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# Occurrence of Contaminant Accumulation in Lead Pipe Scales from Domestic Drinking-Water Distribution Systems

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Previously, contaminants, such as Al, As, and Ra, have been shown to accumulate in drinking-water distribution system solids. Accumulated contaminants could be periodically released back into the water supply causing elevated levels at consumers' taps, going undetected by most current regulatory monitoring practices and consequently constituting a hidden risk. The objective of this study was to determine the occurrence of over 40 major scale constituents, regulated metals, and other potential metallic inorganic contaminants in drinking-water distribution system Pb (lead) or Pb-lined service lines. The primary method of analysis was inductively coupled plasma-atomic emission spectroscopy, following complete decomposition of scale material. Contaminants and scale constituents were categorized by their average concentrations, and many metals of potential health concern were found to occur at levels sufficient to result in elevated levels at the consumer's taps if they were to be mobilized. The data indicate distinctly nonconservative behavior for many inorganic contaminants in drinking-water distribution systems. This finding suggests an imminent need for further research into the transport and fate of contaminants throughout drinking-water distribution system pipes, as well as a re-evaluation of monitoring protocols in order to more accurately determine the scope and levels of potential consumer exposure.

## Introduction

**Background.** Scales form on drinking-water piping through a combination of in situ or upstream corrosion processes, post-treatment deposition of solid materials resulting from treatment, and deposits formed by reaction of the finished water and piping with natural substances passing through the treatment plant. The nature and composition of scales in a drinking-water distribution system are a function of both the water quality and the metal pipe underneath. A voluminous body of research has documented the importance of corrosion control for regulated contaminants, such as lead

(Pb) and copper (Cu), which relies upon the manipulation of water chemistry to develop passivating or immobilizing solid phases on the pipe surfaces. Research has shown that water constituents other than Pb and Cu, such as aluminum (Al), radium (Ra), and arsenic (As), also accumulate in scales on distribution system pipes (1–4). Recently, many prior studies have been reviewed and summarized (5). In some cases, the adsorption and accumulation of constituents, such as Al, could serve to help form corrosion-inhibiting passivating films or diffusion barriers (6–10). Recently, however, concern has begun surrounding the stability of scales and their potential for unpredictable, acute elevations of contaminants in distribution system locations not currently included in regulatory monitoring programs.

Under normal circumstances, trace amounts of known contaminants do not pose a health risk; however, the release of accumulated contaminants in concentrated amounts could result in high levels at consumers' taps (5, 11, 12). Release episodes of both regulated and unregulated contaminants from pipe scales into drinking water, including Pb, As, and Rn (from Ra), have been documented (4, 5, 11–15). The recent occurrences of contaminant releases in domestic water systems challenges the traditional assumption that inorganic contaminants behave conservatively in a distribution system—that is, that inorganic contaminants hold the same concentration from the end of treatment to the tap (3, 5, 16).

Current U.S. drinking-water regulations for inorganic contaminants focus on monitoring effective removal of source water contamination. In the United States, the National Primary Drinking Water Standards (NPDWS) protect public health by limiting the levels of contaminants in drinking water, and National Secondary Drinking Water Standards (NSDWS) regulate contaminants that may cause aesthetic or cosmetic effects in drinking water. With the exception of lead and copper corrosion control and asbestos fiber contamination, these regulations do not require sampling procedures that would be effective in identifying risks associated with the accumulation and re-release of inorganic contaminants or radionuclides from distribution system mains, service lines, or interior premise or building plumbing (17, 18).

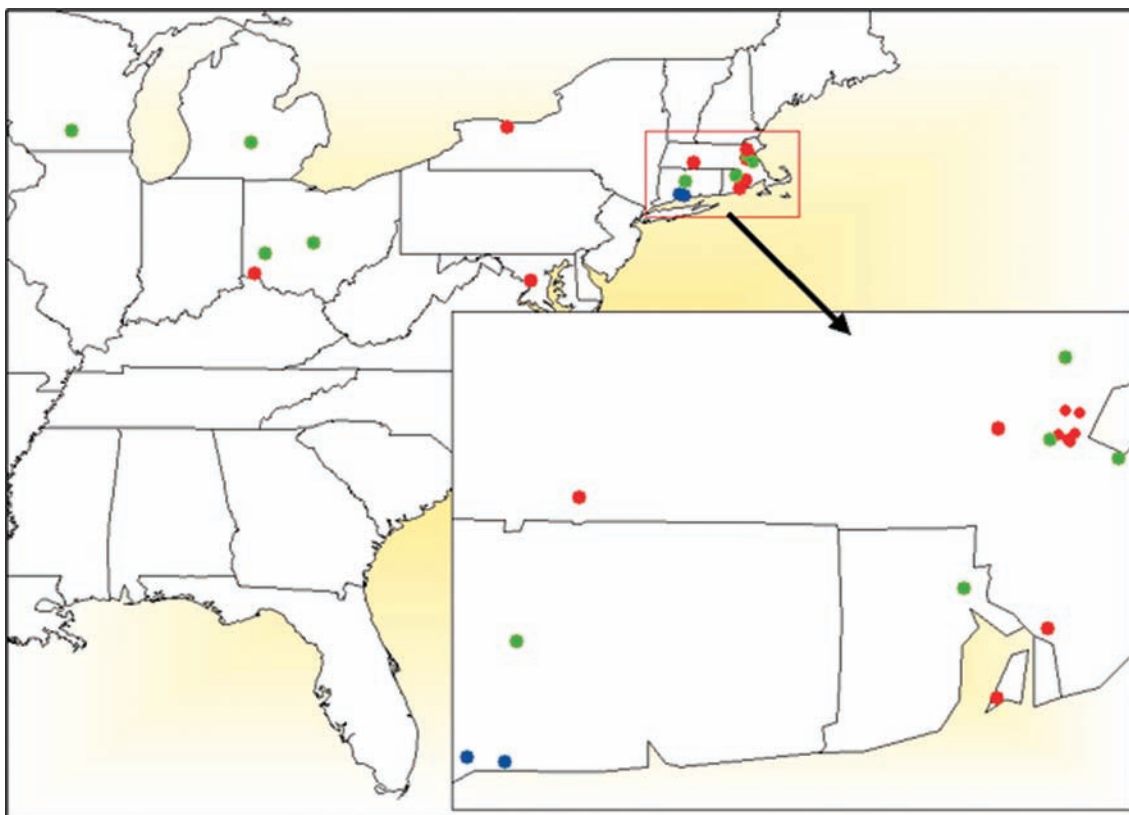
**Scope of Study.** This study was derived from our current research into the development of equilibrium chemical models to predict treatment impacts on lead corrosion. The limited objective of this present work was to use this valuable and unusual existing body of “samples of opportunity” to assess the likely co-occurrence of a broad suite of inorganic contaminants in lead pipe scales. Analytical approaches available included inductively coupled plasma-atomic emission spectroscopy (ICP-AES), inductively coupled plasma-mass spectrometry (ICP-MS), continuous flow-cold vapor-atomic absorption spectrometry (CV-AAS), and total carbon and total sulfur by combustion. The nature of the origin and distribution of these pipe samples precludes their use as either an objective quantitative estimate of national occurrence of metal accumulation either in lead pipes, or in pipe scales generally. These data, however, were intended to substantiate or contradict prior predictions of the need for concern about potential contaminant accumulation in the distribution system, in water systems meeting the Safe Drinking Water Act (SDWA) regulations. Experiments to estimate the mobility of scale contaminants in their respective water supplies were beyond the scope of this investigation.

