinner
Nelson	971	2060	541		3500	30^o Fan
Washington	2800	1610	1010		3600	30^o Fan

Table 10. Test results from the GTRI chemical filtration unit (US 60 Bridge over CSX Railroad in Daviess County)

Sample ID	Pressure	Potable Water (P)	Unfiltered (UF)	Sandfiltered (SF)	Filter Media 1 (FM1)	Filter Media 2 (FM2)	Total Suspended Solids	Dissolved Lead	pH
Daviess Co.	Psi	Total Lead mg/l					mg/l		
1 /CAER	7000	0.002	9.43		0.003	0.170			
2 /CAER	7000				0.004	0.011			
3 /CAER	7000				0.004	0.013			
1 /Microbac	(P) 7000	< 0.100					< 5	< 0.1	8.60
2 /Microbac	(UF) 7000		10.00				43	2.0	7.02
2 /Microbac	(SF) 7000			0.5			65	< 0.1	7.47
2 /Microbac	(FM1) 7000				< 0.100		59	< 0.1	7.64
2 /Microbac	(FM2) 7000					< 0.100	554	< 0.1	9.20
3 /Microbac	(UF) 7000		9.90				46	2.1	6.98
3 /Microbac	(FM1) 7000				< 0.100		44	< 0.1	7.63
3 /Microbac	(FM2) 7000					< 0.100	617	< 0.1	9.17
1 /CAER	9000	0.002	9.48		0.005	0.060			
2 /CAER	9000		29.50		0.003	0.014			
3 /CAER	9000		24.30		0.003	0.014			
2 /Microbac	(UF) 9000		62.00				603	2.0	6.91
2 /Microbac	(SF) 9000			0.4			14	0.2	7.09
2 /Microbac	(FM1) 9000				< 0.100		6	< 0.1	7.13
2 /Microbac	(FM2) 9000					< 0.100	378	< 0.1	9.07
3 /Microbac	(UF) 9000		62.00				576	2.3	6.82
3 /Microbac	(FM1) 9000				< 0.100		6	< 0.1	7.27
3 /Microbac	(FM2) 9000					< 0.100	528	< 0.1	9.07

Table 11. Test results from the GTRI chemical filtration unit (KY 139 over the Little River in Trigg County)

Sample ID	Pressure	Potable Water (P)	Unfiltered (UF)	Sandfiltered (SF)	Filter Media 1 (FM1)	Filer Media 2 (FM2)	Total Suspended Solids	Dissolved Lead	pH
Trigg Co.	Psi	Total Lead in mg/l					mg/l		
AM - 1 /CAER	3800	0.004			0.003	0.17			
AM - 2 /CAER	3800	0.003	20.8	0.60	0.003	0.18			
AM - 3 /CAER	3800		23.2	1.04	0.003	0.20			
PM - 1 /CAER	3800				0.063	0.17			
PM - 2 /CAER	3800		26.7	1.85	0.052	0.16			
PM - 3 /CAER	3800		23.0	2.08	0.050	0.19			
AM - 1 /Microbac	(UF) 3800		25.0				637.0	1.1	7.69
AM - 1 /Microbac	(SF) 3800			1.20			26.0	0.4	7.73
PM - 1 /Microbac	(UF) 3800		25.0				8.6	1.2	7.74
PM - 1 /Microbac	(SF) 3800			2.20			7.0	0.9	7.85

Table 12. Coating thickness, tape adhesion and tensile adhesion readings for existing coatings on test bridges.

Bridge Description	Paint Type/ Coating Thickness (mils)	Tape Adhesion (Method A)	Tensile Adhesion (psi)
1.) KY 551 over Green River Lake in Adair Co.	Aluminum Alkyd Top Coat (1.0) 615D Red Lead Primer (2.5)	2	250 450
	Aluminum Alkyd Top Coat (2.5) 615D Red Lead Primer (2.5)	1	300 350
2.) KY 7 over Grayson Lake Spillway in Carter Co. (Bridge 18)	Pigmented Alkyd Top Coat (1.0) Red Lead Primer (2.5)	5	100 150
3.) KY 7 over Grayson Lake (Clifty Creek) in Carter Co. (Bridge 19)	Pigmented Alkyd Top Coat (1.0) Red Lead Primer (2.0)	1	100 300
4.) US 62 over Cumberland River in Livingston Co.	Pigmented Alkyd Top Coat (1.0) Red Lead Primer (5.0)	3	200 200
5.) KY 30 over Middle Fork Kentucky River in Breathitt Co.	Pigmented Alkyd Top Coat (1.0) Red Lead Primer (5.0)	1	100 200
	Pigmented Alkyd Top Coat (1.0) Red Lead Primer (1.0)	4	900 900
6.) I 275 Twin Bridges over Ohio River at Brent in Campbell Co.	Pigmented Alkyd Top Coat (1.5) Red Lead Primer (2.5)	3	100 150
	Pigmented Alkyd Top Coat (1.0) Red Lead Primer (2.5)	4	700 900
7.) KY 80 over Cumberland Lake in Pulaski Co.	Vinyl Top Coat (2.5) Inorganic Zinc Primer (1.5)	4	450 500
	Vinyl Top Coat (2.5) Inorganic Zinc Primer (1.5)	4	200 300
8.) KY 9002 over Chaplin River (Bluegrass Parkway) in Nelson Co.	Pigmented Alkyd Top Coat (0.5) Red Lead Primer (3.0)	1	200 350
	Pigmented Alkyd Top Coat (0.5) Red Lead Primer (2.5)	1	200 200

Table 13. Test pH values for potable water and unfiltered and filtered wastewater from experimental overcoating projects

P=Potable Water; **U**=Unfiltered Wastewater; **F**=Filtered Wastewater

Bridge Description	Test 1	Test 2	Test 3	Test 4
1.) KY 551 over Green River Lake in Adair Co.	**P** 7.56 **U** 6.10 **F** 6.05	**P** 7.13 **U** 7.14 **F** 7.10	**U** 6.28 **F** 6.29	
2.) KY 7 over Grayson Lake Spillway in Carter Co. (Bridge 18)	**P** 7.57 **U** 7.77 **F** 7.80	**P** 7.34 **U** 6.90 **F** 6.88	**P** 8.13 **U** 7.12 **F** 7.09	
3.) KY 7 over Grayson Lake (Clifty Creek) in Carter Co. (Bridge 19)	**P** 8.43 **U** 7.28 **F** 7.20	**P** 7.83 **U** 7.28 **F** 6.67	**P** 8.35 **U** 6.89 **F** 7.27	
4.) US 62 over Cumberland River in Livingston Co.	**P** 7.51 **U** 7.65 **F** 7.39	**P** 7.52 **U** 7.26 **F** 7.04	**P** 7.72 **U** 7.81 **F** 7.56	**P** 7.90 **U** 7.79 **F** 7.70
5.) KY 30 over Middle Fork Kentucky River in Breathitt Co.	**P** 7.63 **U** 7.03 **F** 7.25	**P** 7.87 **U** 7.71 **F** 7.57	**P** 7.56 **U** 7.67 **F** 7.15	
6.) I 275 Twin Bridges over Ohio River at Brent in Campbell Co.	**P** 7.60 **U** 6.43 **F** 6.61	**P** 7.70 **U** 6.46 **F** 5.81	**P** 7.55 **U** 7.42 **F** 7.34	
7.) KY 80 over Cumberland Lake in Pulaski Co.	**P** 6.84 **U** 7.11 **F** 7.20			
8.) KY 9002 over Chaplin River (Bluegrass Parkway) in Nelson Co.	**P** 8.17 **U** 8.54 **F** 8.45	**P** 7.53 **U** 8.45 **F** 8.37	**P** 7.93 **U** 8.01 **F** 7.53	

Table 14. Wash Water Consumption Reported for Several KYTC Overcoating Projects in 2001 and 2002

Bridge Description	Area of Steel (ft^2)	Wash Water Used (gal)	Wash Water Use Rate (ft^2/gal)
KY 7 over Grayson Lake Spillway in Carter Co. (Bridge 18)	28,000	8,000	3.5
KY 7 over Grayson Lake (Clifty Creek) in Carter Co. (Bridge 19)	28,500	6,000	4.8
I 275 Twin Bridges over Ohio River at Brent in Campbell Co.	1,200,000	100,000	12.0
KY 519 over North Craney Creek in Rowan Co.	27,900	3,700	7.5
KY 1661 over the Big Sandy River in Carter Co.	30,000	4,300	7.0

Figure 1. KY 551 bridge over Green River Lake in Adair County prior to painting.

Figure 2. KY 7 over Grayson Lake Spillway in Carter County prior to painting (Bridge 18).

