Metals Sampling in Groundwater at Small-size Construction and Demolition Landfills

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Summary

Dissolved metals concentrations in groundwater near construction and demolition waste landfills in northern and western Wisconsin indicate leachate is adversely affecting groundwater quality at many of these locations, but only to a limited degree. Of 18 facilities examined, exceedances of at least one ch. NR 140, Wis. Adm. Code groundwater health-based quality standard were observed at 17 facilities. The metals observed to exceed health-based enforcement standards in groundwater downgradient from the C&D landfills in this project were boron, cobalt, manganese, nickel and thallium. Aluminum, arsenic, cadmium and vanadium were observed to exceed NR 140 preventive action limits, but not enforcement standards. This study also provided evidence that routine monitoring of indicator characteristics like conductivity and hardness is an effective method of evaluating the potential for groundwater quality impacts from metals with health- or welfare-based groundwater quality standards. In addition, study results indicate capping of these landfills after closure serves to limit the infiltration of metals into the groundwater. The DNR recommends confirmation sampling at facilities with exceedances, and, where exceedances are confirmed, modifications of the facility's groundwater monitoring program to allow continued evaluation of trends in concentrations and avoid potential groundwater-related health impacts from small C&D landfills.

Purpose

The Department of Natural Resources (DNR) staff conducted groundwater sampling for metals at several small-size construction and demolition waste (C&D) landfill facilities during 2020-2021. The DNR's primary goal in obtaining metals data at groundwater monitoring wells for small C&D landfills was to evaluate whether certain metals show up in groundwater because of impacts from the waste accepted at small C&D landfills. Many small C&D landfills already routinely collect groundwater samples for health-based substances such as volatile organic compounds (VOCs) but not typically for metals. The DNR's focus for this study was to evaluate the metals results in groundwater at actively operating and previously closed small C&D landfills.

Small-Size C&D Landfills in Wisconsin

The Wisconsin DNR regulates small-size C&D landfills under s. NR 503.09, Wis. Adm. Code. To site a small C&D landfill, the facility owner or operator must meet certain locational criteria, such as the minimum separation distance to water supply wells, and meet performance standards such as groundwater quality standards. The DNR requires the facility owner or operator to have an approved plan of operation prior to constructing and operating a small C&D landfill. The DNR attempts to inspect the construction events at small C&D landfills and attempts to conduct compliance inspections semiannually during the active facility life. Under current rules, the DNR requires sampling groundwater monitoring wells at small C&D landfills.

Samples must be analyzed at a lab certified by the DNR, and the results must be electronically submitted to the DNR's groundwater and environmental monitoring system (GEMS) database, which is accessible to the public.

Wisconsin's small C&D landfills are constructed as natural attenuation landfills and do not have liners. As natural attenuation landfills, they rely on the underlying soils to filter, absorb, or otherwise minimize landfill leachate impacts to groundwater. Small C&D landfills are limited to a maximum volume of 50,000 cubic yards for waste including daily or intermediate cover soils. Cover soils are typically used only as needed at small C&D landfills. To minimize the effects of contaminants from landfill leachate after landfill closure, landfill owners or operators must follow requirements for final cover soil placement. Restrictions such as maintaining a separation distance to the groundwater table, implementation of a waste screening plan for incoming loads and maintenance of a separation distance between small C&D landfills are also intended to minimize the environmental impacts of small C&D landfills.

The C&D waste screening plan only allows for disposal of solid waste from the construction, demolition or razing of buildings, roads, and other structures. Such waste typically consists of concrete, bricks, bituminous concrete, wood, glass, masonry, roofing, siding and plaster, alone or in combination. It does not include waste paints, solvents, sealers, adhesives or similar materials. It also does not include rolled or loose carpet (not attached to the subflooring), damaged or rejected manufacturing products such as off-specification manufactured wood, cut lumber ends from truss factories, or broken glass from window factories.

Many of the small C&D landfills in this study are located in previously excavated sand and gravel pits that internally drain. While small C&D landfills do not have a liner, they are required to maintain a separation distance of 10 feet to groundwater or bedrock from the landfill base unless located in a fine-grained soil environment. Some small C&D landfills located in clayey soil environments have a sump or standpipe installed in the waste to prevent the waste from becoming saturated and to allow for leachate to be pumped and hauled to a permitted wastewater treatment plant for proper disposal.

Current rules prohibit small C&D landfills from being located closer than ¼ mile from another C&D landfill. The minimum setback from the landfill to a water supply well is 1,200 feet, and the landfill must be at least 100 feet from the property line. Surface water setbacks are 300 feet from a navigable stream and 1,000 feet from a surface water body. Small C&D landfills must also meet performance standards such as not causing impairments to surface water quality and groundwater quality. In addition, no small C&D landfill can be sited in a location that would have an adverse impact to wetlands or critical habitat.

Final covers at small C&D landfills are required to have maximum 33% side slopes and minimum 2% top slopes; however, the DNR recommends a minimum 5% top slope to shed water off the cover faster and to reduce infiltration into and through the waste. The minimum thickness of final cover is two feet of fine-grained soil overlain by six inches of topsoil. In the past few years, the DNR has approved some small C&D landfills where there is limited or no availability of fine-grained soils to close with a thicker final cover of coarse-grained soil (sand) and steeper top slopes in lieu of two feet of fine-grained soil. Previously, the DNR had allowed small C&D landfills to close with two feet of course-grained soil readily

available onsite.

The groundwater monitoring network at a typical small C&D landfill has three or four groundwater monitoring wells screened at the water table surface. Sampling is conducted semiannually for field parameters (specific conductance, pH and temperature) and select inorganics (alkalinity, chloride, hardness, and sulfate). Chemical oxygen demand (COD) is required by code to be sampled; however, most small C&D landfills have agreed with the DNR to swap COD monitoring for annual VOC sampling. For the past 14 years the DNR has recommended to owners and operators of proposed small C&D landfills to conduct baseline groundwater monitoring for boron to determine background concentrations prior to construction and operation of their small C&D landfills.

Metals Sampling

Between October 2020 to November 2021, during the routine groundwater sampling events at **18** small C&D landfill facilities, DNR staff collected groundwater samples for analysis of 27 metals/metalloids along with hardness, alkalinity, chloride, and sulfate.

Many of the small C&D landfill facilities sampled have at least three groundwater monitoring wells with one upgradient and two downgradient wells. At the time of sampling, **five facilities were actively** operating and **13 were closed** with final cover. The closed landfills have closure dates ranging from 1997 to 2017. The active landfills have operational start dates ranging from 1992 to 2016.

Sampling conducted by DNR staff at these facilities coincided with the facilities' regularly scheduled sampling events. This presented the opportunity for DNR staff to observe sampling procedures conducted by various sampling firms across the northern and western part of the state, where Wisconsin's small C&D landfills are predominantly located. There was no order to when the facilities were chosen to be sampled but rather the facilities were selected based on availability of staff during the facilities' regularly scheduled sampling events. Many of the facilities chosen to be sampled by DNR staff were scheduled to have a compliance inspection completed during the year. There were no formal criteria for choosing these particular facilities to be sampled other than that these facilities have groundwater monitoring requirements.

<u>Metals Analyzed</u>

This study included an analysis of a total of 27 metals/metalloids. The primary focus of this study was on arsenic, boron and manganese, based on results from a groundwater study by the Minnesota Pollution Control Agency (MPCA) of C&D landfills in Minnesota. Nineteen of these metals analyzed in this study have health related groundwater quality standards established in ch. NR 140, Wis. Adm. Code, Table 1, including the eight Resource Conservation Recovery Act (RCRA) Subtitle D metals arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Neither strontium nor titanium have established NR 140 groundwater quality standards; however, strontium has proposed health standards as discussed below.

Three metals, iron, manganese and zinc, are considered substances of public welfare concern that have standards set for aesthetic reasons in NR 140 Table 2. Manganese is the only substance that is listed as both a health-related (NR 140 Table 1) substance and a substance of public welfare concern (NR 140 Table 2). Other metals/metalloids analyzed for include calcium, magnesium, potassium and sodium, none of which have NR 140 standards established but rather are considered indicator parameters listed in NR 140 Table 3.

As a quality check, the DNR collected samples for analysis of alkalinity, chloride, hardness and sulfate during the time the facility representatives were also collecting samples. The DNR found no significant discrepancies among these duplicated samples.

For a complete list of the parameters analyzed in this study along with applicable groundwater standards, see Table A.

Sampling Procedures

DNR staff pre-ordered bottles and sample preservative from the Wisconsin State Lab of Hygiene (WSLH). In general, DNR staff followed procedures found in the groundwater sampling desk reference (PUB DG 00037) and field manual (PUB DG 00038).

