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DMMP Issue Paper: Implementation of Revised Freshwater Sediment Screening Values

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INTRODUCTION

In the early 2000s, Ecology evaluated existing freshwater sediment benthic toxicity screening levels (SLs), and determined that the existing SLs either had extremely high false positive rates, or extremely high false negative rates, depending on how they were derived (SAIC and Avocet, 2002). In 2003, Ecology released the report that lead to the 2006 freshwater SLs currently used by the Regional Sediment Evaluation Team (RSET) and DMMP (SAIC and Avocet, 2003). These values were based on the Floating Percentile Method (FPM) and the dataset and endpoints available at the time. In 2007, the RSET began to revise the freshwater benthic toxicity SLs using FPM with a larger dataset and additional endpoints. The final FPM report was released in 2011 (Avocet, 2011). Through rulemaking, Ecology promulgated these freshwater sediment values in the Sediment Management Standards (SMS) as freshwater benthic sediment standards (WAC 173-204-563) on February 22, 2013. The new freshwater SMS are part of a framework used in setting cleanup standards in the State of Washington.

Dredging and related open water disposal and/or placement is typically regulated under part 3 of the SMS (for freshwater, this would be WAC 173-204-340) not part 5 where the new benthic standards were adopted (WAC 173-204-563, which regulates cleanup actions). WAC 173-204-340 is reserved, allowing case-by-case determination. Under WAC 173-204-340, the DMMP and the RSET agencies are allowed to consider best available science and thus are considering incorporating SMS freshwater benthic sediment standards (WAC 173-204-563) into our guidance for evaluating freshwater sediments. These criteria were developed for the protection of benthic invertebrate communities, and were not intended to address bioaccumulative impacts, potential effects to higher trophic levels, or address effects to individual organisms as required under the federal Endangered Species Act (ESA). As a result, there are concerns that if the sediment benthic criteria are used alone, the benthic SLs would not be adequately protective of aquatic communities or ESA-listed fish species.

The DMMP and RSET agencies agree that additional measures are needed to be more protective of the aquatic environment; for example, SLs must protect other ecological receptors (primarily federally-listed and non-listed fish) in addition to benthic invertebrates, and must account for the potential effects of bioaccumulative compounds, as appropriate.

In 2013 the RSET Freshwater Technical Working Group intended to propose a multi-tiered approach to address these concerns: 1) the elutriate test trigger approach (SEF, Chapter 10) to

develop water quality-based sediment screening values; 2) fish and wildlife-based screening values (which include bioaccumulative compounds); and 3) background-based screening values (for selected metals). However, due to the federal government shutdown in October 2013, the task was not completed in time to present the approach for adoption into the SEF at the RSET 2013 annual meeting in November. Instead, a brief overview of the approach was presented at the annual 2013 RSET meeting. A discussion regarding the fish and wildlife bioaccumulative SLs ensued and concerns were expressed that a precedent for dealing with bioaccumulatives for both freshwater and marine sediments was being made without appropriate public input.

Based on the feedback received at the RSET meeting, the RSET agencies decided to delay development and implementation of evaluation guidelines for bioaccumulative compounds and proceed instead with adoption of the SMS benthic criteria as guidance, supplemented with sediment SLs developed from water quality criteria and a site-specific background approach for metals. The bioaccumulation issue will be addressed in a separate process and will cover both freshwater and marine sediment evaluations. Rather than waiting until the October RSET annual meeting to begin the process, the RSET and DMMP agencies agreed to present the non-bioaccumulative SLs at the 2014 SMARM for DMMP adoption.

The development of a multi-tiered approach for non-bioaccumulative evaluation of freshwater sediment is presented in this paper. This tiered approach is used to determine if additional site-specific analyses (e.g. elutriate tests, bioassays, and modeling) are required to determine the potential for adverse effects. If adverse effects are predicted, then dredged material is unsuited for open water disposal or in-water placement, and/or the surface exposed by dredging would need to be managed.