Figure 3. KY 7 over Grayson Lake (Clifty Creek) in Carter County prior to painting (Bridge 19).

Figure 4. US 62 over the Cumberland River in Livingston County prior to painting.

Figure 5. KY 30 over Middle Fork of the Kentucky River in Breathitt County prior to painting.

Figure 6. I 275 twin bridges (Combs-Heil) over the Ohio River in Campbell County prior to painting.

Figure 7. KY 80 over Cumberland Lake in Pulaski County.

Figure 8. KY 519 in Rowan County prior to painting.

Figure 9. KY 9002 (Bluegrass Parkway) over the Chaplin River in Nelson County prior to painting.

Figure 10. KY 9002 (Bluegrass Parkway) over Chaplin River in Washington County prior to painting.

Figure 11. US 60 bridges over the CSX spur in Daviess County prior to painting.

Figure 12. KY 139 bridge over the Little River in Trigg County prior to painting

Figure 13. Plastic tank used in storing potable water used for pressure washing.

Figure 14. 20,000 psi pressure washer in the foreground and small 4,000 psi pressure washers in the background on the KY 80 bridge over Cumberland Lake in Pulaski County.

Figure 15. Gage to monitor outlet pressure from washer pump on the KY 551 bridge over Green River Lake in Adair Co.

Figure 16. Collection of wastewater samples at KY 80 Bridge over Cumberland Lake in Pulaski County.

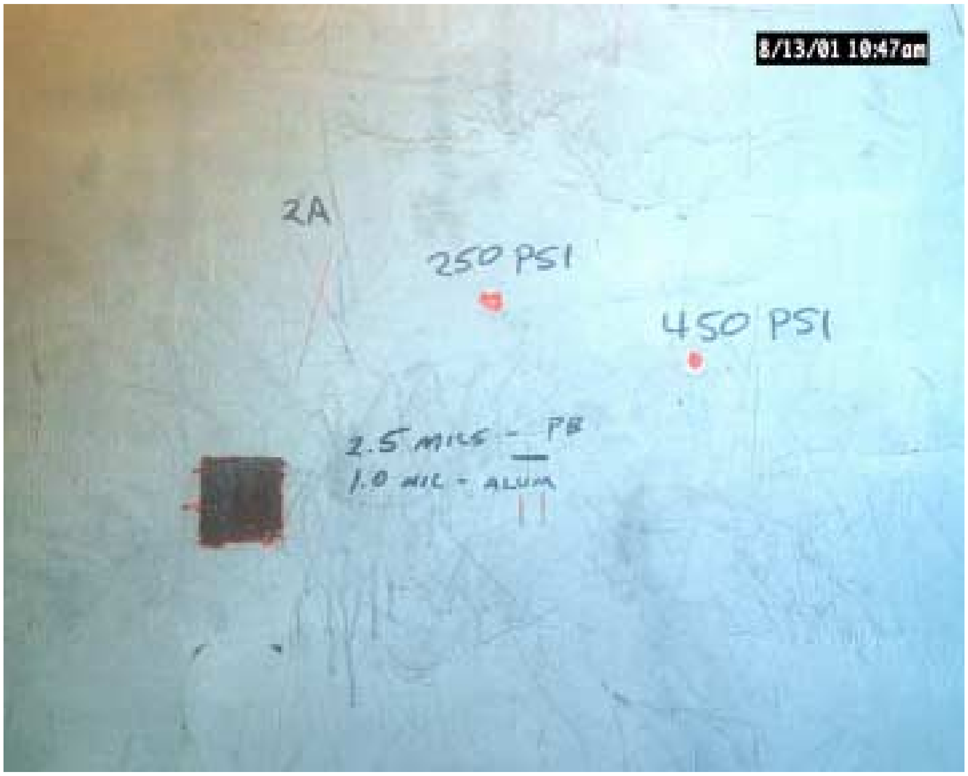

Figure 17. Test area on the KY 551 Bridge in Adair Co. showing tensile adhesion results, knifing adhesion results, and Tooke coating thickness readings.

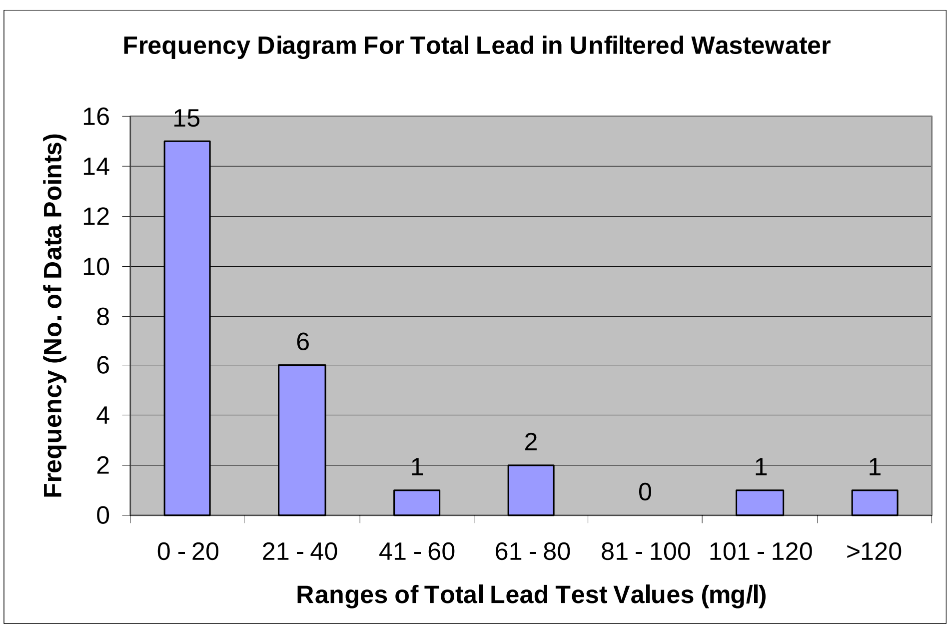

Figure 18. Frequency diagram for total lead in unfiltered wastewater – test values from Table 4.

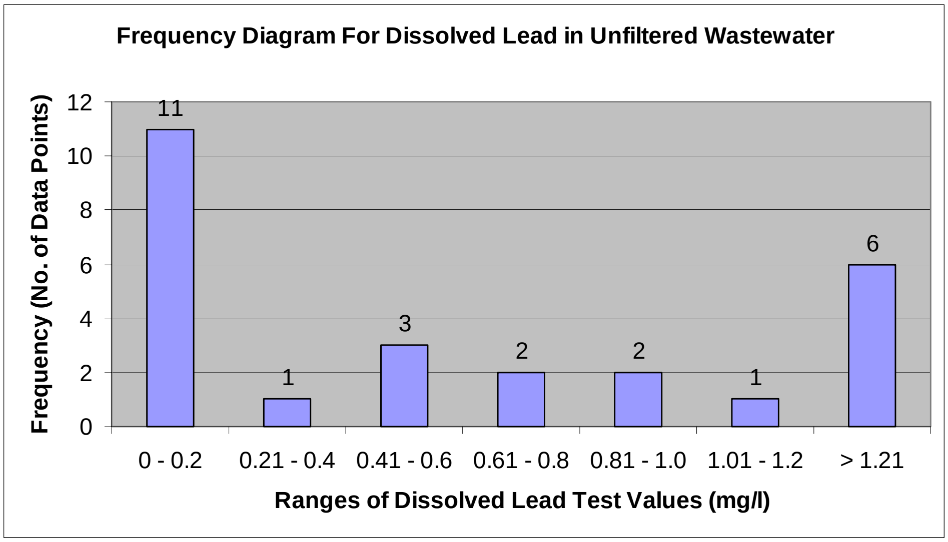

Figure 19. Frequency diagram for dissolved lead in unfiltered wastewater – test values from Table 5.

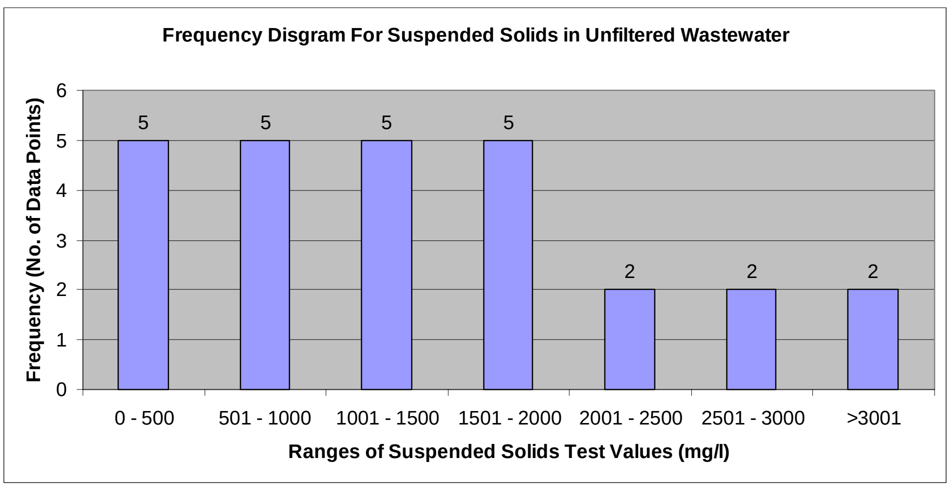

Figure 20. Frequency diagram for total suspended solids unfiltered wastewater – test values from Table 6.