DNR staff completed the appropriate lab slips in advance of the sample event to the extent possible (e.g., sampler name, site name, tests requested, sample date, etc.). At time of sampling, DNR staff completed the remainder of the form (e.g., Sample Start Time and Field ID). Field ID included the facility's monitoring ID and the point ID for the well (e.g., 4468-3). At some sites, the common well name (e.g., 100MW) was used as the field ID. DNR staff filled sample bottles and completed an accompanying form at each well after purging activities were completed. The DNR's sample bottles were filled immediately after the facility's samples bottles were filled. In some cases, DNR staff completed a field duplicate sample. All samples collected by DNR staff were filtered in the field either by the sampling firm staff or by DNR staff

Nitric Acid Preservative

All metals samples were collected with 250 mL LDPE bottles and preserved in the field with nitric acid provided by the lab. All bottles and preservative were ordered in advance usually about a month before but not more than two or three months prior to sampling.

Early in the project, for some sample results the lab reported a comment stating that acid traceability was not known. For those samples the expiration of the nitric acid preservative used was not written on the lab form or the vial was expired. The lab considers acid preservative more than two years old to be expired; however, the lab indicated that expired acid is viable for several years and can be used beyond its expiration as a preservative for non-enforcement samples.

Lab Analysis

Once filled, sample bottles and lab slips were packaged in sealed hard-sided coolers packed with ice and shipped to the State Lab of Hygiene from either the Spooner or Eau Claire DNR Service Center via Spee-Dee Delivery Service. All hold times were met, and sample preservation procedures were followed.

The Wisconsin State Laboratory of Hygiene conducted all analyses on the DNR's samples. Analysis of metals was completed using either Inductively Coupled Plasma- Atomic Emission Spectrometry (ICP-AES) or Graphite Furnace Atomic Absorption Spectroscopy (GFAA)—except mercury, which requires a different method (EPA 245.1).

Groundwater samples for 10 facilities taken at the start of the project were analyzed using ICP-AES until it was discovered that the laboratory detection limits – the limit of detection (LOD) or limit of quantitation (LOQ) or both – were greater than the respective NR 140 groundwater standards for antimony, arsenic, beryllium, lead, selenium, and thallium. Lower lab detection limits could be achieved using GFAA. Samples taken at eight facilities near the latter half of the project were analyzed using GFAA for these six metals in an effort to achieve the project objective to identify those metals with results that may exceed NR 140 groundwater quality standards.

Lab Quantitation Limits

For some substances, the lab reported concentrations between the LOD and LOQ; those results are flagged. A result greater than the lab LOQ is considered a valid result for purposes of this study. For a result to be an exceedance of a groundwater quality standard, the result must be a valid result (above the lab LOQ) and in accordance with s. NR 140. 14 (3), Wis. Adm. Code.

Other parameters such as alkalinity, chloride and sulfate were collected using a 1-quart bottle provided by the lab. No preservative was necessary for these sample bottles. The results for the other parameters are included in this report.

Results

The DNR collected groundwater samples at 18 facilities as part of this study, and found metals concentrations in groundwater greater than the NR 140 PAL in at least one downgradient monitoring well at at least one facility for each of the following 10 metals: aluminum, arsenic, boron, cadmium, cobalt, iron, manganese, nickel, thallium, and vanadium. The DNR found concentrations of boron, cobalt, iron, manganese, nickel and thallium greater than the NR 140 ES in at least one downgradient monitoring well at at least one of the facilities sampled.

Table B summarizes the metals concentrations that were greater than the NR 140 PAL or ES in groundwater monitoring wells and compares the concentration between the upgradient and

downgradient wells at the closed and active small C&D landfills in this study. For purposes of this study, concentrations in Table B include the flagged results because they confirm the presence of the metal. For non-detect results a value of one- half the LOD was used to determine the average concentration.

Table C tallies the closed and active facilities and upgradient and downgradient groundwater monitoring wells with metals concentrations that exceeded the NR 140 PAL or ES. Table C includes *only* valid results (i.e., a concentration greater than the lab LOQ) and have an exceedance of an NR 140 PAL or ES.

Table D summarizes the metals concentrations that were below the NR 140 PAL and compares the concentration between the upgradient and downgradient wells sampled in this study.

Table F contains all the results sampled in this study.

Discussion of Results

The following discussion reviews the groundwater metals concentrations that exceeded either the enforcement standard (ES) or preventive action limit (PAL) established in ch. NR 140, Wis. Adm. Code. This discussion includes those sample concentrations flagged by the lab as lying between the laboratory limit of detection (LOD) and limit of quantitation (LOQ). For purposes of this discussion, all results having a concentration greater than the lab LOQ are valid results.

The discussion also compares the analytical results to the proposed changes by the Department of Health Services to NR 140 groundwater quality standards during the Cycle 10 revision process. For this study, the most notable of these changes is for boron, which would increase by a factor of two under Cycle 10.

Boron

Boron was found in groundwater at 12 of the 18 facilities sampled. Boron was found at a concentration greater than the NR 140 PAL in half of all the downgradient wells sampled (17 out of 33 wells). None of the upgradient wells sampled (18 wells) had boron at a concentration greater than the NR 140 PAL.

Boron impacts in groundwater at small C&D landfills can likely be attributed to landfilling activities including infiltration of leachate. Boron is not typically found in background water quality at levels greater than NR 140 PAL or ES. At least four small C&D landfills approved by the DNR since 2015 had collected baseline groundwater quality data for boron prior to landfill construction and operation. These four sites are located across north central and western Wisconsin in varying hydrogeological environments. Baseline monitoring at these four sites consisted of at least two sample rounds for boron and other metals including arsenic, cadmium, and manganese at upgradient and downgradient monitoring wells. One of the four facilities is included in this study. The three other facilities not included in this study were either not yet approved to begin accepting C&D waste or were not yet constructed.

For the five active small C&D landfills sampled as part of this study, the average concentration for boron was greater than the NR 140 ES in their downgradient wells. At one facility in Northwest Wisconsin, the boron concentration was reported 9.5 times the NR 140 ES of 1,000 ug/l which was also the maximum concentration found in groundwater at the small C&D landfills sampled. Three active facilities had boron concentrations in groundwater greater than the NR 140 ES; two had boron concentrations greater than the NR 140 proposed ES of 2,000 ug/L.

For the 13 closed small C&D landfills sampled, the average concentration for boron was between the NR 140 PAL and the ES in the downgradient wells. Three closed landfills had boron ES exceedances in a downgradient well. One closed landfill in Northwest Wisconsin had a boron concentration approximately eight times the ES. The same closed landfill had detections of several other metals at concentrations exceeding the NR 140 ES for cobalt, iron, manganese, nickel and thallium and exceeding the NR 140 PAL for arsenic, cadmium and vanadium.

Comparison of boron concentrations in downgradient wells between active and closed landfills suggests that final cover placement influences boron concentrations in groundwater. An example of where boron levels appear to correlate with landfill closure is at a site in northwestern Wisconsin, where five small C&D landfills are located in proximity to each other about one-quarter mile apart. The groundwater monitoring wells for each of the five landfills are screened in silty sand and gravel and have water levels typically 30 to 40 feet below ground surface. The boron levels were highest in the downgradient monitoring wells at the active landfills and substantially lower in the downgradient wells at the four closed landfills, which have been closed for several years or decades. Each of the closed landfills operated for similar duration and were developed in sequence. Boron levels in groundwater at the oldest closed landfill were below the NR 140 PAL, while at the other closed landfills, boron was detected above the PAL but below the ES.

There may be a correlation between the very low boron levels found in groundwater and the separation distance to groundwater from the landfill base grade (or bottom of waste). For example, boron concentrations were found to be less than the NR 140 PAL at one active small C&D landfill in northern Wisconsin located on the same property as two closed small C&D landfills separated one-quarter mile apart. Only one of the two closed landfills had a downgradient boron level greater than the NR 140 PAL and below the ES. All three landfills have monitoring wells set in the same unconsolidated unit with a depth to groundwater approximately one hundred feet below ground surface. Not surprisingly, the greater depth to groundwater appears to minimize the potential impacts to groundwater quality from the landfill, compared to active and closed landfills in this study with less separation to groundwater.

Also, placement of the downgradient monitoring wells in relation to the waste may be a factor in detecting metals in groundwater from landfill impacts. For example, at some landfills, the downgradient monitoring wells are located farther away from waste limits or located in a side-downgradient position rather than directly downgradient from the waste mass.

Boron and Indicator Parameters

There may be a correlation between the concentrations of boron and indicator parameters such as alkalinity, hardness and specific conductance, routinely collected in groundwater water samples at small C&D landfills. The facilities that have boron exceedances of the NR 140 ES also typically had a history of exceedances of the PAL for some indicator parameters, confirming that the routine monitoring parameters that the DNR currently requires can indeed indicate the potential for public health or welfare impacts to groundwater.

The three active small C&D landfills that had boron exceeding the ES in a downgradient well also had exceedances of indicator PALs (calculated for alkalinity, hardness and specific conductance). Three of the 13 closed facilities that had boron exceeding the ES in a downgradient well also had elevated indicator parameter levels compared to the upgradient well. Of the six closed facilities that had boron concentration between the NR 140 PAL and the ES in a downgradient well, four had elevated levels of indicator parameters compared to the upgradient well.