**Sample Collection.** Scale samples were collected from 91 pipe specimens made available by 26 different municipal water distribution systems across 8 states over a span of 16

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**FIGURE 1.** Geographic origins of lead pipe specimens from which samples were harvested. For the locations of the pipe specimens, systems distributing treated groundwater are plotted with a green dot, systems distributing treated surface water are shown with a red dot, and systems distributing a mixture of ground and surface water at some or all of the sample locations are shown with a blue dot.

years, though most have been received within the past 5 years. Of the 26 different water distribution systems, samples were mainly exposed to treated surface waters for 15 of the systems, treated groundwater for 9 of the systems, and to a combination of treated surface water and groundwater for 2 of the systems. Figure 1 is a map showing the originating locations of the pipe specimens. The pipe samples used for this study were obtained as part of lead corrosion or simultaneous regulatory compliance studies. They do not represent a statistically valid random sample of the national population of lead service line scales. Notably, with the exception of some exceedences of the lead or copper action level, none of the drinking-water utilities represented by the samples were in violation of any other inorganic contaminant regulations.

## Materials and Methods

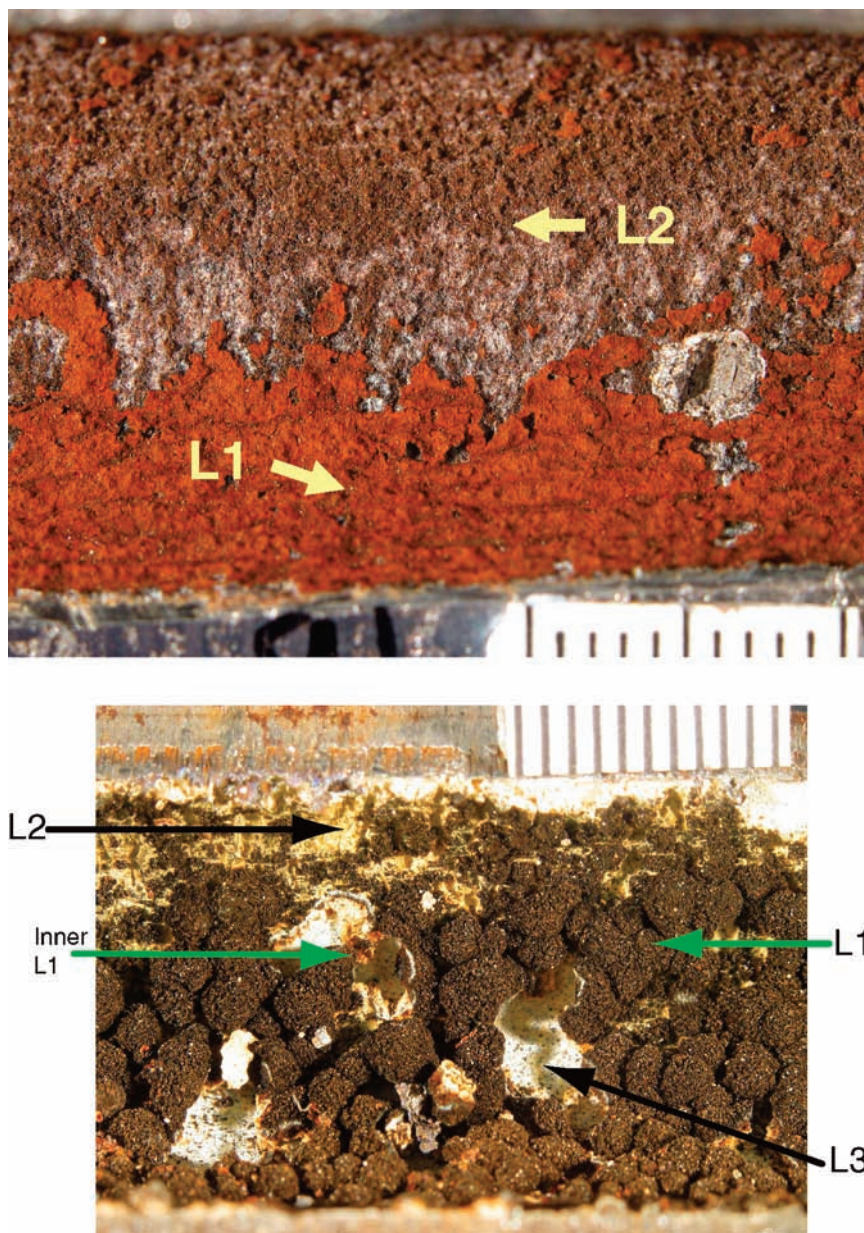
**Sample Preparation.** Upon receipt in the laboratory, prior to any processing, the ends of each sample pipe were plugged with rubber stoppers and all loose material was washed from the outer surface. The pipes were cut longitudinally to expose the inner wall using a band-saw with a fine-toothed carbon-steel blade. During this process, small lead particles often scattered throughout the pipe and became embedded in the existing scale. To the extent possible, these particles were blown off with a laboratory air jet or manually removed from harvested scale using an assortment of fine-tipped tools, such as forceps or dental picks. Some scale material was lost from some pipes during shipment and cutting, though any relatively loose scale material dislodged during transport was collected when the pipe ends were uncapped. Following photography, stereomicroscopic observations, and mineralogical descriptions, scale material was then harvested from the pipe in operationally defined layers. These different

“layers” of scale were harvested using fresh or detergent-cleaned and deionized water-rinsed soft brushes, various metal spatulas, and fine-tipped tools. The discrimination of a “layer” was mainly based on color, textural change, or both, in scale composition, as is illustrated by the photographs in Figure 2. The layers were sequentially numbered from outermost (L1) to innermost, with most pipes appearing to have 3 layers based on these criteria, with exceptions showing either fewer or more layers. The total scale thickness, as well as individual layer thickness, varied widely across samples, and sometimes also within a given pipe sample. Generally, total scale thickness varied from approximately 0.1 to several mm, suggesting strong dependence on water chemistry history. The scale volume harvested from each layer and in total was a function of the length of the pipe specimen and the mineralogical characteristics of the scale. Frequently, less than 20–50 mg of scale from a given layer was available for all analyses, though as much as 1–2 g was occasionally available for long pipe sections with thick scales.

Scales harvested were manually ground with an agate mortar and pestle until able to pass through a 200-mesh ( $\leq 75 \mu\text{m}$  grain size) stainless steel sieve. Aliquots of this material were utilized for both elemental analysis and X-ray diffraction analysis, while only the former is the subject of this study.

**Metallic Elemental Scale Analysis.** All scale analyses for which results are reported here were conducted by the U.S. Geological Survey (USGS). Because the volume of scale material was often limited, the application of analytical techniques were prioritized until the scale aliquot was consumed. The highest priority was for analysis for forty elements via ICP-AES, using a Perkin-Elmer Optima 3000 simultaneous spectrometer. The ICP-AES analyses were performed after decomposition using a sequence of steps





**FIGURE 2.** Examples of layer structure in two different lead pipe scales: (a) a two-layer primarily  $\text{PbO}_2$  scale, with L1 a nearly continuous layer overlying L2; (b) a complex multilayered scale, with dissimilar outer material (L1) rich in Mn, Fe, and Al oxyhydroxides on top of primarily lead hydroxycarbonate layers 2 and 3 (at metal pipe interface). Scale ticks represent 1 mm.

with hydrochloric, nitric, perchloric, and hydrofluoric acids at low temperature (19). The second priority analysis used ICP-MS conducted on a Perkin-Elmer Elan 6000 ICP-MS system. This method applied to rare earth elements and silicon, with solubilization of the sample material by sintering with sodium peroxide, leaching with water, and acidifying with nitric acid (20). The third priority analysis was total carbon and total sulfur by combustion. All total sulfur and total carbon analyses reported were performed at USEPA using a LECO model CS230 combustion furnace instrument (21, 22). Finally, when the scale volume permitted, mercury (Hg) was determined by CV-AAS using a Perkin-Elmer 3030B spectrophotometer. For mercury determinations, samples were digested with nitric acid and sodium dichromate (23). Table 1 presents the summary of elements of interest to this study, and their applicable U.S. drinking-water regulatory limits.