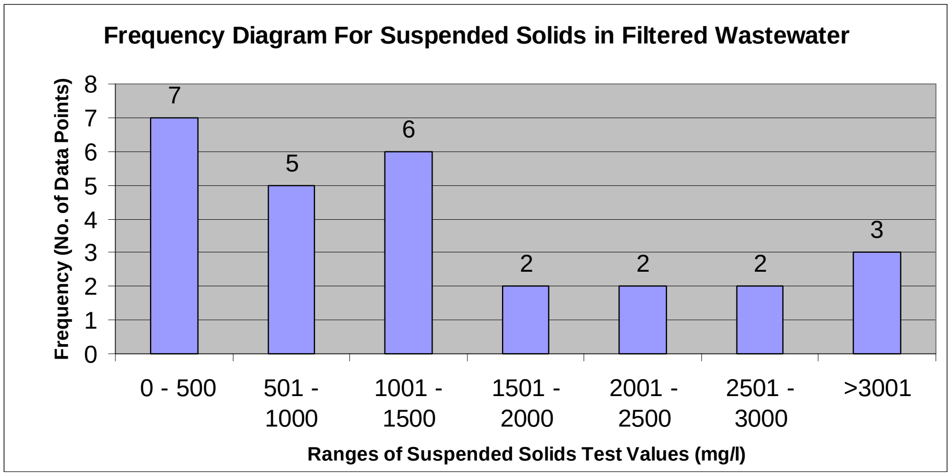

Figure 21. Frequency diagram for total lead in filtered wastewater – test values from Table 7.

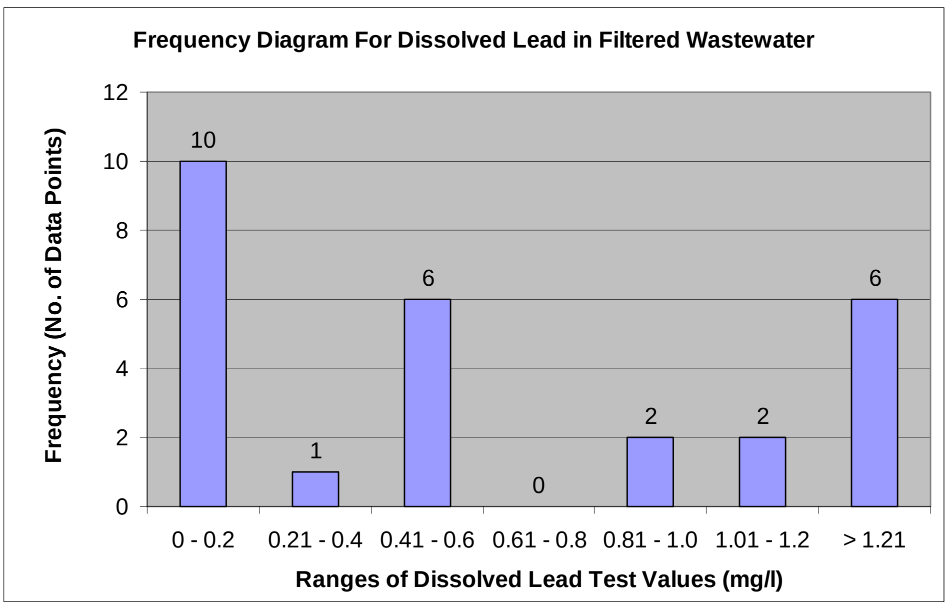

Figure 22. Frequency diagram for dissolved lead in filtered wastewater – test values from Table 8.

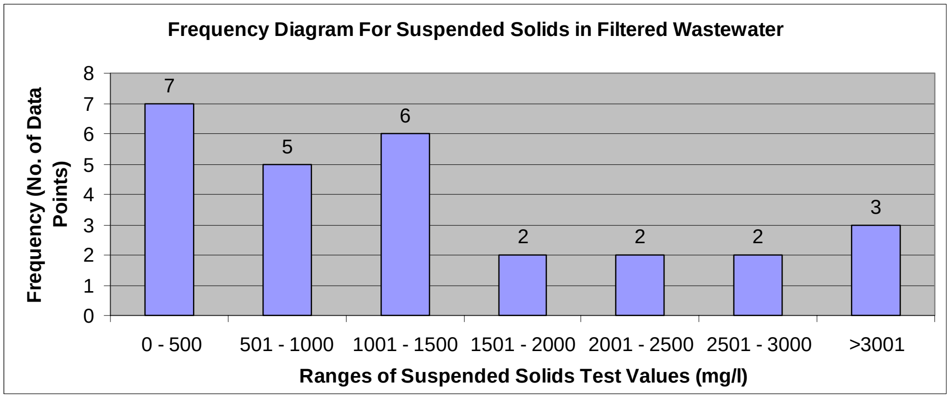

Figure 23. Frequency diagram for total suspended solids unfiltered wastewater – test values from Table 6.

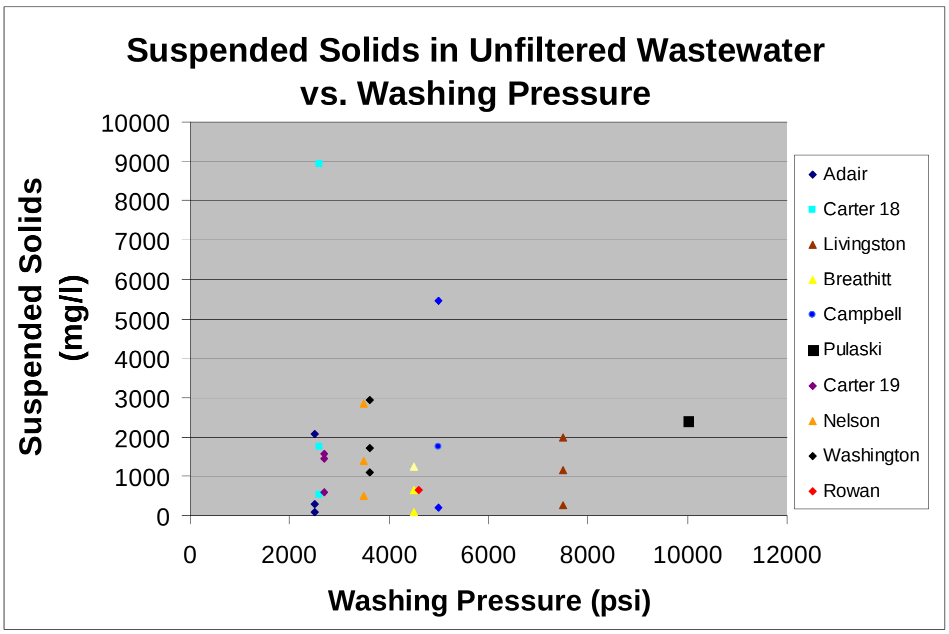

Figure 24. Scatter diagram of total suspended solids in unfiltered wastewater from experimental bridges cleaned at different washing pressures.