Iron and Manganese

Boron and manganese are the predominant metals found in the downgradient wells at concentrations greater than NR 140 PAL at the small C&D landfills sampled in this study. Many of the wells with exceedances of the boron standards also have exceedances of the standards for manganese and, to a lesser extent, iron.

Concentrations of iron and manganese vary significantly in downgradient and upgradient wells. Manganese and iron occur naturally in aquifer formations statewide. At many landfills, manganese is found in baseline groundwater quality monitoring at concentrations many times greater than the NR 140 ES or PAL. Iron is not required to be sampled as part of baseline monitoring at small C&D landfills.

Unlike boron, both iron and manganese are redox sensitive in groundwater and can be mobilized by reducing conditions in groundwater caused by water quality changes. For this reason, iron and manganese can be indicators of groundwater impacts if background water quality is known at the site or baseline monitoring data are available for each well prior to the facility accepting waste.

Manganese is listed as both a public health and a public welfare substance in NR 140. Baseline sampling and analysis for manganese at small C&D landfills required in s. NR 503.09, Wis. Adm. Code, but the code does not require routine detection monitoring for manganese. Because of its relatively recent inclusion (circa 2011) in NR 140 as a health substance, the DNR has been including routine detection monitoring for manganese in recent approvals for small-size C&D landfills.

Iron, which is listed as a public welfare substance, is rarely utilized as an indicator of groundwater quality impacts at small C&D landfills. Because iron is naturally occurring, and because its form and concentrations in wells may be affected by bacterial activity, it may be less useful than other substances monitored as an indicator of groundwater impacts. Other parameters such as alkalinity, hardness, specific conductance and sulfate, which are required for baseline monitoring, are routinely monitored at small C&D landfills, and can be useful as indicators of groundwater impacts.

Strontium

Groundwater quality standards have not been established in NR 140 for strontium. The Department of Health Services has proposed an ES of 1,500 ug/l and a PAL of 150 ug/l for strontium. The small C&D landfills sampled in this study show concentrations of strontium in groundwater greater than the proposed PAL but below the proposed ES. Strontium concentrations in the downgradient wells at the active and closed facilities were greater than the upgradient wells, suggesting there may be some release of strontium to groundwater from some of the small C&D landfills.

Of the five active facilities sampled, three had a sample in at least one downgradient groundwater monitoring well that exceeded the proposed PAL for strontium. The three active landfills that have strontium in groundwater greater than the proposed PAL also have boron concentrations greater than the NR 140 ES for boron and for manganese.

The maximum concentration of strontium in the downgradient wells at the five active facilities was 484 ug/l, and the average was 186 ug/l, both of which are greater than the NR 140 proposed PAL of 150 ug/l. The upgradient wells had a maximum concentration of 142 ug/l and an average of 88.1 ug/l. The other two active facilities had detections of strontium in a downgradient groundwater monitoring well, but the observed concentrations were below the proposed PAL.

Of the 13 closed facilities, six had a sample in at least one downgradient groundwater monitoring well that exceeded the proposed PAL for strontium. Those six closed landfills also had manganese concentrations greater than the NR 140 ES for manganese as well as other metals such as boron, cadmium, cobalt and nickel exceeding its respective PAL or ES. The maximum concentration of strontium in the downgradient wells at the closed small C&D landfills was 652 ug/l, and the average concentration was 179 ug/l, both of which are greater than the proposed NR 140 PAL of 150 ug/l. The upgradient wells had a maximum concentration of 276 ug/l and an average of 110 ug/l. The remaining seven closed landfills had a strontium detection in a downgradient groundwater monitoring well, but the observed concentrations were below the proposed PAL.

Recommendations

The following recommendations should be considered (with additional discussion further below):

- Obtain sampling data at groundwater monitoring wells at small C&D landfills that do not have data available for the following ten metals: aluminum, arsenic, boron, cadmium, cobalt, manganese, nickel, strontium, thallium, and vanadium.

- For landfills having a confirmed metal exceedance in a downgradient monitoring well, summarize and evaluate any correlations between the metal exceedance and locational, operational, or design features.

- Continue to evaluate the metals data against detection monitoring data of other parameters in the

up and downgradient wells to identify whether there's a correlation between metals exceedances and other elevated detection parameter values.

- Use the information obtained in this study and any follow-up data and evaluations to assist in future rule revisions to ch. NR 503, Wis. Adm. Code, such as locational, and setback criteria and design, operational, and environmental monitoring requirements.

- Review the confirmation sampling data to help identify those metals to focus on for the facility's detection monitoring plan as well as identify improvements for baseline monitoring plans when siting new small C&D landfills. To date many of the facilities have conducted follow-up confirmation sampling and the lab chosen by the facility's sampling firm have typically used a method such as inductively coupled plasma- mass spectrometry (ICP-MS) that has lower lab limits than the NR 140 standards for many of the metals. Because of the concerns with the lab limits for some of the metals analyzed for this study being greater than the NR 140 such as with thallium using ICP-AES, the confirmation samples should be done using an analytical method with a limit of quantification below the analyte's PAL.

- Continue to evaluate metals data against the detection monitoring data collected at the facility's monitoring wells to identify whether there's a correlation between metals exceedances like boron and increasing indicator levels like alkalinity, hardness, and specific conductance or anions like sulfate and chloride in the downgradient wells.

- Summarize known locational and design features documented in the plans of operation and construction documentation of the existing small C&D landfills identified in this study such as the average depth to groundwater below the waste, aquifer characteristics (sand and gravel or fine grained), monitoring network (sufficient number and adequate location of monitoring wells and their distance to waste), final cover design (soil types and thicknesses), receptors downgradient of the landfill (nearby water supply wells) and property boundaries as it relates to point of standards application of NR 140 groundwater quality standards for the metals identified in this study.

- Evaluate correlation between the concentrations of elevated metals in groundwater identified in this study to the landfill's site characteristics like depth to groundwater and design features like final cover to assist in understanding the degree of impacts to groundwater from small C&D landfills, and if necessary, assist in future rule revisions to ch. NR 503, Wis. Adm. Code, such as locational, and setback criteria and design, operational, and environmental monitoring requirements.

<u>Update to Follow-up Sampling</u>

DNR staff have reached out to all the facilities in this study to inform them of the need to conduct follow-up sampling to confirm PAL and ES exceedances reported in the DNR's sampling. Many of the facilities have already conducted follow-up sampling and submitted the data electronically to the Groundwater and Environmental Monitoring System (GEMS) database.

For the landfills having confirmed exceedances of metals in the downgradient groundwater monitoring

wells, DNR staff have worked with those landfill owners on the next course of action. Many actively operating small C&D landfills have added boron and manganese, which have been found at levels greater than the NR 140 PAL in at least 2 consecutive sample rounds at many of the facilities identified in this study.

Some of those facilities have gone through closure or will be closing within the next few years and the DNR has added or will be adding boron, manganese, and other metals as needed to the detection monitoring plan to establish whether those concentrations in groundwater are stable or exhibiting increasing or decreasing trends.

As necessary, the DNR will continue to work with the facilities to adjust their landfill monitoring requirements to include metals identified as having NR 140 exceedances in groundwater. The small-size C&D landfills with a plan of operation approved since 2020 include annual sampling for arsenic, boron, and manganese as part of their detection monitoring.

Response to NR 140 Exceedances of Boron and Manganese

The DNR directed three active facilities to provide a response in accordance with s. NR 140.22, Wis. Adm. Code, for those metals having a confirmed exceedance in at least two sample rounds. As a result, three active facilities as part of this study are required to monitor for boron and other metals as part of their detection monitoring program to establish concentration trends.

Between 2022 and 2024, the three facilities reached approved waste grades and ceased to accept waste. These facilities have since installed an approved final cover to permanently close the landfill. In the future, the supplemental metals data obtained at these three landfills should be evaluated to confirm reductions in the concentrations of boron and other substances routinely monitored over time, with consideration given to the site-specific hydrogeology and landfill design features such as the final cover soils used at each facility.

Tables

A. Parameters Analyzed and Applicable Type of Groundwater Standards
B. Concentrations of Metals in Groundwater Monitoring Wells
C. Occurrence of Metals Exceedances in Groundwater Monitoring Wells
D. Non-Exceedance Concentrations of Metals in Groundwater Monitoring Wells
E. DHS Proposed Changes to NR 140 Groundwater Standards
F. All Sample Results

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USGS, 2009, Occurrence and Distribution of Iron, Manganese, and Selected Trace Elements in Ground Water and Glacial Aquifer System of Northern United States.