No specific standard reference materials exist for water pipe corrosion deposits. Aside from having a very different amount of lead, NIST 2782 (Industrial Sludge) was deemed

to be reasonably suitable to represent many of the elements present in the scales and most potential analytical matrix interferences. Table 2 presents recovery data for the elements of interest during the course of the study. The low bias for chromium reflects the resistant form of the Cr in the reference material, and results on actual pipe samples are expected to be much more accurate. Due to lack of analytical sensitivity and small amounts of available material, consistently low reporting limits for the elements could not be achieved for all samples.

**Powder X-ray Diffraction (XRD).** As part of other studies, all samples included in this study had previously been analyzed by powder X-ray diffractometry. A Scintag SDS 2000 theta-theta diffractometer was used for almost all of the samples. This unit is equipped with a Peltier detector and a  $\text{Cu K}\alpha$  X-ray tube, and the scans were performed in step-scan mode. Operating conditions were generally 35–40 kV, 40 mA,  $0.02^\circ$   $2\theta$  step size, and a 1-s hold time. The remaining samples were analyzed using a PANalytical 'Pert with  $\text{CoK}\alpha$

**TABLE 1. Drinking-Water Contaminant Elements and Their Respective Regulatory Status (Bismuth, Nickel, Sulfur, and Tin Are Also Contaminants Considered in This Study but Are Not Regulated or Present on the CCL)**

contaminant list	contaminant	symbol	standard
NPDWS <sup>a</sup>			MCL <sup>b</sup> (mg/L)
	arsenic	As	0.01
	barium	Ba	2
	cadmium	Cd	0.005
	chromium (total)	Cr	0.1
	copper	Cu	1.3 (TT <sup>c</sup> action level)
	lead	Pb	0.015 (TT action level)
NSDWS <sup>d</sup>	mercury	Hg	0.002
			secondary standard (mg/L)
	aluminum	Al	0.05–0.2
	copper	Cu	1.0
	iron	Fe	0.3
	manganese	Mn	0.05
CCL <sup>e</sup>	zinc	Zn	5
	vanadium	V	N/A

<sup>a</sup> National Primary Drinking Water Standards. <sup>b</sup> Maximum Contaminant Level. <sup>c</sup> Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. <sup>d</sup> National Secondary Drinking Water Standards. <sup>e</sup> Contaminant Candidate List.

radiation, PW3050/60 theta-theta goniometer, and PW3011/20 proportional detector.

**Data Analysis.** The elemental data generated by the different methods for all layers of all samples with sufficient material were tabulated, validated, and stored in a Microsoft Access relational database. The outermost layer of scale in contact with the water (Layer 1) was considered to be presumably the most reactive, and those data are used preferentially in this evaluation. If there was insufficient material in Layer 1 for the chemical analysis, Layer 2 data were used. The subset of data for the layers of focus was analyzed using frequency distribution plots created by the frequency plot transform available in Sigma Plot software, and summary statistics were calculated in Microsoft Excel. In the interest of determining general contaminant levels, ranges, and trends, statistical analysis of the data focused on summary distribution statistics and mean values for the elements of interest to this study from those samples that had analysis results at or above the reporting limit for that element. The reporting limits in this study were determined by elemental analysis results that showed finite values reported by the laboratory, while the detection limits were defined here by elemental analysis results that included the concentration of the target contaminant at concentrations below the reporting limit. Detection limits and reporting limits varied by element, as expected, and occasionally by run, as a function of digestion, scale volume, and dilution effects.

The reasons for employing this method of data analysis were various. Primarily, however, the ability to conduct analyses is dependent upon an adequate amount of scale available for harvest from a given layer, and the need to do comparisons of scale deposit layers that were as equivalent as possible across sites. The concentrations of contaminants reported here are indicative of the contaminant concentrations presumed to have most strongly interacted with drinking water flowing in the pipes. The data analysis was restricted to a subset of elements that were of particular interest based

on either their regulation as drinking water contaminants, or as probable important species playing a major role in corrosion control interactions.

## Results

**Contaminant Concentrations.** Contaminants are separated into four arbitrary categories reflecting approximate order-of-magnitude groupings, based on average concentrations. Average concentrations ranging from 0 to 99 mg/kg are categorized as “minimal”, from 100 to 999 mg/kg are categorized as “minor”, from 1000 to 9999 mg/kg are categorized as “moderate”, and  $\geq 10\,000$  mg/kg are categorized as “major.” Table 3 shows a summary of the categories of contaminants and some of their respective descriptive distribution statistics. Frequency distributions are shown in Figures 3 and 5.

Complete results from elemental analyses of the 91 scale samples can be found in the Supporting Information. With the exception of three samples, Pb is the largest component in all the samples analyzed. This was expected considering all scale samples were harvested from Pb pipes. The exceptions are a sample with Al as its largest component, a sample with Fe as its largest component, and a sample with Mn as its largest component.

**Minimal Contaminants Group.** The concentration of As, Cd, Cr was over the reporting limit for 37, 34, and 81 of the 91 samples, respectively. Forty-eight, 53, and 9 results for As, Cd, and Cr, respectively, were above the detection limit but below the reporting limit. All samples contained Cr levels above the detection limit. Figure 2 shows the occurrence frequency across the concentration range (mg/kg) for results of As, Cd, and Cr that are above the reporting limit. Samples contain As concentrations as high as 426 mg/kg, Cd concentrations as high as 308 mg/kg, and Cr concentrations as high as 1290 mg/kg. Concentrations above the reporting limit for Hg exist in 23 of 29 samples, with concentrations up to 2 mg/kg.

**Minor Contaminants Group.** The contaminants Ba, Bi, Ni, and U comprise the minor contaminants group, with ICP analysis results for Ba, Bi, and Ni showing results over the reporting limit for 87, 49, and 65 of the 91 samples, respectively. Three, 28, 24, and 52 results for Ba, Bi, Ni, and U, respectively, are above the detection limit but below the reporting limit. All 91 samples contained Ba concentrations above the detection limit. Results for Bi were not available for 13 samples, 1 sample had no results for Ni, and 38 of the 91 samples had no results for U. Figure 3 shows the occurrence frequency across the concentration range (mg/kg) for concentrations above the reporting limit. Ba concentrations as high as 2850 mg/kg were found in the pipe samples, while Bi concentrations were as high as 1960 mg/kg, and Ni concentrations were as high as 1800 mg/kg.