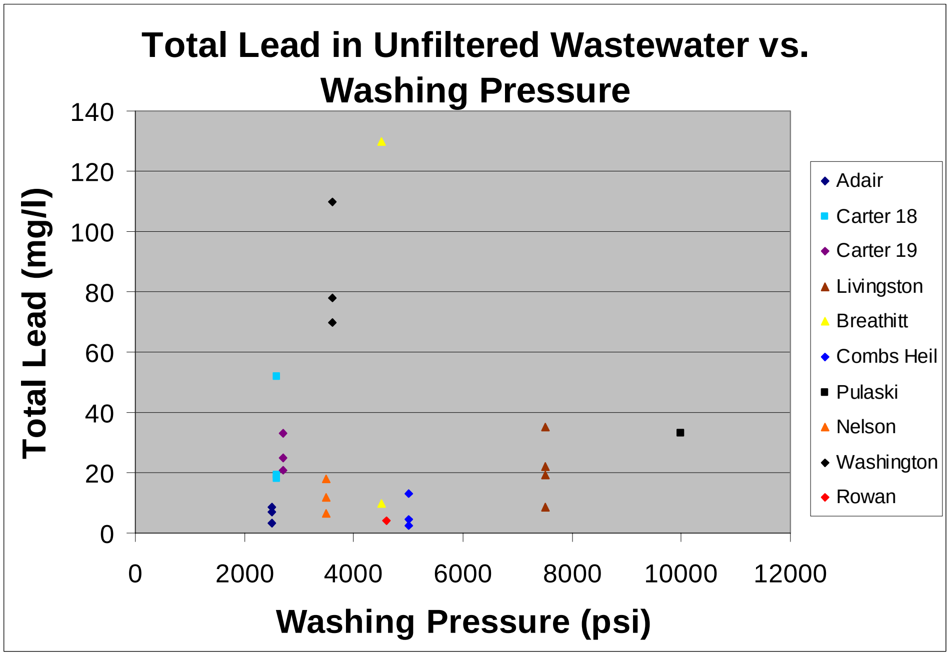

Figure 25. Scatter diagram of total lead in unfiltered wastewater from experimental bridges cleaned at different washing pressures.

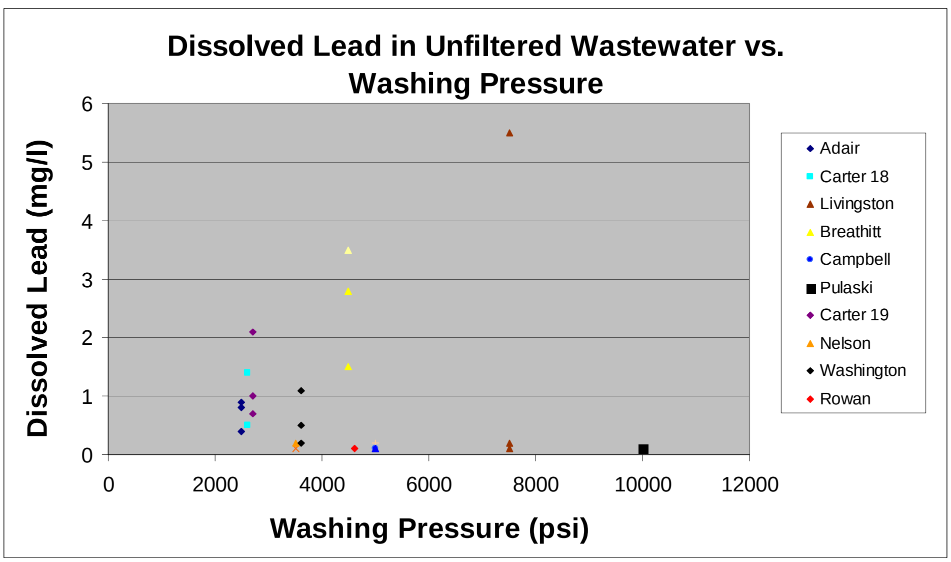

Figure 26 Scatter diagram of dissolved lead in unfiltered wastewater from experimental bridges cleaned at different washing pressures.

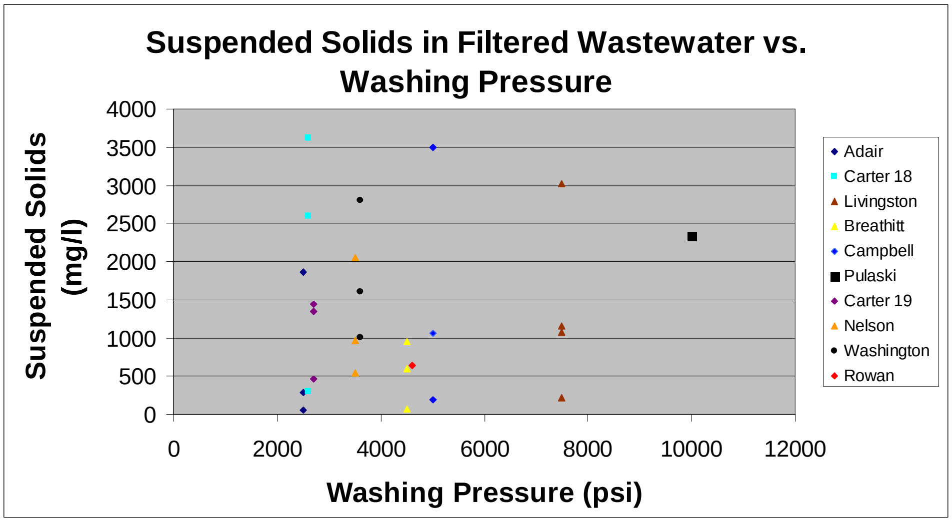

Figure 27. Scatter diagram of total suspended solids in filtered wastewater from experimental bridges cleaned at different washing pressures.

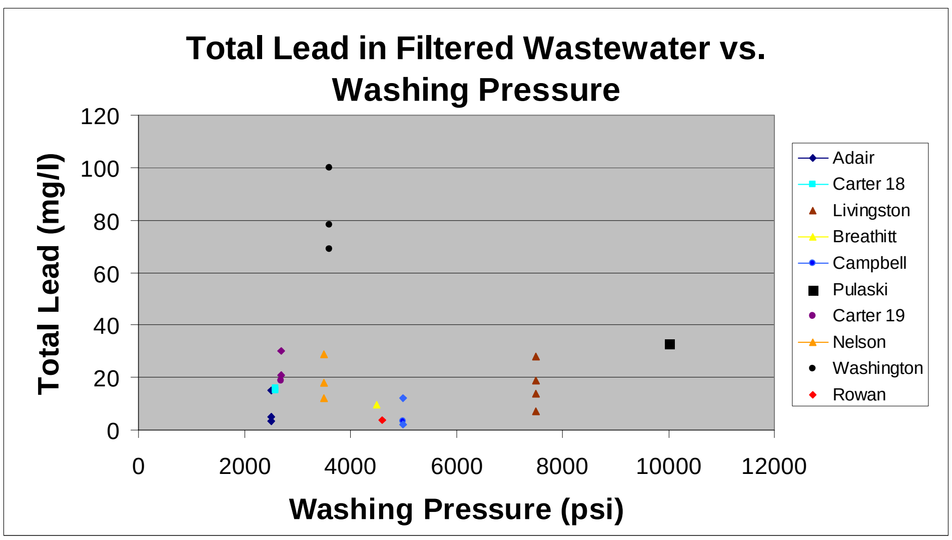

Figure 28. Scatter diagram of total lead in filtered wastewater from experimental bridges cleaned at different washing pressures.

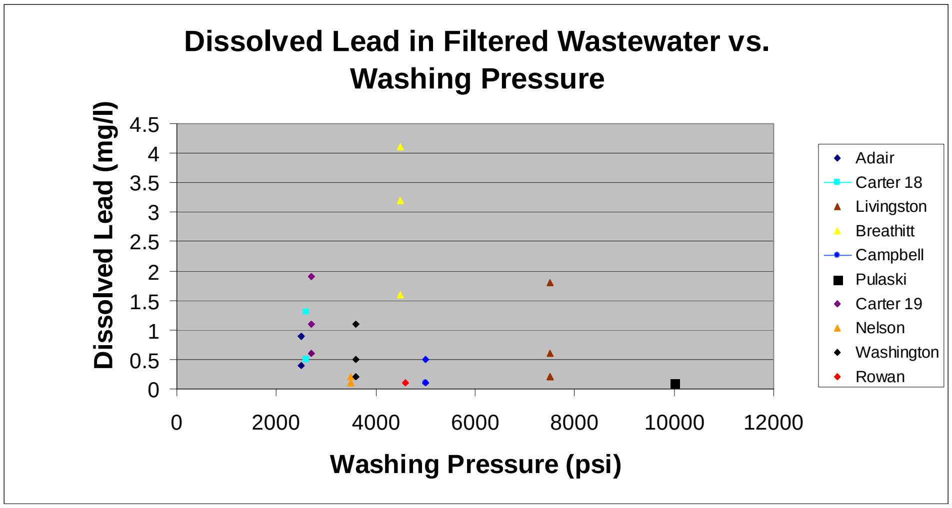

Figure 29. Scatter diagram of total suspended solids in filtered wastewater from experimental bridges cleaned at different washing pressures