Table A: Parameters Analyzed and Applicable Type of Groundwater Standard

NR 140 Table 1 Public Health Substance	NR 140 Table 2 Public Welfare Substance	NR 140 Table 3 Indicator Parameter	No standard
Aluminum Antimony Arsenic Barium Beryllium Boron Cadmium Chromium, total Cobalt Copper Lead Manganese Mercury Molybdenum Nickel Selenium Silver Strontium (proposed) Thallium Vanadium Note: Strontium does not have existing public health standards. DHS has proposed public health standards in Cycle 10.	Iron Manganese Zinc Note: Manganese is both a public health and a public welfare substance in NR 140.	Alkalinity Calcium Hardness Magnesium Potassium Sodium Specific Conductance Note: Alkalinity, hardness and specific conductance are typically monitored, for which some facilities have a well-specific preventive action limit (PAL) established.	Titanium

Table B Concentrations of Metals Exceeding Public Health or Welfare Standards in Groundwater Monitoring Wells Sampled at 18 Small C&D Landfills

Parameter (Parameter code)	NR 140 Standard (ug/L)		Proposed Standard (ug/L)		Closed Small C&D Landfills						Active Small C&D Landfills					
					Upgradient Well Concentration (ug/L)			Downgradient Well Concentration (ug/L)			Upgradient Well Concentration (ug/L)			Downgradient Well Concentration (ug/L)		
	ES	PAL	ES	PAL	Median	Average	Range	Median	Average	Range	Median	Average	Range	Median	Average	Range
Those with a result equal to or greater than NR 140 ES in at least one downgradient well																
Boron (1020)	1000	200	2000	400	24.8	32.8	<10.0 – 70.0	*214*	*724*	<10.0 – **8440**	20	16	<10.0 – 29*	*291*	**2225**	<10.0 – **9500**
Cobalt (1035)	40	8	40	4	0.5	2.9	<1.00 – *29.9*	0.5	*11.5*	<1.00 – **117**	--	--	<1.00	1.3	2.7	<1.00 – *10.2*
Iron (1046)	300	150	--	--	25	**364**	<50 – **4000**	50	**2425**	<50 – **29900**	--	--	<50	37.5	265	<50 – **2250**
Manganese Health (1056)	300	60	--	--	2.8	*181*	<0.500 – **1670**	31.3	**3641**	<0.50 – **43500**	0.5	3.6	<0.500 – 15.9	*138*	**1561**	<0.50 – **8510**
Manganese Welfare (1056)	50	25	--	--	2.8	**181**	<0.500 – **1670**	*31.1*	**3641**	<0.50 – **43500**	0.5	3.6	<0.500 – 15.9	**138**	**1561**	<0.50 – **8510**
Nickel (1065)	100	20	--	--	0.5	2.7	<1.00 – *24.4*	3.1	13.8	<1.00 – **198**	--	--	<1.00	0.94	8.5	<1.00 – *40.2*
Thallium (1057)	2	0.4	--	--	**2.5**	**3.9**	*<0.400* – **20.2**	**2.0**	**2.4**	*<0.400* – **9.2***	**2.5**	**6**	*<5.00* – **15.3**	3.9	**4.5**	*<5.00* – **12***
Those with a result equal to or greater than NR 140 PAL but below ES in at least one downgradient well																
Aluminum (1106)	200	40	200	20	5	13.2	<10.0 – *72.9*	5	10.3	<10.0 – *62.9*	--	--	<10.0	5	20.7	<10.0 – *147*
Arsenic (1000)	10	1	--	--	--	--	<1.00	0.5	0.5	<1.00 – *4*	--	--	<1.00	0.5	0.5	<1.00 – *2.89**
Arsenic (50250)	10	1	--	--	--	--	*<7.00*	--	--	*<7.00*	--	--	*<7.00*	*3.5*	*3.5*	<1.00 – *7.13**
Cadmium (1025)	5	0.5	--	--	0.25	*0.52*	*<0.500* – *1.73*	0.25	*0.57*	*<0.500* – *1.94*	*0.57*	*0.64*	*<0.500* – *1.11**	*0.59*	*0.60*	*<0.500* – *1.16**
Strontium (1080)	--	--	1500	150	96.9	110	<0.500 – *276*	96.4	*179*	<0.500 – *652*	91.5	88.1	<0.500 – 142	*163*	*186*	<0.500 – *484*
Vanadium (1085)	30	6	--	--	1.6	2.5	<1.00 – *12.6*	3.2	3.8	<1.00 – *22*	0.5	1.3	<1.00 – 3.59	2.01	1.96	<1.00 – 4.47

NR 140 ES Exceedance in bold

NR 140 PAL Exceedance in italics

Note: Average includes valid results (greater than the lab LOQ), result values for flagged results (between the lab LOD and LOQ) and non-detect results equal to ½ LOD.

* Maximum concentration is a flagged result (between the lab LOD and LOQ)

Table C: Occurrence of Metals Exceedances in Groundwater Monitoring Wells Sampled at 18 Small C&D Landfills.

Parameter	Closed Small C&D Landfills (13)						Active Small C&D Landfills (5)					
	Facility Count (13)		Well Count				Facility Count (5)		Well Count			
			Upgradient (13)		Downgradient (23)				Upgradient (5)		Downgradient (10)	
	≥ ES	≥ PAL (< ES)	**≥ ES**	≥ PAL (< ES)	**≥ ES**	≥ PAL (< ES)	**≥ ES**	≥ PAL (< ES)	**≥ ES**	≥ PAL (< ES)	**≥ ES**	≥ PAL (< ES)
Those with a result equal to or greater than NR 140 ES in at least one downgradient well												
Boron	**3**	6	**-**	-	**4**	8	**3**	(1)	**-**	-	**4**	1
Cobalt	**2**	3	**-**	1	**2**	2	-	1	**-**	-	**-**	1
Iron	**5**	2	**2**	-	**5**	2	**1**	-	**-**	-	**1**	-
Manganese (Health)	**7**	3	**2**	2	**8**	3	**3**	(3)	**-**	-	**3**	3
Manganese (Welfare)	**10**	1	**4**	-	**11**	3	**3**	-	**-**	-	**6**	-
Nickel	**1**	2	**-**	1	**1**	2	-	1	**-**	-	**-**	1
Thallium	**2**	-	**1**	-	**1**	-	**1**	-	**1**	-	**-**	-
Those with a result equal to or greater than NR 140 PAL but below ES in at least one downgradient well												
Aluminum	**-**	3	**-**	2	**-**	1	-	1	**-**	-	**-**	1
Arsenic	**-**	1	**-**	-	**-**	1	-	-	**-**	-	**-**	-
Cadmium	**-**	1	**-**	1	**-**	1	-	-	**-**	-	**-**	-
Vanadium	-	4	**-**	1	**-**	3	-	-	**-**	-	**-**	-

Notes:
Only those wells with a valid result (above the lab LOQ) and attains or exceeds the NR 140 PAL (or ES) for the metal listed are shown.
(3) Same three facilities that have an exceedance of the PAL (< ES) in one well also have an ES exceedance in another well
(1) The same facility that has an exceedance of the PAL (< ES) in one well also has an ES exceedance in another well.

Table D: Concentrations of Metals Not Exceeding Public Health or Welfare Standards in Groundwater Monitoring Wells Sampled at 18 Small C&D Landfills

Parameter (Parameter code)	NR 140 Standard		Proposed Standard		Upgradient Well Concentration		Downgradient Well Concentration	
	ES (ug/L)	PAL (ug/L)	ES (ug/L)	PAL (ug/L)	Average (ug/L)	Range (ug/L)	Average (ug/L)	Range (ug/L)
Antimony (1095)	6	1.2	--	--	--	<10.0	3.1	<10.0 - 13.4*
Barium (1005)	2000	400	2000	400	44.3	<0.500 - 151	75.1	4.35 - 361
Beryllium (1010)	4	0.4	--	--	--	<0.500	--	<0.500
Calcium (915)	IP	IP	--	--	51400	8170 - 156000	75400	6990 - 258000
Chromium, Total (1030)	100	10	--	--	1.0	<1.00 - 6.65	1.0	<1.00 - 5.94
Copper (1040)	1300	130	--	--	3.6	<5.00 - 19.6	6	<5.00 - 27.7
Lead (1049)	15	1.5	--	--	1.2	<0.300 - 4.27*	1.4	<0.300 - 6.33*
Magnesium (925)	IP	IP	--	--	17500	20200 - 47600	28100	1650 - 142000
Mercury (71890)	2	0.2	--	--	--	<0.030	0.02	<0.030 - 0.055*
Molybdenum (1060)	40	8	60	6	--	<5.00	3.0	<5.00 - 12.2*
Potassium (935)	IP	IP	--	--	1755	301 - 8200	4760	811 - 35300
Selenium (1145)	50	10	--	--	--	<2.00	--	<2.00 - 2.46*
Silver (1075)	50	10	--	--	1.4	<2.00 - 3.03*	--	<2.00
Sodium (930)	IP	IP	--	--	19500	1850 - 241000	20600	1390 - 122000
Titanium (1150)	--	--	--	--	0.5	<1.00 - 2.16*	0.8	<1.00 - 4.21
Zinc (1090)	5000	2500	--	--	4.9	<1.00 - 45.5	3.8	<1.00 - 26.6