**Moderate Contaminants Group.** ICP analysis results for Cu, Sn, V, and Zn show results over the reporting limit for 91, 49, 78, and 85 samples, respectively. Sulfur analysis was not conducted on all samples used in this study, as a result of limited sample volume. Nineteen results for Sn, 10 results for V, and four results for Zn are above the detection limits but below the reporting limits. All samples contained Cu concentrations above the reporting limit. Tin could not be analyzed in 20 samples. Cu concentrations were observed to be as high as 42 600 mg/kg, S concentrations were as high as 5972 mg/kg, Sn concentrations were as high as 9440 mg/kg, V concentrations were as high as 22 000 mg/kg, and Zn concentrations were as high as 24 700 mg/kg. Other research in this laboratory using X-ray absorption near-edge spectroscopy (to be reported in detail elsewhere) revealed that a primary mechanism of vanadium accumulation was in the form of the mineral vanadinite ( $\text{Pb}_5(\text{VO}_4)_3\text{Cl}$ ).

**Major Contaminants Group.** The contaminants Al, Fe, Mn, and Pb, which compose the major contaminants

**TABLE 2. Measurement Summary for NIST2872 Used for Analytical Quality Assurance**

element	true value	95% confidence value	mean observed value	observed std. dev.
	weight %	weight %	weight %	weight %
Al	1.37	±0.09	1.4	0.058
Fe	26.9	±0.7	26.8	0.346
Mn	0.03	NA	0.036	0.009
Pb	0.0574	±0.0011	0.064	0.005
Cu	0.2594	±0.0052	0.26	0.009
Zn	0.1254	±0.0196	0.132	0.005
	mg/kg	mg/kg	mg/kg	mg/kg
V	80	±10	81	3.1
Ba	254	±24	365	214
Ni	154.1	±3.1	153	5.77
As	166	±20	167	5.77
Cd	4.17	±0.09	4.5	2.2
Cr	109	±6	79	9.5

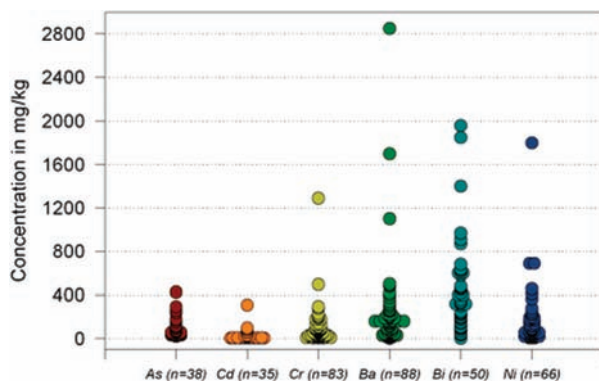
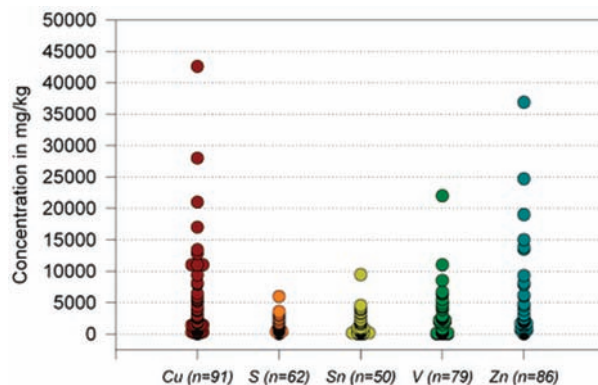
**TABLE 3. Contaminant Categorization and Some Summary Statistics**

contaminant category	contaminant	minimum (mg/kg)	maximum (mg/kg)	median (mg/kg)	average (mg/kg)	std. dev. (mg/kg)	n
minimal (0 to 99 mg/kg)	As	10.6	426	49	87	88	38
	Cd	2	308	6.4	28	55	35
	Cr	3	1290	40	83	156	82
	Hg	0.03	2	0.18	0.33	0.44	23
minor (100 to 999 mg/kg)	Ba	1	2850	105	199	368	88
	Bi	0.6	1960	320	422	417	50
	Ni	3	1800	57	129	242	66
	U		reporting limit <4000 mg/kg				53
moderate (1000–9999 mg/kg)	Cu	19	42600	967	3404	6335	91
	S	35	5972	949.8	1202	1054	62
	Sn	5	9440	345	1129	1741	50
	Zn	10	36900	612	2616	5705	86
major (≥ 10 000 mg/kg)	V	12	22000	302	1729	3208	79
	Al	29	44000	8400	11366	11258	73
	Fe	0.6	578000	19000	44722	79393	90
	Mn	7	177200	4960	17451	33148	91
	Pb	25600	915000	544600	530615	192414	91

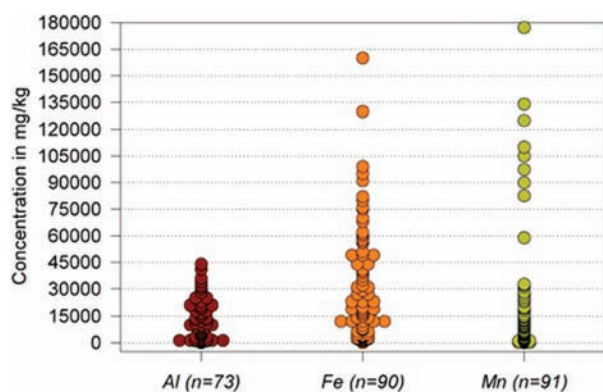
group, were present in the scale samples. ICP analysis results for Al, Fe, Mn, and Pb show results over the reporting limit for 72, 89, 91, and 91 samples, respectively. Four results for Al are above the detection limit but below the reporting limit. All samples contained Mn and Pb concentrations above the reporting limit. Samples contain Al concentrations as high as 44 000 mg/kg, Fe concentrations as high as 578 000 mg/kg, Mn concentrations as high as 177 200 mg/kg, and Pb concentrations as high as 915 000 mg/kg.

## Discussion

Contaminant accumulation in pipe scales is a complex process that can be influenced by various factors, including source water composition, type and order of treatment unit processes, pH, redox potential, and pipe composition (5, 11, 24). Research has shown that, in both natural and drinking water, desorption characteristics of elements such as Cd, Cr, Cu, and Zn are influenced by parameters similar to those often related to drinking-water quality (5, 14, 25, 26). The results shown here indicate that lead pipe scales can


**FIGURE 3. Frequency distribution of concentrations for minimal and minor contaminants.**

**FIGURE 4. Frequency distribution of concentrations for moderate contaminants. Note that 50 000 mg/kg represents 5% by weight.**





**FIGURE 5. Frequency distribution of concentrations for major contaminants.**

harbor several noxious contaminants across a range of concentrations and, depending on the contaminant, perhaps at levels that may pose a risk to consumers if mobilized into solution or released as particulates.

It is important to note that the samples used in this study were harvested from only a small portion of pipe, and extrapolation to sometimes tens of thousands of other lead service lines spread across a community water distribution system contains many uncertainties. Multiple samples were available from several utilities, but further analyses of within-system and between-system levels were not attempted because of their small number.

Different scale mineral compositions certainly have varying affinity for immobilizing different elements by an assortment of mechanisms, the relative importance of which is determined in large part by the background water composition, the physicochemical nature of the scale material, and the chemistry of the element (5, 11). However, with concentrations—from such small samples—of highly toxic contaminants such as As and Hg as high as 426 and 2 mg/kg, respectively, this work strongly suggests the possibility that these contaminants are accumulating in scales across entire distribution systems at levels of serious concern.