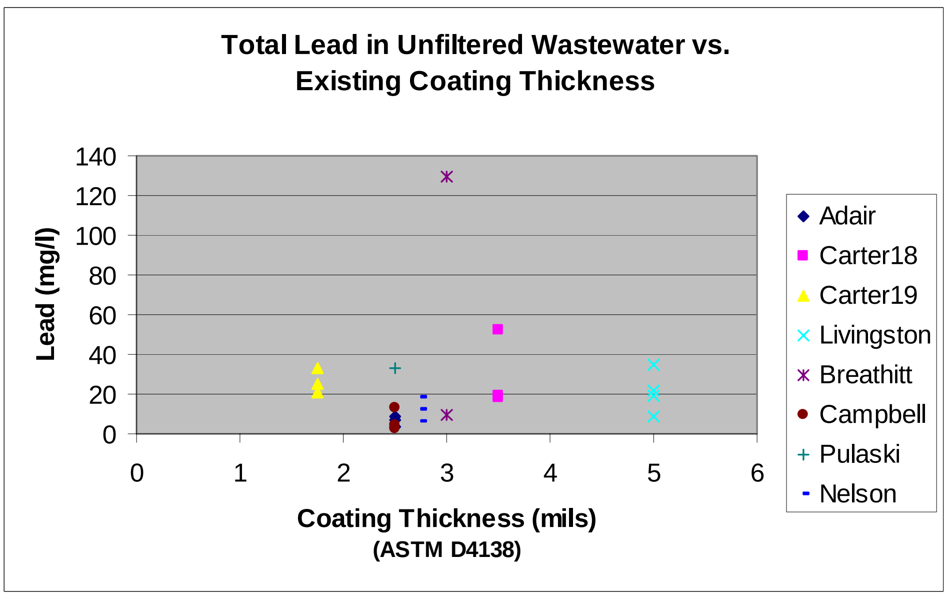

Figure 30. Scatter diagram of total lead in unfiltered wastewater plotted against coating thicknesses for experimental bridges.

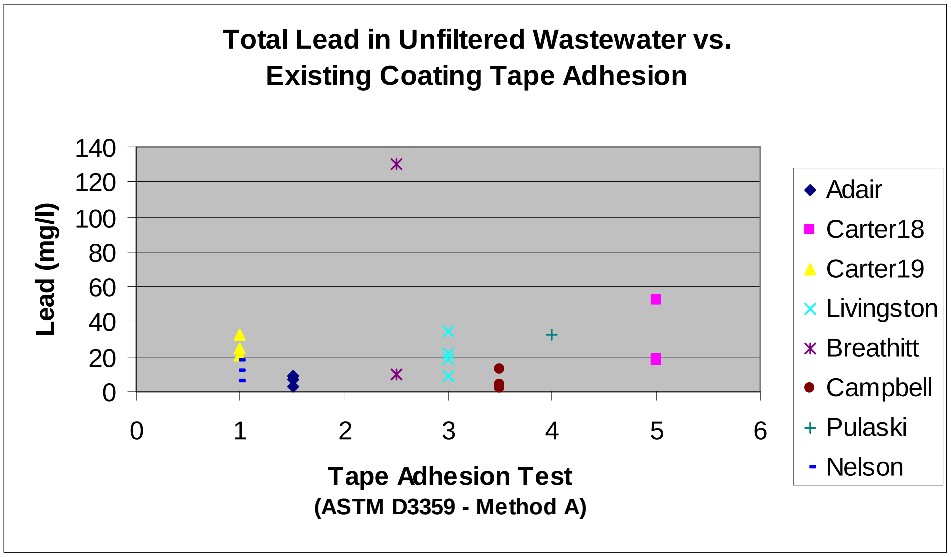

Figure 31. Scatter diagram of total lead in unfiltered wastewater plotted against coating adhesion (tape method) for experimental bridges.

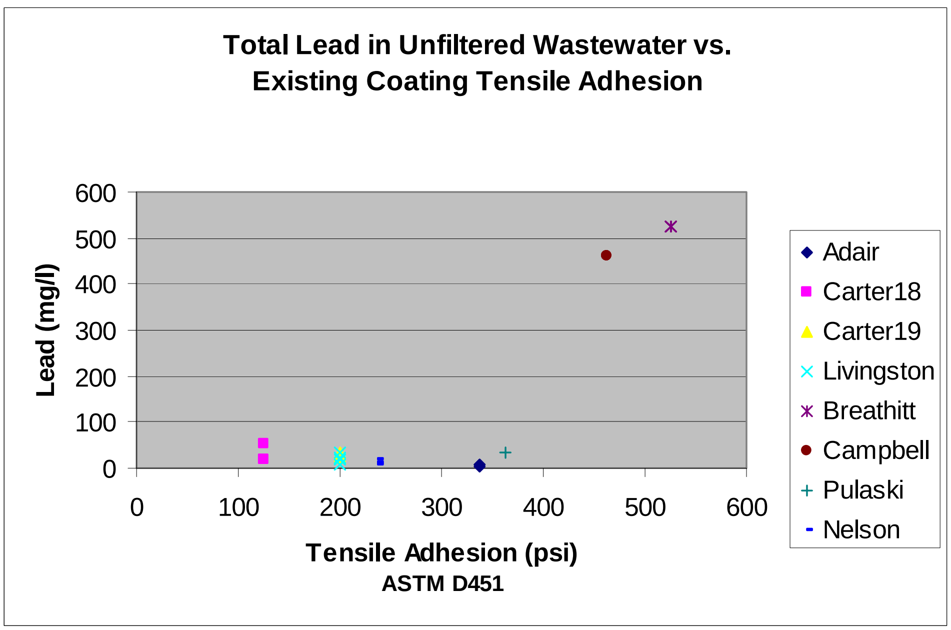

Figure 32. Scatter diagram of total lead in unfiltered wastewater plotted against coating tensile adhesion for experimental bridges.

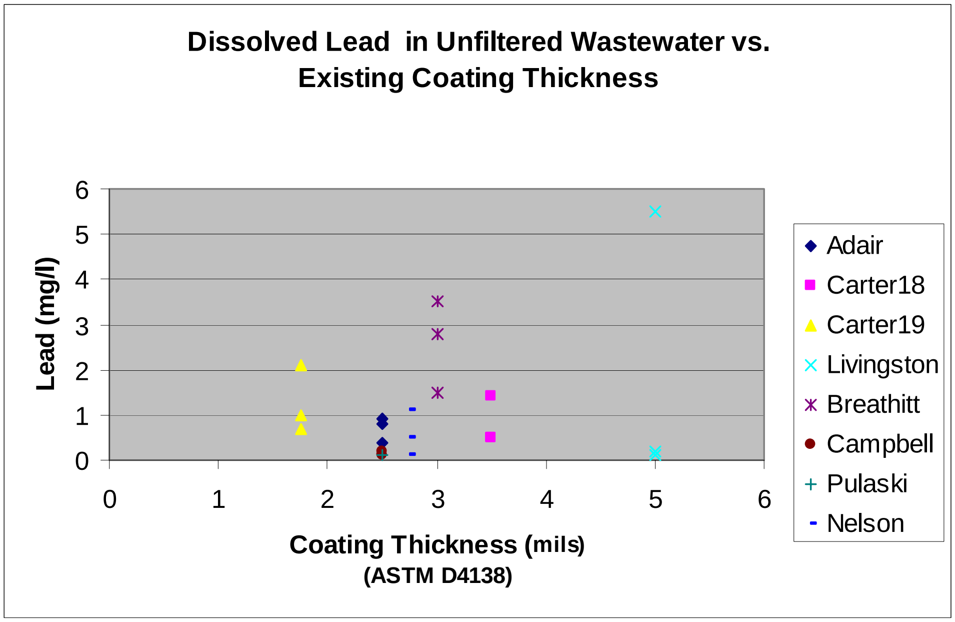

Figure 33. Scatter diagram of dissolved lead in unfiltered wastewater plotted against existing coating thickness for experimental bridges.

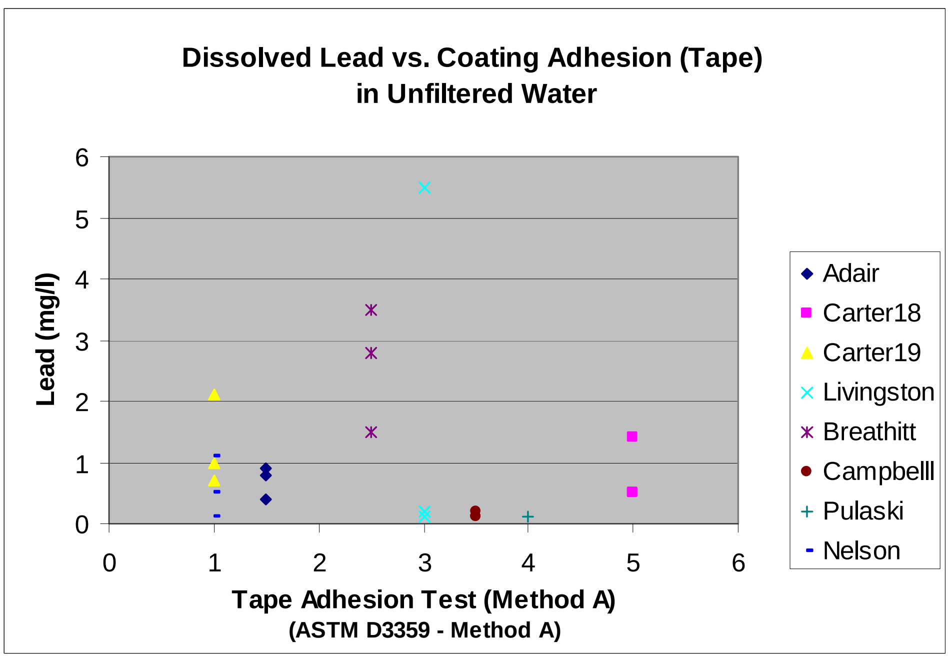

Figure 34. Scatter diagram of dissolved lead in unfiltered wastewater plotted against coating tape adhesion for experimental bridges.