Notes:
Average includes valid results (greater than the lab LOQ), result values for flagged results (between the lab LOD and LOQ) and non-detect results equal to ½ LOD.
* Maximum concentration is a flagged result (between the lab LOD and LOQ)
IP - Indicator Parameter

Table E: Department of Health Services Proposed Changes to NR 140 Groundwater Standards

DHS' 10th Cycle of Proposed Groundwater Standards – January 2022

	Enforcement Standard		Preventive Action Limit	
Substance	**Existing**	**Recommended**	**Existing**	**Recommended**
1,1-Dichloroethane (1,1-DCA)	850 µg/L	No change	85 µg/L	No change
1,2,3-Trichloropropane (1,2,3-TCP)	60 µg/L	0.3 ng/L	12 µg/L	0.03 ng/L
1,4-Dioxane	3 µg/L	0.35 µg/L	0.3 µg/L	0.035 µg/L
Aluminum	200 µg/L	No change	40 µg/L	20 µg/L
Bacteria (E. coli)	N/A	0	N/A	0
Bacteria (total coliform)	0	(1)	0	(1)
Barium	2,000 µg/L	No change	400 µg/L	No change
Boron	1,000 µg/L	2,000 µg/L	200 µg/L	400 µg/L
Chromium, Hexavalent	N/A	70 ng/L	N/A	7 ng/L
Clothianidin	N/A	1,000 µg/L	N/A	200 µg/L
Cobalt	40 µg/L	No change	8 µg/L	4 µg/L
Dacthal MTP degradate	N/A	70 µg/L(2)	N/A	7 µg/L(2)
Dacthal TPA degradate	N/A	70 µg/L(2)	N/A	7 µg/L(2)
Glyphosate	N/A	10 mg/L	N/A	1 mg/L
AMPA (glyphosate degradate)	N/A	10 mg/L	N/A	2 mg/L
Imidacloprid	N/A	0.2 µg/L	N/A	0.02 µg/L
Isoxaflutole and DKN	N/A	3 µg/L	N/A	0.3 µg/L
Isoxaflutole BA degradate	N/A	800 µg/L	N/A	160 µg/L
Molybdenum	40 µg/L	**60 µg/L**	**8 µg/L**	**6 µg/L**
Perfluorooctane Sulfonate (PFOS)	N/A	20 ng/L(3)	N/A	2 ng/L(3)
Perfluorooctanoic Acid (PFOA)	N/A	20 ng/L(3)	N/A	2 ng/L(3)
Strontium	N/A	1,500 µg/L	N/A	150 µg/L
Sulfentrazone	N/A	1,000 µg/L	N/A	100 µg/L
Tetrachloroethylene (PCE)	5 µg/L	20 µg/L	0.5 µg/L	2 µg/L
Thiamethoxam	N/A	**120 µg/L**	N/A	**12 µg/L**
Thiencarbazone-methyl	N/A	10 mg/L	N/A	2 mg/L
Trichloroethylene (TCE)	5 µg/L	0.5 µg/L	0.5 µg/L	0.05 µg/L

Bold text indicates changes based on feedback received during the public comment period.

(1) DNR has proposed transiting total coliform from a groundwater standard to an indicator parameter. DHS does not have concerns with this proposal.

(2) DHS recommends combined standards for dacthal, MTP, and TPA.

(3) DHS recommends combined standards for PFOA and PFOS.

Table F-1: Sample Results																							
Active Landfills: Sampling Sites 1, 2, 7, 9, and 12								Site 1			Site 2			Site 7			Site 9			Site 12		
Gradient: D-down; U-up; SU-side/up; SD-side/down								100 MW	200 MW	400 MW	4468-1	4468-2	4468-3	MW-A	MW-B	MW-C	MW1	MW2	MW3	133	134R	135R
Parameter Description	Parameter Code		NR140 ES	NR140 PAL	LOD	LOQ	Units	D	U	D	U	D	D	U	D	D	U	D	D	U	D	D
Exceedance Metals:																						
ALUMINUM DISS	1106		200	40	10.0	30.0	ug/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0		<10.0	<10.0	<10.0	19.9	*147*	<10.0	<10.0	<10.0
			200	40	15.0	*45.0*	ug/L							<15.0								
ARSENIC DISS	1000		10	1	1.00	3.00	ug/L										<1.00	*2.39*	<1.00	<1.00	<1.00	<1.00
ARSENIC DISSOLVED	50250		10	1	7.00	21.0	ug/L	<7.00	<7.00	<7.00	<7.00	<7.00	<7.00	<7.00	<7.00	*7.13*						
BORON DISS	1020		1000	200	10.0	30.0	ug/L	**6040**	20.7	**9500**	29	*442*		<10.0	11.6	<10.0	<10.0		50.8	20	140	<10.0
			1000	200	100	*300*	ug/L						**3620**					**2440**				
CADMIUM DISS	1025		5	0.5	*0.500*	*1.50*	ug/L	<0.500	<0.500	*0.507*	*1.01*	*0.761*	*1.16*	*1.11*	*0.642*	*0.574*	<0.500	*0.578*	*0.605*	*0.568*	*0.641*	<0.500
COBALT DISS	1035		40	8	1.00	3.00	ug/L				<1.00	1.16	3.65	<1.00	<1.00	<1.00	<1.00	*10.2*	1.49	<1.00	<1.00	<1.00
			40	8	2.00	6.00	ug/L	2.04	<2.00	6.09												
IRON DISS	1046		0.3	0.15	0.0500	*0.150*	MG/L								<0.0500	<0.0500	<0.0500	**2.25**	<0.0500	<0.0500	<0.0500	<0.0500
			0.3	0.15	0.100	**0.300**	MG/L	<0.100	<0.100	<0.100	<0.100	<0.100	0.12	<0.100								
MANGANESE DISS	1056		300	60	0.500	1.50	ug/L								<0.500	4.91	<0.500		*288*	0.891	9.81	0.802
			300	60	1.00	3.00	ug/L	*84.5*	<1.00	**2420**	15.9	*192*		<1.00								
			300	60	10.0	30.0	ug/L						**4100**									
			300	60	5.00	15.0	ug/L											**8510**				
NICKEL DISS	1065		100	20	1.00	3.00	ug/L	10	<1.00	*40.2*	<1.00	<1.00	16.7		<1.00	<1.00	<1.00	14.1	1.38	<1.00	<1.00	<1.00
			100	20	2.00	6.00	ug/L							<2.00								
STRONTIUM, DISS	1080		(blank)	(blank)	0.500	1.50	ug/L	208	37.2	274	142	118	230		65.2	60.9	91.5	484	269	115	118	34.4
			(blank)	(blank)	1.50	4.50	ug/L							54.8								
THALLIUM DISS	1057		2	0.4	*0.400*	*1.20*	ug/L										<0.400	<0.400	<0.400	<0.400	<0.400	<0.400
			2	0.4	**5.00**	**15.0**	ug/L	**5.28**	<5.00	<5.00	**15.3**	**8.37**	**7.12**	**11.5**	**12**	**8.92**						
VANADIUM DISS	1085		30	6	1.00	3.00	ug/L	2.03	1.33	3.69	3.59	3.19	4.47	<1.00	<1.00	<1.00	<1.00	2.24	1.98	<1.00	<1.00	<1.00
Typical Indicators/Anions:																						
ALKALINITY FILTERED CACO3	39036		(blank)	(blank)	20.0	20.0	MG/L	237	35.2	435		427		275	305	281	74.1	455	59.2	129	93.8	25.9
			(blank)	(blank)	36.0	36.0	MG/L				574		572									
CHLORIDE DISS	941		250	125	1.36	4.55	MG/L	24	7	29	2.01	5.06	23.7	3.1	4.48	3.12	11.5	18.6	25.8	5.47	23.7	<1.36
			250	125	2.72	9.10	MG/L															
CONDUCTIVITY - DISS	82561		(blank)	(blank)	10.0	10.0	uS/cm	770	125	989	1010	834	1120	530	601	534	256	996	406	329	435	59.2
HARDNESS, CA MG CALCULATED (MG/L AS CACO3)	46570		(blank)	(blank)	0.660	2.00	MG/L	314	50.2	378	585	457	596	282	335	290	110	482	171	156	184	24.3
PH, LAB, DISS	99956		(blank)	(blank)	(blank)	(blank)	SU	6.59	6.34	6.88	7.35	7.29	6.97	7.81	7.67	7.8	7.19	6.55	5.58	6.72	6.63	6.45
SULFATE DISS, AS SO4	946		250	125	0.730	2.43	MG/L							17.8	26.1	15.2	2.68					2.4
			250	125	19.1	63.5	MG/L	*139*														
			250	125	2.19	7.29	MG/L											91.6	99.5			
			250	125	3.65	12.2	MG/L													21.4	72.2	
			250	125	3.81	12.7	MG/L		4.23		10.1	38.5	32.6									
			250	125	7.62	25.4	MG/L			64												