Lead pipe scales may accumulate metals via several different mechanisms, and this study establishes that in many water systems, in addition to the expected lead pipe corrosion byproduct solids, those lead pipes are coated with scales at the water contact that are entirely comprised of, or that contain, major fractions of iron, manganese, and sometimes aluminum oxyhydroxides. These compound families have a particular selectivity toward arsenic and some other metals relative to lead oxides, carbonates, and hydroxycarbonates. The results here suggest that, if in the case of As for example, monitoring distribution system entry points at treatment ensure maximum contaminant levels after treatment installation  $\leq 0.01$  mg/L, then As scale concentrations could provide a long-term reservoir to release back arsenic conceivably at levels equal to or greater than the MCL for an extended period of time.

Others have observed much higher levels of As accumulating in iron pipe, as would be geochemically expected from differences in lead and iron chemistry (2, 14). It is also important to note that many systems, particularly many smaller systems, are just now reaching compliance with the recent changes in the Arsenic Rule. These systems may be particularly susceptible to unobserved accumulation and release especially if undertaking treatment changes in order to reach compliance under the new Arsenic Rule, or to balance compliance with other regulatory requirements, such as Pb corrosion or disinfection/disinfection byproducts.

Elements or chemical species that would accumulate through relatively simple surface complexes logically would

be expected to have relatively reversible accumulation, and would thus be most sensitive to water quality variations such as pH ionic strength, carbonate and phosphate concentrations. If the mechanism of accumulation is via incorporation into a discrete solid phase crystal lattice, or through coprecipitation and enmeshment in the solid phase structure, presumably the accumulation would be less speedily reversible than surficial mechanisms. Depending on the volume of the scale, depth of incorporation of the contaminant metal, the solid phase characteristics, and the type of water chemistry change, prolonged release for years to decades could be possible.

The discovery of nearly percent levels of vanadium in pipes from many geographically diverse systems raises interesting questions to consider if a regulation is eventually developed for vanadium in drinking water.

Periodic hydraulic disturbances or sudden water quality changes could conceivably cause contaminant concentrations to quickly exceed the levels of existing MCLs, especially with substantial microparticulate release. Currently, the only indication of this occurrence and consumer protection would be if the water quality were deteriorated sufficiently to generate aesthetic concerns from consumers concurrently with the contaminant release. Only in rare instances would health effects from these contaminants be acute enough to cause immediate illness that could be associated with the disturbance event. More likely, and of unknown impact, would be long-term intermittent exposures that might contribute to chronic illness, which could easily go undetected. Long after treatment changes were in place, there could be a legacy of exposure. The results of this study indicate that monitoring techniques for contaminants beyond Pb and Cu need re-evaluation to better assess and reflect the extent and locations of accumulation of contaminants in scales in the diverse array of distribution system materials.

Though all scale samples in this study were also analyzed by powder X-ray diffraction, no crystalline solid phases of the moderate contaminant group or below were detected or identified. Further research using more sensitive and appropriate analytical methodologies is needed to better identify and understand speciation of the contaminants and mechanisms of the accumulation across larger arrays of water chemistries, and what chemical and hydraulic factors directly contribute to contaminant accumulation or release into the drinking water. This line of research could model and test the hypotheses of the specific chemical reactions affecting accumulation and release, and hence, the relative vulnerability of the contaminants to solubilization or other release mechanisms into the water. This would help characterize and estimate human risk, and serve to support refinement of drinking-water regulatory monitoring strategies to be more accurate and protective of public health.

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## Supporting Information Available

Tabular and statistical summaries of sample concentrations above the reporting limit, as well as those above the detection limit but below the reporting limit, along with some information on time of service for samples where data was furnished. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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## Supporting Information For:

### The Occurrence of Contaminant Accumulation in Lead Pipe Scales from Domestic Drinking-Water Distribution Systems

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Eight pages containing three tables:

**Table S1-S1. ICP-AES reporting limits for elements of interest**

**Table S1-S2. Sample concentrations above the reporting limit and summary statistics**

**Table S1-S3. Sample concentrations above the detection limit but below the reporting limit**

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**Table S1-S1. Respective ICP-AES reporting limits for elements of interest**

Element	Hg (mg/kg)	Al (mg/kg)	As (mg/kg)	Ba (mg/kg)	Bi (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	S (mg/kg)	Sn (mg/kg)	Th (mg/kg)	U (mg/kg)	V (mg/kg)	Zn (mg/kg)
Reporting Limit *	0.1	11	1	5	0.04	0.1	1	0.5	10	5	0.5	0.5	10	0.1	0.2	0.1	1	1

\* The reporting limit is determined, per Briggs, 2002, based on a 0.200g sample. As stated in-text, consistently low reporting limits for all samples were not always achievable due to the scarcity of sample material. Conversely, when a relative abundance of sample was available lower reporting limits were achievable.

**Key for Tables S1-S2 and S1-S3****<RL** = Less than the Reporting Limit**NA** = Not analyzed (due to insufficient amount of sample)**R** = Above the detection limit but flagged by laboratory as an unreliable concentration value**Table S1-S2. Sample concentrations above the reporting limit and summary statistics**

Pipe Sample ID	Length of service (years) <sup>1</sup>	HgCVAA Hg (mg/kg)	ICP 40 Al (mg/kg)	ICP40 As (mg/kg)	ICP40 Ba (mg/kg)	ICP40 Bi (mg/kg)	ICP40 Cd (mg/kg)	ICP40 Cr (mg/kg)	ICP40 Cu (mg/kg)	ICP40 Fe (mg/kg)	ICP40 Mn (mg/kg)	ICP40 Ni (mg/kg)	ICP40 Pb (mg/kg)	EPA S (mg/kg)	ICP40 Sn (mg/kg)	ICP40 V (mg/kg)	ICP40 Zn (mg/kg)
CTBFEM3 L2	63	0.1	3800	<RL	420	<RL	<RL	<RL	940	35000	2740	<RL	703000	NA	3260	330	3040
CTNBDA1 L2	68	NA	<RL	<RL	84	680	<RL	22	1200	2000	1600	<RL	685000	NA	<RL	600	780
CTNBH11 L2	105	NA	2400	<RL	25	88	<RL	51	3860	12000	921	20	670700	922	3980	788	154
CTNBNO1 L2	114	NA	200	<RL	74	1850	2.4	3.4	1290	800	23	<RL	683900	2356	124	14	20
CTNHFO1 L1	50	0.06	28000	<RL	220	<RL	<RL	88	2820	40000	32600	55	288000	NA	310	150	4790
CTNHHA1 L1	>100	0.31	15000	<RL	1100	<RL	<RL	33	13400	19000	28200	<RL	438000	NA	9440	1900	9300
CTNHYA2 L1	82	NA	21000	<RL	1700	600	<RL	<RL	5260	578000	125000	140	194000	NA	940	<RL	24700
DC13NE1 L1	60	NA	23000	64	142	100	3.6	72	21000	23000	18000	455	533100	128	48	6690	981
DC2SE1 L1	UNK	NA	30000	71	160	NA	<RL	180	12800	3400	14600	223	536000	1338	170	4440	6190
DC39NW1 L1	72	NA	17000	42	150	NA	<RL	280	2530	29000	8340	58	676000	35	16	6540	643
DCADMNW1 L1	UNK	NA	32000	45	285	68	3.6	47	11000	49000	27000	363	406100	681	NA	5480	770
DCAMENE1 L2	UNK	NA	11000	41	203	251	2.2	82	11000	0.61	2570	54	501900	1619	NA	4370	891
DCFANW1 L1	67	NA	9000	43	62	NA	<RL	110	2680	12000	9510	56	748000	NA	<RL	4280	409
DCGASW1 L1	UNK	NA	25000	110	262	43	<RL	294	28000	27000	24000	414	411700	397	NA	22000	982
DCGASW2 L1	UNK	NA	25000	33	206	<RL	<RL	89	5920	18000	4960	89	406300	NA	NA	4870	347
DCHENW1 L1	76-78	NA	13000	<RL	57	<RL	<RL	96	1300	840	5330	56	690000	NA	170	2760	310
DCHENW2 L1	76-78	NA	8400	<RL	35	<RL	<RL	64	820	7400	2460	<RL	752000	455	220	1900	260
DCJENNW1 L1	UNK	NA	13000	34	184	35	<RL	36	802	2400	13000	50	547900	1247	159	2910	247
DCLNE1 L1	79	NA	10000	46	120	NA	<RL	130	8050	2200	6490	78	814000	370	<RL	4310	454
DCMONW1 L1	90-97	NA	36000	<RL	160	<RL	<RL	210	6450	4000	2860	69	411000	472	210	3900	2950
DCNCANE1 L1	UNK	NA	31000	98	250	96	<RL	102	17000	51000	11000	184	414900	2045	NA	11000	559
DCRNW1 L1	UNK	NA	41000	150	320	<RL	<RL	230	9380	1700	19100	190	406000	391	130	6330	1700
DCRNW2 L2	81	NA	34000	43	220	<RL	<RL	55	3700	80000	12400	190	468000	686	270	1500	810
DCRNW3 L2	82	NA	18000	70	189	108	3.3	129	11000	70000	20000	199	522000	132	40	8500	744
DCWAR1 L1	UNK	NA	18000	NA	124	45	3.5	49	579	23000	14000	116	552100	345	NA	2560	929
MAALAS1 L1	91	NA	3100	240	100	<RL	<RL	82	1500	99000	5500	<RL	269000	NA	<RL	44	220