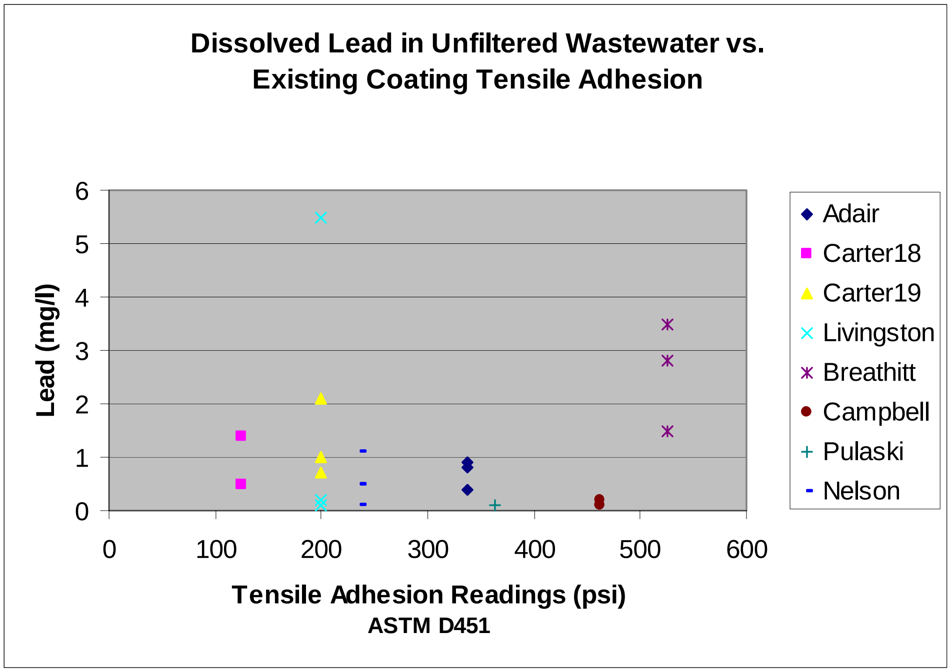

Figure 35. Scatter diagram of dissolved lead in unfiltered wastewater plotted against coating tensile adhesion for experimental bridges.

APPENDIX I: Summary of Relevant Literature Search Documents

1. U.S. EPA, Office of Wastewater Management, **Introduction to the National Pretreatment Program**, February1999.

The 1972 Clean Water Act required the elimination of pollution discharge into the nation's waters and improvement in water quality. A key component is the EPA's National Pollution Discharge Elimination System (NPDES) Permitting Program. It requires permitting of all point source discharges into waters of the U.S. (direct discharges). To address "indirect discharges" from industries into Public Owned Treatment Works (POTW) the EPA established the National Pretreatment Program. That Program requires industrial and commercial dischargers to treat or control pollutants in their wastewater prior to discharges into POTW. This monograph outlines the need for the pretreatment program and gives overviews of the national pretreatment program, pretreatment standards, POTW pretreatment program responsibilities, industrial user pretreatment program responsibilities, hauled wastes, and pollution prevention.

2. Boyer, D and Henry, G., **Don't Let Wastewater Woes Waste Your Cleaning Projects**, Cleaner Times, September 14, 2001, pp. 14, 16 and 17.

Wastewater generated by portable pressure washers is becoming a significant to Public Owned Treatment Works. Unease about the disposal of contaminated wash water can be overcome by Contractors knowing: what is in the resulting wastewater, how to handle the wastewater, and how to dispose of it. This is best planned before a project begins. One of the greatest concerns is the pH level of the wastewater. Neutralizing is discussed as a solution to that problem.

3. Frenzel, L.M. **Just Add Water,** Cleaner Times, December 28, 2001 pp.28, 29.

Using high pressure water as a cleaning agent before harsh chemicals seems to be the solution to a lot of pollution concerns. The water can be used and then recycled and reused many times over. They only waste is the solids and the impurities that you pick up in the washing project but these can be removed. The Armed Forces of the U.S. have been utilizing this technique for quite some time on there bases, typically in car washes. By using this method you do not have the chemical byproducts to dispose of.

4. **Teck**cominco, **Lead Metal Material Safety Data Sheet**, September 15, 2001, pp. 1-5.

This firm's Material Safety Data Sheet provided data on the hazards and permitted exposures to elemental lead. The permitted occupational exposure limit for airborne lead is $0.05 mg/m^3$ (OSHA). In powdered form, lead is a moderate fire and explosion hazard. When heated, the resulting fumes can be toxic. Lead can be inhaled or ingested causing headaches vomiting, nausea and other symptoms. Prolonged exposure can cause damage to the body and exposure to pregnant women can result in infant neurological disorders. Lead can be hazardous to the environment, especially in the air and water. Bioaccumulation can take place in water organisms, especially shellfish.

5. U.S. EPA, **Statistical Support Document of Proposed Effluent Limitations Guidelines and Standards for the Transportation Equipment Cleaning Category**, Report No. EPA-821-B-98-014, May 1998.

This report discusses methods for reducing pollution from effluents and provides scientific/engineering approach for assessing and addressing pollution loads from transportation equipment cleaning industry operations.

6. Koob, T.J and Barber, M.E., **WSDOT BMPs for Stormwater Runoff in Confined Spaces**, Report No. WA-RD 451.1 September 1999.

This report addresses mechanical/chemical filtration of stormwater runoff from roadways which includes metals such as cadmium, copper, lead, and zinc in relatively high concentrations. Speciation of metals depends upon pH, complexation and redox conditions with organic metal complexes possible. The report reviews the design and mechanical filters and the performance of various filter materials including organic materials such as peat moss, compost, and garden bark and various sands and perolite.

7. Nahra, M., Walton, R., and Rost, J., **Hydro-Surface Preparation and Coating for Painted Structural Steel**, Iowa Department of Transportation, Project Development Division, Final Report for TR-407, April 1999.

This report describes water-jetting tests conducted on a bridge with a basic lead silico-chromate primer with topcoats having high chrome contents (Pb-2,400 ppm and Cr-43,900 ppm). The bridge was washed at three pressure levels (20,000 psi to etch the topcoat and remove rust, 20,000 psi to remove the topcoat, and 40,000 psi to remove all paint. Air monitors in the containment showed no detectable lead. The wastewater was filtered in two passes down to a 2 micron opening size. No lead was detected and the chrome was present at about 4 mg/l.

8. Hunt, H. and Gidley, J. **"The Toxicities of Selected Bridge Painting Materials and Guidelines for Bridge Painting Projects"**, Division of New Technology, Materials and Research, California DOT, Report No. FHWA/CA/TL-90/08, September 1990

The effects of bridge painting operations on aquatic ecosystems were studied. Existing and proposed paint systems (including past lead-based coatings) were analyzed. The results indicated that both lead and zinc pigmented paints cause toxicity in aquatic wildlife. Biocides and cleaning detergents were also found to be highly toxic. A set of guidelines was developed to assist highway workers in determining and mitigation the impacts of bridge painting projects on the aquatic environment. In those guidelines, the aquatic setting is first determined, and then the nature of the project is established. From the aquatic setting and nature of the project, the Area of Potential Environmental Impact and the impacts of the project are determined. Finally, mitigation methods are discussed.

9. Min, M., Barbour, R., and Huang, J., **Testing Land Ban Wastes**, Pollution Engineering, August 1991, pp. 64-70.

This article describes the use of precipitation to remove heavy metals from wastewater. The dissolved contaminant is transformed into an insoluble solid facilitating its removal from the liquid phase. To do this, the pH is adjusted to shift the chemical equilibrium to a point no longer favoring solubility. A chemical precipitant is added to cause the precipitate particles to agglomerate. The precipitate can occur as hydroxides, sulfides or carbonates. A flocculent is added to float the precipitated particles to the surface where they are removed by skimming. Contaminant concentrations in wastewater can be reduced below 1 mg/l.