Table F-1: Sample Results																					
Active Landfills: Sampling Sites 1, 2, 7, 9, and 12							Site 1			Site 2			Site 7			Site 9			Site 12		
Gradient: D-down; U-up; SU-side/up; SD-side/down							100 MW	200 MW	400 MW	4468-1	4468-2	4468-3	MW-A	MW-B	MW-C	MW1	MW2	MW3	133	134R	135R
Parameter Description	Parameter Code	NR140 ES	NR140 PAL	LOD	LOQ	Units	D	U	D	U	D	D	U	D	D	U	D	D	U	D	D
Non-exceedance Metals:																					
ANTIMONY DISS	1095	6	1.2	1.00	3.00	ug/L										<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
		6	1.2	**10.0**	**30.0**	ug/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	**13.4**	<10.0						
BARIUM DISS	1005	2000	400	0.500	1.50	ug/L	49.6	5.64	95.6	87.1	79.7	124		11.6	5.29	22.2	66.6	176	26	29	4.35
		2000	400	2.00	6.00	ug/L							<2.00								
BERYLLIUM DISS	1010	4	0.4	0.500	1.50	ug/L	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500
CHROMIUM DISS	1030	100	10	1.00	3.00	ug/L				<1.00	<1.00	<1.00		<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
		100	10	2.00	6.00	ug/L	<2.00	<2.00	3.35				<2.00								
COPPER DISS	1040	1300	130	5.00	15.0	ug/L	9.2	<5.00	27.7	<5.00	<5.00	13.2	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
LEAD DISS	1049	15	1.5	0.300	1.00	ug/L										<0.300	<0.300	<0.300	<0.300	<0.300	<0.300
		15	1.5	3.00	10.0	ug/L	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00									
		15	1.5	3.00	9.00	ug/L							<3	<3	<3						
MERCURY DISS	71890	2	0.2	0.030	0.080	ug/L	<0.030	<0.030	0.05	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
MOLYBDENUM DISS	1060	40	8	5.00	15.0	ug/L	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
SELENIUM DISS	1145	50	10	15.0	45.0	ug/L				<15.0	<15.0	<15.0		<15.0	<15.0						
		50	10	2.00	6.00	ug/L										<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
		50	10	20.0	60.0	ug/L	<20.0	<20.0	<20.0				<20.0								
SILVER DISS	1075	50	10	2.00	6.00	ug/L	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00									
		50	10	3.00	9.00	ug/L							<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00
ZINC DISS	1090	5000	2500	1.00	3.00	ug/L				<1.00	<1.00	<1.00		<1.00	<1.00	<1.00	2.03	<1.00	5.14	12.9	1.5
		5000	2500	5.00	15.0	ug/L	<5.00	7.96	26.6				10.4								
Others:																					
CALCIUM DISS	915	(blank)	(blank)	0.100	0.300	MG/L	77.3	12.5	97.7	156	124	159	48.1	64.6	48.8	31.4	128	49.1	40	46.6	6.99
		(blank)	(blank)	1.00	3.00	MG/L															
MAGNESIUM DISS	925	(blank)	(blank)	0.0500	0.150	MG/L								42.2	40.9	7.54	39.1	11.6	13.8	16.5	1.65
		(blank)	(blank)	0.100	0.300	MG/L	29.5	4.64	32.6	47.6	35.8	48.2	39.3								
POTASSIUM DISS	935	(blank)	(blank)	0.200	0.600	MG/L	0.892	0.59	1.29	1.83	1.57	1.96	1.24	1.26	1.31	0.769	1.9	2.99	2.21	2.1	0.919
SODIUM DISS	930	(blank)	(blank)	0.200	0.600	MG/L	44.1	3.07	83	5.3	5.8	29.1									
		(blank)	(blank)	0.300	0.900	MG/L							1.85	2.09	2.37	8.52	36.9	12.6	6.28	6.5	1.39
TITANIUM, DISSOLVED	1150	(blank)	(blank)	1.00	3.00	ug/L	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1.53	<1.00	<1.00	<1.00	<1.00

Table F-2: Sample Results																								
Closed Landfills: Sampling Sites 3, 4, 5, 6, 8, 10, 11, 13, 14, 15, 16, 17, 18							Site 3			Site 4		Site 5		Site 6		Site 8			Site 10			Site 11		
Gradient: D-down; U-up; SU-side/up; SD-side/down							4254-2	4254-3	4254-4	3479-1	3479-2	3952-4	3952-6	4241-7	4241-9	MW6	MW7	RMW2	8901	8903	8904	106	107	132
Parameter Description	Parameter Code	NR140 ES	NR140 PAL	LOD	LOQ	Units	SU	D	D	U	D	U	D	SU	D	SD	D	U	U	D	D	U	SD	D
Exceedance Metals:																								
ALUMINUM DISS	1106	200	40	10.0	30.0	ug/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	24.8	<10.0	<10.0	<10.0	20.7	*62.9*	<10.0	<10.0	<10.0
		200	40	15.0	*45.0*	ug/L																		
ARSENIC DISS	1000	10	1	1.00	3.00	ug/L										<1.00	<1.00	<1.00				<1.00	<1.00	<1.00
ARSENIC DISSOLVED	50250	10	1	7.00	21.0	ug/L	<7.00	<7.00	<7.00	<7.00	<7.00	<7.00	<7.00	<7.00	<7.00				<7.00	<7.00	<7.00			
BORON DISS	1020	1000	200	10.0	30.0	ug/L	57.7	*482*	*248*	<10.0	13.2	24.8	*602*	13.8	*224*	104	17.7	22	45.7	21.8	65.5	55.9	11.8	182
		1000	200	100	*300*	ug/L																		
CADMIUM DISS	1025	5	0.5	*0.500*	*1.50*	ug/L	*0.707*	*0.66*	<0.500	<0.500	*0.502*	*1.02*	*1.29*	<0.500	<0.500	*0.622*	*0.635*	*0.651*	*1.73*	<0.500	<0.500	<0.500	<0.500	<0.500
COBALT DISS	1035	40	8	1.00	3.00	ug/L	2.14	<1.00	<1.00	<1.00	<1.00	<1.00	5.6	<1.00	<1.00	<1.00	<1.00	<1.00	*29.9*	1.35	7.83	<1.00	<1.00	<1.00
		40	8	2.00	6.00	ug/L																		
IRON DISS	1046	0.3	0.15	0.0500	*0.150*	MG/L										0.0893	<0.0500	<0.0500	<0.0500	*0.157*	0.0928	<0.0500	<0.0500	<0.0500
		0.3	0.15	0.100	**0.300**	MG/L	**0.402**	<0.100	<0.100	<0.100	<0.100	**4**	**22.3**	<0.100	<0.100									
MANGANESE DISS	1056	300	60	0.500	1.50	ug/L										2.84	0.791	<0.500	**394**	*118*	5.71	<0.500	0.965	3.85
		300	60	1.00	3.00	ug/L	*202*	*121*	31.3	<1.00	31.1	**1670**		<1.00	5.13									
		300	60	10.0	30.0	ug/L							**3050**											
		300	60	25.0	75.0	ug/L																		
		300	60	5.00	15.0	ug/L																		
NICKEL DISS	1065	100	20	1.00	3.00	ug/L	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	4.44	<1.00	<1.00	3.75	2.96	<1.00	*24.4*	2.63	16.3	<1.00	<1.00	<1.00
		100	20	2.00	6.00	ug/L																		
STRONTIUM, DISS	1080	(blank)	(blank)	0.500	1.50	ug/L	107	96.4	54	17.7	68.2	112	167	59	85.6	108	89.4	96.9	258	34.7	68.7	276	45.9	100
		(blank)	(blank)	1.50	4.50	ug/L																		
THALLIUM DISS	1057	2	0.4	*0.400*	*1.20*	ug/L										<0.400	<0.400	<0.400				<0.400	<0.400	<0.400
		2	0.4	**5.00**	**15.0**	ug/L	**7.85**	**6.18**	<5.00	<5.00	<5.00	**11.1**	**9.18**	<5.00	<5.00				**20.2**	**6.79**	**5.38**			
VANADIUM DISS	1085	30	6	1.00	3.00	ug/L	3.45	4.05	4.46	*12.6*	5.48	2.65	3.68	1.88	5.73	4.1	3.17	4.46	1.72	<1.00	3.23	<1.00	1.05	<1.00
Typical Indicators/Anions:																								
ALKALINITY FILTERED CACO3	39036	(blank)	(blank)	20.0	20.0	MG/L	299	210	174	63.8	213			129	169	353	292	452				134	55.3	84.8
		(blank)	(blank)	36.0	36.0	MG/L						472	499											
ALKALINITY TOTAL CACO3	410	(blank)	(blank)	20.0	20.0	MG/L																		
		(blank)	(blank)	36.0	36.0	MG/L																		
CHLORIDE DISS	941	250	125	1.36	4.55	MG/L	2.38	3.37	1.97	<1.36	2.95	2.41	11.5	26.8	33.4	12.4	9.71	2.45				2.74	1.77	4.67
		250	125	2.72	9.10	MG/L																		
CONDUCTIVITY - DISS	82561	(blank)	(blank)	10.0	10.0	uS/cm	593	433	359	138	432	847	929	376	484	713	577	809				381	137	318
CONDUCTIVITY FIELD	94	(blank)	(blank)	(blank)	(blank)	UMHOS/CM													1716	338	169			
CONDUCTIVITY, UMHOS/CM @ 25C	95	(blank)	(blank)	10.0	10.0	uS/cm																		
HARDNESS, CA MG CALCULATED (MG/L AS CACO3)	46570	(blank)	(blank)	0.660	2.00	MG/L	325	230	171	64	228	437	485	171	228	380	324	456	431	165	96.3	180	61.7	141
		(blank)	(blank)	6.60	20.0	MG/L																		
PH FIELD	400	(blank)	(blank)	(blank)	(blank)	SU													6.2	6.2	5.6			
PH LAB	403	(blank)	(blank)	(blank)	(blank)	SU																		
PH, LAB, DISS	99956	(blank)	(blank)	(blank)	(blank)	SU	7.23	7.43	7.75	8.32	7.6	7.1	6.84	7.59	7.5	7.54	7.6	7.29				6.52	6.71	6.65
SULFATE DISS, AS SO4	946	250	125	0.730	2.43	MG/L										27.9	7.74	11.5					8.82	
		250	125	1.46	4.86	MG/L																		
		250	125	2.19	7.29	MG/L																		
		250	125	2.92	9.72	MG/L																		
		250	125	3.65	12.2	MG/L																47.3		60.5
		250	125	3.81	12.7	MG/L	17	14.8	10.5	4.38	14.3	11.7	28.2	6.51	10.5									
SULFATE TOTAL	945	250	125	0.730	2.43	MG/L																		
		250	125	2.92	9.72	MG/L																		
		250	125	3.65	12.2	MG/L																		
		250	125	73.0	243	MG/L																		