PROBLEM STATEMENTS

1. The SMS benthic criteria, developed under the FPM, only account for chemical toxicity to benthic invertebrate communities and may not be protective of sensitive fish species and other organisms. Since other species occur in nearly all dredging and habitat restoration projects in the Pacific Northwest, the RSET has identified the need to develop more specific SLs to protect other receptors of concern.

2. The water quality criteria-derived SLs described later in this paper were developed using typical values for water quality parameters (hardness, pH, and TOC). These SLs do not account for site-specific conditions. For some chemicals, RSET and DMMP have identified the need to develop procedures for the use of SLs based on site-specific parameters.

3. The Pacific Northwest region is known to have naturally elevated metals concentrations in large part due to the volcanic nature of this region. In some cases, sediment background concentrations should be taken into consideration.

APPROACH

The proposed SLs include the FPM-based screening levels (benthic SLs), water quality-based SLs using methodologies presented in the SEF chapter 10 (elutriate tests), and background-based values where appropriate. This approach mirrors the SMS framework and tiered process (WAC 173-204-560), which compares the lowest risk-based screening value (in this case, the benthic SLs or water quality-based SLs) to background values. The higher of either the risk-based value or the background value would be used as the dredged material screening value.

As with the existing marine sediment SLs, tiered testing procedures are available for both the benthic and WQ-based SLs. Similar to marine SLs, sediments failing the benthic SLs can conduct bioassays to gather additional information for decision-making. For WQ-based SLs, the tiered testing would involve elutriate testing and/or modeling to determine if water quality criteria would be met. Additionally, project proponents will have the opportunity to calculate site-specific water quality-based SLs by adjusting the variables (e.g., sediment TOC, expected % suspended sediments) used to develop the water quality-based SLs. Additional site-specific adjustments may include water hardness and pH. Site-specific background may also be considered. However, <u>any adjustments of variables in these equations for site-specific SLs or proposed background metrics are subject to pre-approval by the agencies.</u>

DERIVATION OF THE VALUES

Development of Screening Values for Benthic Communities (SMS Benthic Criteria or Benthic SLs)

The benthic SLs are the combined result of the RSET Freshwater subgroup (2007 through 2009) and the SMS rule revision process that culminated in the adoption of the freshwater sediment benthic criteria in 2013 (WAC 173-204-563). The benthic screening values were derived using the FPM model, which is described in Ecology's publication #11-09-05, "Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho (Avocet, 2011). These values are presented in Table 1 as the benthic SLs.

Development of Screening Values for Other Receptors (Water Quality Criteria-based SLs)

For development of SLs that are protective of other receptors such as fish, RSET and DMMP propose the equilibrium partitioning approach which was used to develop the Elutriate Triggers (ETs) in Chapter 10 of the Sediment Evaluation Framework (SEF, 2009). The equations for calculating these triggers are described below.

Elutriate testing triggers for metals are derived using the following equation:

$$\mathbf{ET_{metal} = K_d \times WQC}$$

where:

K_d is the metal partitioning coefficient in L/kg.

WQC is the water quality criterion in µg/L.

The calculation of elutriate testing triggers for organic constituents is modified in two important ways. First, the equilibrium partitioning coefficients are expressed as a function of the organic carbon content of the sediments. Second, because organic constituents are regulated on a "total" basis (whereas metals are regulated on a "dissolved" basis), both the dissolved and the particulate fractions of the water column concentration should be considered.

The elutriate testing triggers for organics are derived using the following equation:

$$\mathbf{ETorganic = WQC / [(TSSinc \times 10^{-6}) + (Koc \times f_{oc}) -1]}$$

where:

WQC is the water quality criterion in µg/L.

K_{oc} is the organic carbon partitioning coefficient in L/kg-oc.

f_{oc} is the decimal fraction of organic carbon in kg-oc/kg-sed.