MABOHA1 L1	~91	0.14	NA	NA	222	NA	NA	21	3940	56000	12600	51	156000	1089	120	60	2130
MABOMER1 L1	UNK	0.27	NA	170	17	<RL	<RL	31	1690	23000	2170	12	584000	2445	1570	100	242
MABOPUT1 L1	91	NA	9000	<RL	89	<RL	<RL	45	5500	14000	1400	<RL	418000	NA	940	NA	140
MABOUNK1 L1	UNK	0.17	1300	<RL	40	360	<RL	<RL	180	2600	170	<RL	793000	3002	550	<RL	560
MABOUNK2 L1	UNK	NA	29	<RL	140	610	<RL	27	1400	44000	4090	<RL	665000	NA	490	100	880
MABOUNK3 L1	UNK	0.03	3300	<RL	170	600	<RL	29	1500	44000	5640	<RL	658000	1152	370	140	370
MABOWDS1 L1	UNK	0.29	1500	<RL	170	<RL	<RL	<RL	2760	9800	3060	<RL	670000	1016	<RL	41	430
MABRAN1 L1	94	NA	21000	<RL	160	200	<RL	22	210	12000	400	<RL	399000	NA	<RL	NA	170
MABRASH1 L2	95	NA	21000	NA	160	320	NA	NA	190	2900	520	NA	692000	NA	NA	NA	58
MABPRAR L2	UNK	NA	<RL	NA	56	340	<RL	32	930	7800	5900	<RL	682000	NA	400	94	97
MABRWE1 L1	UNK	NA	1300	<RL	29	320	<RL	<RL	1000	3300	660	<RL	576000	NA	<RL	<RL	94
MACAUNK1=MAC ACAM1 L1	71	NA	11000	58	160	NA	97	200	8140	57000	110000	84	403000	NA	741	2680	6070
MACAUNK2 L1	77	NA	16000	58	266	NA	33	190	334	91000	134000	170	417000	NA	140	2630	13800
MACAUNK2=MAC ACAM2 L1	77	NA	14000	42	260	870	30	180	290	130000	105000	170	382000	1085	150	2400	13500
MADORASM1 L1	UNK	0.34	NA	44	100	<RL	<RL	28	837	82000	570	16	757000	1691	548	29	580
MADORHOP L1	102	0.16	NA	180	44	<RL	6	27	5830	251000	1510	19	339000	NA	16	120	741
MADORNOR1 L1	UNK	0.15	20000	<RL	340	<RL	<RL	32	42600	31000	4060	<RL	410000	3032	<RL	73	400
MADORROX1 L1	85	2	NA	31	54	320	<RL	16	967	4100	1060	4	816000	839.1	4220	17	489
MADORSPI L2	93	NA	<RL	<RL	<RL	400	<RL	<RL	290	95000	940	<RL	604000	2475	170	<RL	<RL
MADORSUM1 L1	UNK	0.09	NA	426	33	NA	6.9	75	1430	241000	10400	26	349000	NA	34	300	411
MADORWM1 L1	UNK	NA	1000	<RL	43	300	<RL	20	130	1500	63	<RL	614000	811.6	<RL	<RL	<RL
MAFRALB1 L1	UNK	NA	500	<RL	34	633	5.8	4.9	571	2700	1040	67	772700	324.4	989	138	237
MAFRBAR1 L1	UNK	NA	1800	<RL	109	908	19	7.7	433	1100	9190	278	699300	510.9	2230	302	2340
MAFRCOU1 L1	UNK	NA	1300	<RL	<RL	<RL	<RL	5.7	281	15000	7.4	<RL	576800	1138	687	19	10
MAFRCUV1 L1	UNK	NA	900	<RL	24	<RL	6.2	10	780	1900	1630	118	723200	5972	2730	196	335
MAFRPAL1 L1	UNK	NA	1300	<RL	39	1960	13	10	327	2700	984	117	739400	2041	1710	110	761
MAFRPLY1 L1	UNK	NA	7700	94	19	97	<RL	20	1400	4200	104	19	504900	2909	<RL	85	88
MAFRUNK1 L1	UNK	0.54	NA	259	13	470	4.4	15	1930	17000	267	33	472000	359.2	3840	323	80
MAJPHOL1 L1	UNK	0.28	NA	293	304	NA	6.3	96	4410	248000	6410	32	299000	3272	90	180	737
MAMATCA1 L1	78	NA	NA	<RL	<RL	NA	<RL	26	290	6300	62	<RL	543000	3573	320	<RL	<RL
MANEFO1 L2	83	NA	1000	<RL	30	479	89	4.5	57	4600	1060	3.4	709400	213.2	NA	37	1890
MAREFRE1 L1	105	NA	10000	<RL	2850	150	23	14	389	49000	177200	688	86000	959	NA	237	541
MAROSALB1 L1	UNK	0.29	NA	32	43	400	<RL	9.6	842	6300	492	15	791000	1593	2050	13	41
MAROSPH1 L1	90	NA	1400	<RL	64	240	<RL	20	330	2200	1900	<RL	524000	NA	<RL	<RL	<RL
MAROXALB1 L2	UNK	1.2	NA	NA	83	40	NA	7.4	208	4600	410	10	824000	1515	214	12	35