Table F-2: Sample Results																							
Closed Landfills: Sampling Sites 3, 4, 5, 6, 8, 10, 11, 13, 14, 15, 16, 17, 18							Site 3			Site 4		Site 5		Site 6		Site 8			Site 10			Site 11		
Gradient: D-down; U-up; SU-side/up; SD-side/down							4254-2	4254-3	4254-4	3479-1	3479-2	3952-4	3952-6	4241-7	4241-9	MW6	MW7	RMW2	8901	8903	8904	106	107	132
Parameter Description	Parameter Code	NR140 ES	NR140 PAL	LOD	LOQ	Units	SU	D	D	U	D	U	D	SU	D	SD	D	U	U	D	D	U	SD	D
Non-exceedance Metals:																								
ANTIMONY DISS	1095	6	1.2	1.00	3.00	ug/L										<1.00	<1.00	<1.00				<1.00	<1.00	<1.00
		6	1.2	10.0	30.0	ug/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0				<10.0	<10.0	<10.0			
BARIUM DISS	1005	2000	400	0.500	1.50	ug/L	51.6	33	21.1	8.73	29	94.1	131	30.6	34.2	178	127	151	25.3	18.6	22.1	53.1	8.07	20.2
BERYLLIUM DISS	1010	4	0.4	0.500	1.50	ug/L	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500
CHROMIUM DISS	1030	100	10	1.00	3.00	ug/L	<1.00	<1.00	<1.00	2.39	2.48	<1.00	<1.00	<1.00	<1.00	5.94	4.89	6.65	<1.00	<1.00	1.95	<1.00	<1.00	<1.00
COPPER DISS	1040	1300	130	5.00	15.0	ug/L	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	19.6	<5.00	<5.00	<5.00	<5.00	<5.00
LEAD DISS	1049	15	1.5	0.300	1.00	ug/L																<0.300	<0.300	<0.300
		15	1.5	*3.00*	*10.0*	ug/L	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00									
		15	1.5	*3.00*	*9.00*	ug/L										<3	<3	<3	<3	<3	<3			
MERCURY DISS	71890	2	0.2	0.030	0.080	ug/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
MOLYBDENUM DISS	1060	40	8	5.00	15.0	ug/L	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
SELENIUM DISS	1145	50	10	15.0	45.0	ug/L	<15.0	<15.0	<15.0	<15.0	<15.0	<15.0	<15.0	<15.0	<15.0				<15.0	<15.0	<15.0			
		50	10	2.00	6.00	ug/L										<2.00	<2.00	<2.00				<2.00	<2.00	<2.00
SILVER DISS	1075	50	10	2.00	6.00	ug/L	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00									
		50	10	3.00	9.00	ug/L										<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00
ZINC DISS	1090	5000	2500	1.00	3.00	ug/L	<1.00	<1.00	<1.00	<1.00	1.17	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	45.5	3.62	4.61	4.6	12.7	5.7
Others:																								
CALCIUM DISS	915	(blank)	(blank)	0.100	0.300	MG/L	85.4	67	47.7	16.8	64.1	113	126	46.6	62.1	106	94.3	129	104	37	24.8	47.4	15.7	36.1
		(blank)	(blank)	1.00	3.00	MG/L																		
MAGNESIUM DISS	925	(blank)	(blank)	0.0500	0.150	MG/L										27.9	21.5	32.6	41.4	17.7	8.36	15	5.44	12.3
		(blank)	(blank)	0.100	0.300	MG/L	27.2	15.2	12.5	5.38	16.5	37.3	41.5	13.2	17.8									
		(blank)	(blank)	0.500	1.50	MG/L																		
POTASSIUM DISS	935	(blank)	(blank)	0.200	0.600	MG/L	1.28	1.22	0.823	0.33	0.966	1.29	1.45	0.832	1.13	1.49	1.21	0.903	3.8	0.893	1.55	1.46	0.943	1.62
SODIUM DISS	930	(blank)	(blank)	0.200	0.600	MG/L	9.3	4.45	4.09	2.25	4.14	4.35	16.3	4.61	7.18									
		(blank)	(blank)	0.300	0.900	MG/L										5.35	3.93	4.37	241	2.85	3.73	7.14	3.22	6
TITANIUM, DISSOLVED	1150	(blank)	(blank)	1.00	3.00	ug/L	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	2.44	<1.00	<1.00	<1.00