10. Skinner, J. **Hazardous Waste Treatment Trends in the US**, Waste Management & Research, October 1991, pp 55-63.

Of the several reasons underlying the tremendous amount of activity in the development of hazardous waste treatment technologies in the U.S., at least three are prominent. One is that the U.S. is beginning to harvest the produce of several regulatory and legislative programs started up in the past decade, and administered by the U.S. Environmental Protection Agency (EPA). The second reason lies with an enthusiastic increase in public support for strong environmental policies. Thirdly, in response to increasing regulation, liability, public pressure and its own initiative, U.S. industry has begun to adopt waste management policies that emphasize the reduction of waste at its source, and the treatment of wastes that are generated, to destroy or degrade their toxic components. There are two environmental laws that are largely responsible for a transition in the U.S. away from the uncontrolled dumping of wastes on the land and toward preventive hazardous waste management and improved treatment processes. These laws are: the Resource Conservation and Recovery Act, or “RCRA”, and the Comprehensive Environmental Response, Compensation and Liability Act, More commonly known as “Superfund”. The paper will also discuss the effects of RCRA and Superfund, including industry’s response to the regulatory programs that have been established.

11. Min, M., Barbour, R., and Huang, J., **Land Ban Technologies, Impacts and Implications**, Pollution Engineering, July 1991, pp. 62-71.

This is a follow up article to the Pollution Engineering’s July 1991, “Land Ban Technologies, Impacts Implications”. Discussed in this article are ways of disposing of the hazardous waste in compliance with EPA’s Land Ban. The methods discussed in this article are alkaline chlorination, chemical precipitation, immobilization, incineration, wet air oxidation, solvent extraction, carbon adsorption, in-situ vitrification, bioremediation, and UV/ oxidation

12. Biedy, J., **Managing Waste to Meet Federal Land Ban Rules**, Pollution Engineering, October 1990, pp. 46-49.

The Third Third Land Ban was enacted under the Hazardous and Solid Waste Amendments (HSWA) in June 1990. Lead is categorized as a Characteristic Waste D008. Waste codes require that listed wastes be subject to specific treatments prior to disposal unlike characteristic wastes that must be treated below specific limits prior to disposal.

13. Schleck, D.S., **Treatment Technologies for Refinery Wastes and Wastewater**, Presentation to the Natural Petroleum Refiners Association Annual Meeting, San Antonio, TX, March 25, 1990.

The author describes a treatment whereby dewatering is used by evaporation and the contaminant is stabilized by the use of Portland cement or lime. This removes heavy metals down to 0.05 mg/l.

14. Mosher, G., **EPA Publishes New Land Ban Regulations**, Modern Casting, January 1990, p. 40.

The EPA provided effluent limitation guidelines under the Third Third Land Ban. This law specifies treatment standards in lieu of methods (BDAT). Hazardous wastes have two categories, wastewaters and non-wastewaters. Wastewaters include listed wastes and those generated from mixtures and "derived from" rules that contain less than 1 percent total organic carbon and less than 1 percent solids. Wastes that do not meet those criteria are classified as non-wastewaters. The treatment for low lead (less than 2.5 percent) non-wastewaters is 0.51 mg/l by stabilization.

15. Roy, R. **"Developing a Water jetting Specification: Removal of Lead-Based Paint Using Water Jetting**, Prepared for NACE Halifax, May 2001.

This presentation discusses the use of water jetting to prepare structural steel for maintenance painting. This includes the removal of existing lead based coatings from thel steel. The resulting wastewater contains from 5 ppm to upwards of 20 ppm lead. He states that containment, capture and filtration are required to remove heavy metals. In Canada he notes the pH level must be adjusted prior to release of the treated water. In Canada, testing of treated wastewater is done using the *LC 50 Test Protocol*.

16. Bonk, L. **The EPA Land Ban and Possible Effects on the Foundry Industry** Modern Casting, April 1990, pp. 30-32.

This article discusses the EPA's new regulations on disposing of hazardous lead waste in land fills. It notes that the EPA treatment standards are below its characteristic hazardous waste limits (e.g. 0.51 mg/l treatment for Pb v. 5.0 mg/l concentration as in a hazardous waste). The article covers Land Ban proposal concerns, possible Land Ban effects, and preparation for the Land Ban. The American Foundry Society and the American Cast Metals Association held meetings with the EPA to discuss these new waste disposal rules.

17. Reddi, L.M., Ming, X., Hajra, M.G., and Lee, I.M., **Permeability Reduction of Soil Filters Due to Physical Clogging"**, Journal of Geotechnical and Geoenvironmental Engineering , March 2000, pp.. 236-246

Soil filters, which are commonly used to provide stability to the base soils in subsurface infrastructure, are prone to long-term accumulation of fine micron-sized particles. This causes reduction in the permeability, which in turn may lead to intolerable decreases in their drainage capacity. The extent of this reduction is addressed using results from both experimental and theoretical investigations. In the experimental phase, a sandy soil commonly used as a filter or drainage layer was subjected to pore-penetrating fluids containing polystyrene or kaolinite particles, and their permeability reductions were determined in terms of the pore fluid suspension parameters. In the theoretical phase of the investigation, a representative elemental volume of the soil filter was modeled as an ensemble of capillary tubes and the permeability reduction due to physical clogging was simulated using basic principles of flow in cylindrical tubes. The results from the experimental and theoretical investigation were in good agreement. In general, the permeability reduces by more that one order of magnitude, even when the migration particles were smaller than the majority of the soils filter pores. The concentration of particles in the pore stream affected the rate at which the permeability reduced. Self-filtration of particles, which is prominent at higher flow rates, may itself lead to a 20percent reduction in the permeability for these sands.

18. Sergy, G. and Scroggins, S., **Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout**, Environmental Protection Conservation and Protection Environment Canada, Reference Method EPS 1/RM/13, July 1990

Explicit standard or reference methods for measuring the acute lethal toxicity of effluents to rainbow trout (Oncorhynchus Mykiss) are provided in this report. Specific instructions for performing and reporting acute lethality tests with samples of effluent are given, and the guidance provided in the generic methodology report "acute Lethality Test using Rainbow Trout" is built upon (Environment Canada, 1990a). Methods are given for: 1). A single-concentration test, with full-strength effluent unless otherwise specified: 2). A multi-concentration test to determine the median lethal concentration (LC50): and 3). A test with a reference toxicant. Instructions are included on holding trout in the laboratory, facilities and water supply, handling and storage of samples, preparation of solutions, test conditions, observations to be made, endpoints with methods of calculation, and the use of reference toxicants.

19. Journal of Protective Coatings & Linings, **Responses to Land Ban: A Survey of State Highway Departments**, August 1990, pp. 42-53.

State highway departments have thousands of bridges coated with a lead-based paint, that will over time have to be removed and the hazardous waste properly disposed of. The quantity of lead waste generated during a common abrasive blast job can become enormous, and because of the new EPA regulation requiring that lead-containing hazardous waste be treated to below 5 ppm lead before it is disposed of. This article discusses a few plans that state highway departments plan to use to meet the Land Ban's regulations. The information was obtained through interviews of key personnel in highway agencies, who have adopted or are contemplating various approaches to controlling the cost of compliance with the new regulation.

20. Appleman, B.R., **Removing Lead Paint from Bridges: Costs and Practices**, : Journal of Protective Coating & Linings, September 1998, pp. 64-74.

This article concludes a report that began in the August 1998 JPCL (pp. 52-60). The report is base on a study SSPC conducted on behalf of the National Cooperative Highway Research Program (NCHRP) on lead-based paint removal from steel bridges. Based on data collected between 1993 and 1996, the study was designed to define current practices and costs among state and local highway agencies for removing lead paint, specifying containment, handling waste, writing specifications for lead paint removal projects, developing and administering contracts and selecting removal strategies.

21. Better Roads, **How to Control Bridge Painting-Related Pollution"**

May 1992, pp. 16-18.

Bridge painting and paint removal mean big environmental problems, says Wayne Kober, Chief of the Environmental Quality Division of Pennsylvania's Department of Transportation. PennDOT has developed guidelines to keep the cost of bridge painting to a minimum. Also briefly discussed are some of Michigan's, New Jersey's, New York's, North Carolina's, and Virginia's plans for bridge painting.

22. Elliott, B., Zanoni, P., Ralle, E., and Fuller, B., **Lead-Based Paint Removal Presents Challenges**, Water/Engineering & Management**,** February 1998, pp. 30-32.