MASPMAY1 L2	UNK	NA	1800	<RL	23	578	57	8.2	86	7900	63	5.9	660300	1533	NA	13	4500
MASPNO1 L1	83	NA	10000	<RL	402	628	56	34	352	10	623	23	392100	1163	NA	58	2410
MASPWAL1 L1	~86	NA	4500	<RL	85	194	77	22	136	32000	147	17	560800	757	NA	38	8120
MASPWES1 L1	~86	NA	5700	<RL	375	466	23	34	316	260000	740	38	364000	1301	NA	41	15000
MASPWEX1 L1	UNK	NA	5200	33	482	967	308	28	578	76000	4200	39	467700	1246	NA	50	19000
MAWEST1 L1	UNK	0.21	NA	31	190	NA	6.7	89	570	2400	58900	81	327000	361	<RL	110	3820
MAWEWAS1 L1	UNK	0.18	NA	<RL	288	NA	5.4	56	430	37000	25400	56	156000	NA	<RL	83	2490
MAWEWAS2 L1	UNK	0.17	NA	20	484	NA	7.2	55	729	60000	82600	140	140000	1774	<RL	81	7840
MAWRAVA1 L1	~73	0.13	19000	<RL	200	<RL	<RL	23	420	12000	1100	<RL	537000	NA	<RL	<RL	2000
MILARAD1 L2	72	NA	8700	<RL	63	<RL	<RL	46	400	39000	11100	93	222000	335	170	140	1100
MILARAN1 L1	64	NA	2000	38	160	140	<RL	10	330	68000	19800	49	354000	NA	86	50	74
NYRORI1 L1	107	NA	4400	57	6.5	NA	<RL	18	7930	75000	1300	12	915000	NA	4550	315	100
NYROTP1 L2	79	NA	14000	30	11	NA	<RL	92	1400	1800	3900	19	792000	1391	3360	774	67
OHICAT1 L1	UNK	NA	3300	<RL	160	<RL	<RL	79	240	12000	2400	73	737000	558	460	2200	390
OHCOLA L1 <sup>2</sup>	UNK	NA	35900	10.6	29	0.59	3.29	8.19	188	3560	781	68.7	206000	NA	5.47	182	36900
OHOAKUNK2 L1	UNK	0.44	6500	<RL	190	<RL	<RL	<RL	1800	62000	32200	<RL	613000	1256	290	230	470
OHOAKUNK5 L1	UNK	0.04	44000	<RL	480	<RL	<RL	35	150	41000	2880	<RL	25600	204	810	75	89
RINPHE1 L1	112	NA	9500	<RL	47	220	<RL	60	1900	31000	16000	180	460000	NA	<RL	2700	1500
RINPHE2 L1	86	NA	12000	<RL	32	1400	<RL	44	3000	27000	9000	230	540000	591	1900	2200	1700
RINPVR1 L1	91	NA	8300	76	27	327	5.2	58	1880	61000	31000	119	628200	NA	<RL	3880	964
RIPRHE1 L1	106	NA	1400	<RL	30	455	6	1290	413	58000	8220	31	544600	1560	NA	581	83
RIPRHIL1 L1	81	NA	1400	<RL	17	<RL	7.7	20	727	20000	23000	252	620600	941	NA	760	72
RIPRLO1 L1	76	NA	1300	<RL	13	90	5.3	6.7	194	14000	9550	13	637300	465	NA	544	96
RIPRLOR1 L1	91	NA	5500	<RL	47	<RL	<RL	27	215	19000	15000	50	591400	696	NA	849	54
RIPRPRI1 L2	107	NA	400	<RL	47	<RL	<RL	107	273	3000	4460	27	687100	715	NA	666	46
RIPRVA1 L1	108	NA	6700	<RL	60	419	28	494	135	19000	7080	36	565800	634	NA	728	2300
WIMADJF1 L1	85-95	NA	2200	120	500	630	<RL	140	1100	160000	97400	1800	197000	369	<RL	140	1400
WIMAELI1 L3	UNK	NA	<RL	<RL	1.1	230	6.7	<RL	19	<RL	61	<RL	830000	59	NA	<RL	NA
WIMAVH2 L1	78-87	NA	1500	52	33	178	<RL	91	5320	49000	90000	68	506800	NA	NA	457	771
WIMAVN2 L2	UNK	NA	300	35	34	179	3.3	103	1830	16000	12000	14	630400	NA	NA	68	192
Minimum	50	0.03	29	10.6	1.1	0.59	2.2	3.4	19	0.61	7.4	3.4	25600	35.2	5.47	12	10
Maximum	114	2	44000	426	2850	1960	308	1290	42600	578000	177200	1800	915000	5972	9440	22000	36900
Count	50	23	73	38	88	50	35	82	91	90	91	66	91	62	50	79	86
Median	N/A	0.18	8400	49	104.5	320	6.4	40	967	19000	4960	57	544600	949.8	345	302	611.5
Average	N/A	0.33	11366.15	87.36	199.25	421.65	27.54	83.29	3403.71	44722.34	17451.41	129.18	530615.4	1202.20	1128.75	1729.3	2616.11

<sup>1</sup>The installation date of a pipe is not always know, but required to calculate years in service. The known years in service for pipe specimens are provided here.

<sup>2</sup>This sample contained concentrations above the reporting limit for both Th and U. Those concentrations were 0.685 and 20.4 ppm, respectively.



**Table S1-S3. Sample concentrations above the detection limit but below the reporting limit**

Pipe Sample ID	Length of service (years) <sup>1</sup>	ICP 40 Al (mg/kg)	ICP40 As (mg/kg)	ICP40 Ba (mg/kg)	ICP40 Bi (mg/kg)	ICP40 Cd (mg/kg)	ICP40 Cr (mg/kg)	ICP40 Fe (mg/kg)	ICP40 Ni (mg/kg)	ICP40 Sn (mg/kg)	ICP40 U (mg/kg)	ICP40 V (mg/kg)	ICP40 Zn (mg/kg)
CTBFEM3 L2	63	R	<200	R	<200	<40	<20	R	<40	R	<1000	R	R
CTNBND1 L2	68	<0.1	<200	R	R	<40	R	R	<40	<100	NA	R	R
CTNBNH1 L2	105	R	<30	R	R	<2	R	R	R	R	NA	R	R
CTNBNRO1 L2	114	R	<30	R	R	R	R	R	<3	R	<2000	R	R
CTNHFO1 L1	50	R	<200	R	<200	<40	R	R	R	R	<2000	R	R
CTNHHA1 L1	>100	R	<200	R	<200	<40	R	R	<40	R	<4000	R	R
CTNHYA2 L1	82	R	<400	R	R	<90	<40	R	R	R	NA	<90	R
DC13NE1 L1	60	R	R	R	R	R	R	R	R	R	<200	R	R
DC2SE1 L1	UNK	R	R	R	NA	<4	R	R	R	R	<200	R	R
DC39NW1 L1	72	R	R	R	NA	<4	R	R	R	R	NA	R	R
DCADMNW1 L1	UNK	R	R	R	R	R	R	R	R	NA	NA	R	R
DCAMENE1 L2	UNK	R	R	R	R	R	R	R	R	NA	<200	R	R
DCFANW1 L1	67	R	R	R	NA	<3	R	R	R	<8	NA	R	R
DCGASW1 L1	UNK	R	R	R	R	<2	R	R	R	NA	NA	R	R
DCGASW2 L1	UNK	R	R	R	<30	<2	R	R	R	NA	<2000	R	R
DCHENW1 L1	76-78	R	<200	R	<200	<40	R	R	R	R	<2000	R	R
DCHENW2 L1	76-78	R	<200	R	<200	<40	R	R	<40	R	NA	R	R
DCJENNW1 L1	UNK	R	R	R	R	<2	R	R	R	R	<200	R	R
DCLNE1 L1	79	R	R	R	NA	<4	R	R	R	<10	<2000	R	R
DCMONW1 L1	90-97	R	<200	R	<200	<40	R	R	R	R	NA	R	R
DCNCANE1 L1	UNK	R	R	R	R	<2	R	R	R	NA	<500	R	R
DCRNW1 L1	UNK	R	R	R	<50	<9	R	R	R	R	<400	R	R
DCRNW2 L2	81	R	R	R	<40	<8	R	R	R	R	NA	R	R
DCRNW3 L2	82	R	R	R	R	R	R	R	R	R	NA	R	R
DCWAR1 L1	UNK	R	NA	R	R	R	R	R	R	NA	<1000	R	R
MAALAS1 L1	91	R	R	R	<200	<40	R	R	<40	<100	NA	R	R
MABOHA1 L1	~91	NA	NA	R	NA	NA	R	R	R	R	<200	R	R
MABOMER1 L1	UNK	NA	R	R	<20	<4	R	R	R	R	<1000	R	R
MABOPUT1 L1	91	R	<200	R	<200	<40	R	R	<40	R	<2000	R	R
MABOUNK1 L1	UNK	R	<200	R	R	<40	<20	R	<40	R	<2000	<40	R
MABOUNK2 L1	UNK	R	<200	R	R	<40	R	R	<40	R	<2000	R	R
MABOUNK3 L1	UNK	R	<200	R	R	<40	R	R	<40	R	<2000	R	R