Table F-2: Sample Results																								
Closed Landfills: Sampling Sites 3, 4, 5, 6, 8, 10, 11, 13, 14, 15, 16, 17, 18							Site 13			Site 14			Site 15			Site 16			Site 17			Site 18		
Gradient: D-down; U-up; SU-side/up; SD-side/down							125	126	129	4235-01	4235-02	4235-03	3933-01	3933-02	3933-03	101-4242	102-4242	103-4242	3478-1	3478-2	3478-3	3480-1	3480-4	3480-5
Parameter Description	Parameter Code	NR140 ES	NR140 PAL	LOD	LOQ	Units	D	U	D	U	D	D	D	U	SD	U	D	D	U	SD	D	U	D	D
Exceedance Metals:																								
ALUMINUM DISS	1106	200	40	10.0	30.0	ug/L	<10.0	<10.0	<10.0	<10.0	<10.0	19	<10.0	<10.0	<10.0	*72.9*	<10.0	<10.0	<10.0	<10.0	10.9	*43.2*	<10.0	14.3
		200	40	15.0	*45.0*	ug/L																		
ARSENIC DISS	1000	10	1	1.00	3.00	ug/L	<1.00	<1.00	<1.00							<1.00	<1.00	<1.00	<1.00	<1.00	*4*	<1.00	<1.00	<1.00
ARSENIC DISSOLVED	50250	10	1	7.00	21.0	ug/L				<7.00	<7.00	<7.00	<7.00	<7.00	<7.00									
BORON DISS	1020	1000	200	10.0	30.0	ug/L	*571*	<10.0	*372*	62.5	**1620**	116	**1330**	42.2	**1180**	<10.0		<10.0	16.6	156	*571*	70	*214*	101
		1000	200	100	*300*	ug/L											**8440**							
CADMIUM DISS	1025	5	0.5	*0.500*	*1.50*	ug/L	*0.833*	<0.500	*0.646*	<0.500	*1.44*	<0.500	<0.500	<0.500	<0.500	<0.500	*1.08*	<0.500	*0.588*	*0.575*	*1.94*	<0.500	<0.500	<0.500
COBALT DISS	1035	40	8	1.00	3.00	ug/L	4.06	<1.00	7.71	<1.00	**76**	<1.00	*24.3*	<1.00	1.2	<1.00	*13*	<1.00	<1.00	<1.00	**117**	<1.00	<1.00	<1.00
		40	8	2.00	6.00	ug/L																		
IRON DISS	1046	0.3	0.15	0.0500	*0.150*	MG/L	**0.305**	<0.0500	**0.306**	<0.0500	**29.9**	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	*0.247*	<0.0500	<0.0500	<0.0500	**1.93**	<0.0500	<0.0500	<0.0500
		0.3	0.15	0.100	**0.300**	MG/L																		
MANGANESE DISS	1056	300	60	0.500	1.50	ug/L		1.68		0.874		27	**1820**	3.65	*105*	3.75		1.68	2.8	**1170**		*68.1*	14.6	11.7
		300	60	1.00	3.00	ug/L																		
		300	60	10.0	30.0	ug/L																		
		300	60	25.0	75.0	ug/L															**43500**			
		300	60	5.00	15.0	ug/L	**6940**		**4690**		**10200**						**11900**							
NICKEL DISS	1065	100	20	1.00	3.00	ug/L	5.01	<1.00	3.79	4.53	*31.9*	3.57	4.25	<1.00	3.05	<1.00	18.9	<1.00	<1.00	14	**198**	1.11	1.37	<1.00
		100	20	2.00	6.00	ug/L																		
STRONTIUM, DISS	1080	(blank)	(blank)	0.500	1.50	ug/L	259	31.1	193	185	518	385	349	146	99.8	43.5	468	51.3	39.8	96	652	61.5	67.3	49.1
		(blank)	(blank)	1.50	4.50	ug/L																		
THALLIUM DISS	1057	2	0.4	*0.400*	*1.20*	ug/L	<0.400	<0.400	<0.400							<0.400	<0.400	<0.400	<0.400	<0.400	**2.03**	<0.400	<0.400	<0.400
		2	0.4	**5.00**	**15.0**	ug/L				<5.00	<5.00	**6.2**	**5.25**	<5.00	<5.00									
VANADIUM DISS	1085	30	6	1.00	3.00	ug/L	4.61	<1.00	3.07	<1.00	*7.47*	1.49	1.24	1.24	<1.00	<1.00	*6.44*	<1.00	<1.00	2.23	*22*	1.58	1.82	<1.00
Typical Indicators/Anions:																								
ALKALINITY FILTERED CACO3	39036	(blank)	(blank)	20.0	20.0	MG/L	264	44.8	250	0		235	253	74.8	193							45.2	98.2	77.9
		(blank)	(blank)	36.0	36.0	MG/L					840													
ALKALINITY TOTAL CACO3	410	(blank)	(blank)	20.0	20.0	MG/L										29		65.9	47.7	142				
		(blank)	(blank)	36.0	36.0	MG/L											696				840			
CHLORIDE DISS	941	250	125	1.36	4.55	MG/L	15.4	1.67	22.4	17.6		40.3	4.25	15.4	2.86							62.6	56.6	27.4
		250	125	2.72	9.10	MG/L					*125*													
CONDUCTIVITY - DISS	82561	(blank)	(blank)	10.0	10.0	uS/cm	778	105	716	226	2260	811	1250	239	805							304	417	255
CONDUCTIVITY FIELD	94	(blank)	(blank)	(blank)	(blank)	UMHOS/CM																		
CONDUCTIVITY, UMHOS/CM @ 25C	95	(blank)	(blank)	10.0	10.0	uS/cm										69.2	1440	138	116	523	3760			
HARDNESS, CA MG CALCULATED (MG/L AS CACO3)	46570	(blank)	(blank)	0.660	2.00	MG/L	389	48	327	80.8	577	328	150	78.3	50.5	28.7		63.5	48.9	216		74.7	134	76.7
		(blank)	(blank)	6.60	20.0	MG/L											754				1230			
PH FIELD	400	(blank)	(blank)	(blank)	(blank)	SU																		
PH LAB	403	(blank)	(blank)	(blank)	(blank)	SU										6.05	6.8	6	6.35	6.46	6.67			
PH, LAB, DISS	99956	(blank)	(blank)	(blank)	(blank)	SU	6.55	6.78	6.67	6.06	6.73	6.39	7.37	6.36	7.08							6.61	6.59	6.41
SULFATE DISS, AS SO4	946	250	125	0.730	2.43	MG/L		5.44		32.4				9.55								4.41	22	7.11
		250	125	1.46	4.86	MG/L						46.3												
		250	125	2.19	7.29	MG/L							97		81.8									
		250	125	2.92	9.72	MG/L					*156*													
		250	125	3.65	12.2	MG/L	*130*		97.6															
		250	125	3.81	12.7	MG/L																		
SULFATE TOTAL	945	250	125	0.730	2.43	MG/L										3.98		2.76	6.76					
		250	125	2.92	9.72	MG/L														121				
		250	125	3.65	12.2	MG/L											*178*							
		250	125	73.0	243	MG/L															**1190**			

Table F-2: Sample Results																								
Closed Landfills: Sampling Sites 3, 4, 5, 6, 8, 10, 11, 13, 14, 15, 16, 17, 18							Site 13			Site 14			Site 15			Site 16			Site 17			Site 18		
Gradient: D-down; U-up; SU-side/up; SD-side/down							125	126	129	4235-01	4235-02	4235-03	3933-01	3933-02	3933-03	101-4242	102-4242	103-4242	3478-1	3478-2	3478-3	3480-1	3480-4	3480-5
Parameter Description	Parameter Code	NR140 ES	NR140 PAL	LOD	LOQ	Units	D	U	D	U	D	D	D	U	SD	U	D	D	U	SD	D	U	D	D
Non-exceedance Metals:																								
ANTIMONY DISS	1095	6	1.2	1.00	3.00	ug/L	<1.00	<1.00	<1.00							<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
		6	1.2	10.0	30.0	ug/L				<10.0	<10.0	<10.0	<10.0	<10.0	<10.0									
BARIUM DISS	1005	2000	400	0.500	1.50	ug/L	49.6	6.91	52.4	56.4	361	192	223	122	85.6	7.68	88.4	9.36	27.2	56.7	33.7	20.5	43.9	18
BERYLLIUM DISS	1010	4	0.4	0.500	1.50	ug/L	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500
CHROMIUM DISS	1030	100	10	1.00	3.00	ug/L	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
COPPER DISS	1040	1300	130	5.00	15.0	ug/L	5.03	<5.00	<5.00	<5.00	22.7	6.97	10.8	<5.00	20.8	5.48	21.1	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
LEAD DISS	1049	15	1.5	0.300	1.00	ug/L	<0.300	<0.300	0.349							<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300
		15	1.5	*3.00*	*10.0*	ug/L																		
		15	1.5	*3.00*	*9.00*	ug/L				*4.27*	*6*	*6.33*	*4.32*	*3.23*	*4.61*									
MERCURY DISS	71890	2	0.2	0.030	0.080	ug/L	<0.030	<0.030	<0.030	<0.030	0.055	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
MOLYBDENUM DISS	1060	40	8	5.00	15.0	ug/L	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	*12.2*	<5.00	*9.72*	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
SELENIUM DISS	1145	50	10	15.0	45.0	ug/L				<15.0	<15.0	<15.0	<15.0	<15.0	<15.0									
		50	10	2.00	6.00	ug/L	<2.00	<2.00	<2.00							<2.00	<2.00	<2.00	<2.00	<2.00	2.46	<2.00	<2.00	<2.00
SILVER DISS	1075	50	10	2.00	6.00	ug/L																		
		50	10	3.00	9.00	ug/L	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	<3.00	3.03	<3.00	<3.00
ZINC DISS	1090	5000	2500	1.00	3.00	ug/L	1.6	2.94	2.07	1.59	4.33	7.15	11.6	9.14	2.46	<1.00	1.31	<1.00	<1.00	2.55	13.5	<1.00	<1.00	<1.00
Others:																								
CALCIUM DISS	915	(blank)	(blank)	0.100	0.300	MG/L	98.6	12	80.5	23.2	131	80.8	38.2	20.2	12.1	8.17		16.2	12.2	44.5		19.4	37.9	21.9
		(blank)	(blank)	1.00	3.00	MG/L											186				258			
MAGNESIUM DISS	925	(blank)	(blank)	0.0500	0.150	MG/L	34.8	4.37	30.7	5.57	60.8	30.7	13.4	6.73	4.9	2.02		5.61	4.47	25.3		6.38	9.6	5.35
		(blank)	(blank)	0.100	0.300	MG/L																		
		(blank)	(blank)	0.500	1.50	MG/L											70.5				142			
POTASSIUM DISS	935	(blank)	(blank)	0.200	0.600	MG/L	2.63	0.993	2.53	2.52	19.2	26.9	35.3	8.2	15.8	0.301	3.45	0.811	0.926	2.35	15.1	2.11	2.1	1.52
SODIUM DISS	930	(blank)	(blank)	0.200	0.600	MG/L																		
		(blank)	(blank)	0.300	0.900	MG/L	15.4	2.42	20.1	6.92	122	25.6	13	11.9	6	2.81	62.6	3.12	3.29	8.13	69.3	26.2	29	19
TITANIUM, DISSOLVED	1150	(blank)	(blank)	1.00	3.00	ug/L	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1.17	3.96	<1.00	<1.00	<1.00	4.21	2.16	<1.00	<1.00