The 18th Street Bridge spanning the Kaw River in Kansas City, Kansas, a Kansas Department of Transportation (KDOT) structure, needed the removal of aging coats of hazardous lead-based paint from a water main pipe mounted along the underside of the bridge. The project was going to be costly so KDOT personnel reviewed options for the most cost efficient type of removal. Four methods of restoration were discussed: replace the entire main, rehabilitate the existing main using sandblasting, rehabilitate the existing main using a vacuum-evacuating power tool cleaning system, or encapsulate the existing coating. The vacuum-evacuating power tool cleaning was selected due to its lower cost and relative simplicity.

23. Hosea, J.M., Nelis, P.M., Mayne, M.D., and Greene, M.C., **Metal Recovery by Ion Exchange - Seven Crucial Issues**, BioRecovery Systems Inc.
pp 879-889.

Since federal legislation has banned the disposal of metal sludges in landfills unless it is stabilized, electroplaters and metal finishers are seeking alternatives to conventional waste treatment techniques. Primary interest has focused upon waste treatment technologies which reduce the amount of hazardous waste generated and allow metal to be recovered in the elemental form (i.e., metallic sheets or granules) or as purified metal salts. These materials can be recycles into useful products and are therefore not classified as hazardous waste. Ion exchange (IX) is one technology which provides an opportunity for such metal recovery and recycling. Several articles have been published describing the application of ion-exchange methods for the treatments of electroplating and metal finishing wastes. These reports provide general descriptions of ion-exchange treatment operations, but they do not typically address specific operation procedures and processes which are necessary components of an efficient ion-exchange metal recovery system. The purpose of any wastewater treatment system should be to achieve compliance in the most economical and efficient manner. Therefore, this paper describes, in detail, certain operational criteria and system components which should be part of an efficient and economical ion-exchange system.

24. Kapsanis, K.A., **Strategies for Dealing With Hazardous Waste from Lead Paint Removal Operations,** Journal of Protective Coatings & Linings, August 1990, pp. 55-69.

Among the urgent questions posed by the Third Land Disposal Restrictions Act (Land Ban) are, first, what types of treatment for wastes containing lead are emerging; and, second, what options, if any, are available for reuse or recycling of the waste materials from lead paint removal operations. A limited survey of end users, waste treatment firms, and representatives of the EPA has yielded three general strategies: stabilization and disposal, incineration, and reuse of materials.

25. Appleman, B.R., **Lead Paint Regulations Challenge Bridge Workers**, Roads & Bridges, April 1989, pp. 42-55.

Highway agencies have been using lead-containing bridge paints extensively for several decades. They have proven to be effective systems for protection against corrosion and also are forgiving of surface preparation and application quality. Consequently, an estimated 80% of all existing highway bridges in the United States have lead-containing systems. Unfortunately, lead compounds, including those used in bridge paint, are toxic to humans and other life forms. They are cumulative poisons which affect the central nervous system and can lead to debilitating illnesses and eventually, death. The regulations for removal of the lead paint are discussed, along with different strategies for lead paint removal.

APPENDIX 2: Advanced Effluent Filtration Systems

AquaKlean

AquaKlean is a product of Carolina Equipment and Supply based in Charleston, SC. There are two types of units 1) manual unit and 2) automatic unit. The automatic units cost approximately $40,000. With some modifications to the unit, the amount of total and dissolved lead removed can be adjusted based on the requirements of the consumer.

System Operation

The *AquaKlean* uses centrifugal force, up to eight hundred times the force of gravity, to remove solid waste produced during the washing process. When *AquaKlean* is ready for operation, the rotor is engaged, and it starts to spin. Solid blast particles begin to move out towards the perimeter. The blast waste is collected on the outside of the rotor while the water is removed and recycled back into a holding tank, suitably cleaned and essentially free of solid contamination.

Figure 36. AquaKlean Manual Unit.

Four Models are available:
There are two manual units:
1) C-50M - rated at 10 gallons per minute
2) C-80M - rated at 15 gallons per minute

The C-50M and C-80M manual units are normally used for separating liquid and solid waste in small batch-type jobs. With a manual model, an operator periodically stops the unit, removes and cleans the inner basket, and restarts the machine. This operation requires about fifteen minutes with minimal tools. *AquaKlean* manual units can also be mounted on wheels to provide a portable unit that can be utilized on field washing operations.

There are two automatic units:
3) C-100A - rated at 18 gallons per minute
4) C-150A - rated at 30 gallons per minute

The C-100A and C-150A AquaKlean automatic units can be used where more than one manual units is required because an operator never needs to clean out the solid waste from the unit. As the unit reaches full capacity, it automatically stops the rotor and the pump. It then locks the rotor in place and scrapes the interior clean of the solid waste. The solids are then discharged into a container for disposal. When the barrel is clean, automatic sensors restart the pump and rotor re-initiating the cleaning operation. The AquaKlean technology eliminates the use of filters or other consumable materials. As with the manual models, the automatic AquaKlean is easily installed into any existing water blasting operation.

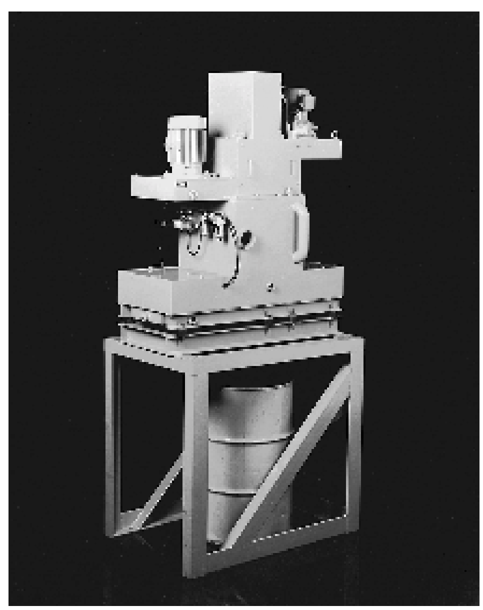

Figure 37. AquaKlean Automatic Unit.

Aria SM Water Treatment Systems

The Aria micro-filtration system is a product of the Pall Corporation based in East Hills, NY. The approximate cost of this system is $155,000.

System Operation

A micro-filtration system is composed of several racks of filters working in parallel. A system alternates from filtration phases to short cleaning phases to remove the particles concentrated during the filtration. This step is called Simultaneous-Air-Scrub-Reverse Flow (SASRF). Periodically, thorough cleaning is performed flushing the filters with acids and/or bases. This is the Clean-in-Place phase (CIP). Pall is also able to dramatically extend the CIP intervals by implementing an Enhanced Flux Maintenance (EFM). The EFM is an automated cleaning step that recovers the TMP (Fluctuations in Transmembrane Pressure) and prolongs the need for a complete CIP. An EFM can be easily retrofitted to Pall's standard ARIA series.

Figure 38. Aria Micro-filtration Unit.

The unit employs *Microza*® micro-filtration modules operate in an outside-in mode. In conventional filtration or single-pass filtration, the membrane filter is perpendicular to feed flow direction. Solids are dead-end filtered by the media and are generally removed when the filters are backwashed. For *Microza* modules, the membranes are placed parallel to the feed direction and only clean liquid passes through the membrane.

US Filters Wastewater Ion Exchange (WWIX)

The *Wastewater Ion Exchange* (WWIX) is a product of US Filters of Waukesha, WI. This system uses ion exchange technology to remove heavy metals from water.

System Operation

US Filter unit employs resins and other media to remove specific ionic contaminants from water. The filter capacity of the media or resins is limited and the filters must be sent back to US filters periodically remove contaminates removed from the media. US Filters have a 24-hour phone service and they will come out to the site to exchange the tanks.

Maximum Flow: 75 GPM
Maximum Pressure: 75 PSI
Minimum Flow: 0.5 GPM

Figure 39. US Filters Wastewater Ion Exchange Unit.

Georgia Tech Research Institute Experimental Chemical Filtration System

A Filter Column system was developed by Bob Lewallyn, who was doing research for Georgia Tech Research Institute (GTRI) as shown in figure 40.

Figure 40. Georgia Tech Research Institute Filter Column Unit.

The wastewater is pumped into a holding tank that holds approximately 330 gallons. The contaminated water is then pumped into a sand bed where the insoluble particles are filtered out (Fig. 41). From there the water can go two separate routes: 1) into a chemical filter media (#1) in a column, where the water is forced from the bottom of the column to the top 2) into a chemical filter media (#2) in a column, where the water is pumped to the top and then flows down and out the bottom. In either column the lead is almost completely removed from the water.

Figure 41.The wastewater holding tank and the sand bed of the filter system.