MABOWDS1 L1	UNK	R	<200	R	<200	<40	<20	R	<40	<100	<1000	R	R
MABRAN1 L1	94	R	<200	R	R	<40	R	R	<40	<100	NA	<40	R
MABRASH1 L2	95	R	NA	R	R	NA	NA	R	NA	NA	<1000	NA	R
MABPRAR L2	UNK	<0.1	NA	R	R	<40	R	R	<40	R	<1000	R	R
MABRWE1 L1	UNK	R	<200	R	R	<40	<20	R	<40	<100	<200	<40	R
MACAUNK1=MACA CAM1 L1	71	R	R	R	NA	R	R	R	R	R	NA	R	R
MACAUNK2 L1	77	R	R	R	NA	R	R	R	R	R	<400	R	R
MACAUNK2=MACA CAM2 L1	77	R	R	R	R	R	R	R	R	R	<200	R	R
MADORASM1 L1	UNK	NA	R	R	<20	<4	R	R	R	R	<200	R	R
MADORHOP L1	102	NA	R	R	<20	R	R	R	R	R	<2000	R	R
MADORNOR1 L1	UNK	R	<200	R	<200	<40	R	R	<40	<100	<200	R	R
MADORROX1 L1	85	NA	R	R	R	<4	R	R	R	R	<1000	R	R
MADORSPI L2	93	<0.1	<200	<20	R	<40	<20	R	<40	R	<200	<40	<40
MADORSUM1 L1	UNK	NA	R	R	NA	R	R	R	R	R	<1000	R	R
MADORWM1 L1	UNK	R	<200	R	R	<40	R	R	<40	<100	NA	<40	<40
MAFRALB1 L1	UNK	R	<30	R	R	R	R	R	R	R	NA	R	R
MAFRBAR1 L1	UNK	R	<30	R	R	R	R	R	R	R	NA	R	R
MAFRCOU1 L1	UNK	R	<30	<1	<30	<2	R	R	<3	R	NA	R	R
MAFRCUV1 L1	UNK	R	<30	R	<30	R	R	R	R	R	NA	R	R
MAFRPAL1 L1	UNK	R	<30	R	R	R	R	R	R	R	NA	R	R
MAFRPLY1 L1	UNK	R	R	R	R	<2	R	R	R	<20	<200	R	R
MAFRUNK1 L1	UNK	NA	R	R	R	R	R	R	R	R	<200	R	R
MAJPHOL1 L1	UNK	NA	R	R	<20	R	R	R	R	R	<1000	R	R
MAMATCA1 L1	78	NA	<200	<20	<200	<40	R	R	<40	R	NA	<40	<40
MANEFO1 L2	83	R	<30	R	R	R	R	R	R	NA	NA	R	R
MAREFRE1 L1	105	R	<30	R	R	R	R	R	R	NA	<200	R	R
MAROSALB1 L1	UNK	NA	R	R	R	<4	R	R	R	R	<1000	R	R
MAROSPH1 L1	90	R	<200	R	R	<40	R	R	<40	<100	NA	<40	<40
MAROXALB1 L2	UNK	NA	NA	R	R	NA	R	R	R	R	NA	R	R
MASPMAY1 L2	UNK	R	<30	R	R	R	R	R	R	NA	NA	R	R
MASPNO1 L1	83	R	<30	R	R	R	R	R	R	NA	NA	R	R
MASPWAL1 L1	~86	R	<30	R	R	R	R	R	R	NA	NA	R	R
MASPWES1 L1	~86	R	<30	R	R	R	R	R	R	NA	NA	R	R
MASPWEX1 L1	UNK	R	R	R	R	R	R	R	R	NA	<200	R	R
MAWEST1 L1	UNK	NA	R	R	NA	R	R	R	R	<10	<200	R	R

MAWEWAS1 L1	UNK	NA	<20	R	NA	R	R	R	R	<10	<200	R	R
MAWEWAS2 L1	UNK	NA	R	R	NA	R	R	R	R	<10	<2000	R	R
MAWRAVA1 L1	~73	R	<200	R	<200	<40	R	R	<40	<100	<400	<40	R
MILARAD1 L2	72	R	<40	R	<20	<7	R	R	R	R	<200	R	R
MILARAN1 L1	64	R	R	R	R	<4	R	R	R	R	<200	R	R
NYRORI1 L1	107	R	R	R	NA	<4	R	R	R	R	<200	R	R
NYROTP1 L2	79	R	R	R	NA	<3	R	R	R	R	<3000	R	R
OHCICAT1 L1	UNK	R	<300	R	<300	<60	R	R	R	R	<4000	R	R
OHOAKUNK2 L1	UNK	R	<400	R	<400	<70	<40	R	<70	R	<2000	R	R
OHOAKUNK5 L1	UNK	R	<200	R	<200	<40	R	R	<40	R	<1000	R	R
RINPHE1 L1	112	R	<200	R	R	<40	R	R	R	<100	<1000	R	R
RINPHE2 L1	86	R	<200	R	R	<40	R	R	R	R	NA	R	R
RINPVR1 L1	91	R	R	R	R	R	R	R	R	<20	NA	R	R
RIPRHE1 L1	106	R	<30	R	R	R	R	R	R	NA	NA	R	R
RIPRHIL1 L1	81	R	<30	R	<30	R	R	R	R	NA	NA	R	R
RIPRLO1 L1	76	R	<30	R	R	R	R	R	R	NA	NA	R	R
RIPRLOR1 L1	91	R	<30	R	<30	<2	R	R	R	NA	NA	R	R
RIPRPRI1 L2	107	R	<30	R	<30	<2	R	R	R	NA	NA	R	R
RIPRVA1 L1	108	R	<30	R	R	R	R	R	R	NA	<200	R	R
WIMADJF1 L1	85-95	R	R	R	R	<4	R	R	R	<10	NA	R	R
WIMAEI1 L3	UNK	<0.005	<30	R	R	R	<2	<0.005	<3	NA	NA	<2	R
WIMAVH2 L1	78-87	R	R	R	R	<2	R	R	R	NA	NA	R	R
WIMAVN2 L2	UNK	R	R	R	R	R	R	R	R	NA	NA	R	R
Count		4	48	3	28	53	8	1	24	18	52	10	4