TSS_{inc} is the incremental added mass of suspended solids in the water column generated by the dredging action in mg/L.

10^{-6} is a conversion factor of milligrams per kilogram of sediment.

Since water quality criteria are developed for protection of multiple receptors, using elutriate triggers as an additional screening process provides protection for species not covered by the benthic SLs. For the lower screening value (SL1), chronic WQ standards were used in the calculations; the higher screening value (SL2) used the acute water quality standards. This approach was used for all compounds that have EPA-promulgated water quality standards. In order to develop protective screening values for aquatic placement of dredged material, the parameters in the ET formula were assigned the following default values:

- Total organic carbon: 1%
- Total suspended solids: 100 mg/L
- Water hardness: 18.9 mg/L $CaCO_3$
- pH: 7.0

The default value of 18.9 mg/L $CaCO_3$ for water hardness differs from the SEF default (100 mg/L $CaCO_3$), and is based on a survey of water hardness in the Willamette River (Portland Harbor RI/FS August 29, 2011). This change generated lower SLs and was considered more realistic and protective than the SEF default.

Resulting values are presented in Table 1 as the WQ-based SLs. A spreadsheet is provided in Attachment 1 to allow for entry of site specific information if applicants prefer to develop site-specific WQC-based SLs.

Development of Freshwater Background Sediment Concentrations for DMMP Use in Washington State

The Pacific Northwest region is known to have naturally elevated metals concentrations and in some cases, sediment background concentrations should be taken into consideration. However, background concentrations vary between regions, watersheds, and water body types. Very little natural background data exists for freshwater sediments, and while substantially more data are available for soil background values near freshwater areas, the applicability of soil background to sediments is not defined in policy for Washington or Oregon.

In Oregon, the RSET FW technical group is proposing that the Willamette upstream sediment natural background metals values calculated for the Portland Superfund area (LDWG 2012) be used for sediment natural background unless there are other data to support sediment natural background for other regions. However, based on data in Ecology's publication #09-03-032 ("Baseline characterization of nine proposed freshwater sediment reference sites, 2008"), many metals in Washington sediment had higher concentrations compared to the background values from the Willamette, thus Willamette background may not be appropriate for Washington.

Using available sediment data for Washington State and performing outlier analysis, only nickel appears to clearly have sediment background higher than the risk-based level (see Appendix A). However, more freshwater sediment data are needed before a statistically robust background concentration can be calculated.

Since it appears that the Willamette sediment background may not be appropriate for Washington sediments, and sufficient Washington sediment data are not yet available, the DMMP agencies developed interim background values using Washington State soil data from Ecology's publication #94-115 (Natural Background Soil Metals Concentrations in Washington State). Using this data set, nickel had a background concentration higher than the benthic or WQ- based SLs (see Appendix A). In Washington, the DMMP agencies propose to use the 90th percentile of the Washington State soil background data for nickel until sufficient sediment data are available to calculate background.

PROPOSED VALUES AND APPLICATION FOR SEDIMENT EVALUATIONS

The proposed table of screening values (Table 1) includes risk-based values (benthic screening levels and water-quality derived screening levels) and a Washington background-based value for a single metal (nickel). If project sediment data are below all proposed screening levels, then the material is suitable for open water disposal or in-water placement and passes antidegradation evaluation.

If project sediment data exceed one or more screening levels, then the material is considered unsuitable unless further evaluation is conducted. Sulfide and ammonia differ from this general rule, since these compounds typically disperse rapidly in the dredging and disposal process. Sulfide and ammonia SLs will be used to inform bioassay testing (e.g. special handling to remove ammonia/sulfides prior to bioassays) and water quality monitoring requirements at the dredging site (extremely high values may result in dissolved oxygen monitoring in addition to turbidity monitoring), rather than to determine suitability of the material for open water disposal or in-water placement.

Table 2 provides a matrix for comparison and the further evaluations for the various SLs. Note that if a sample exceeds more than one screening level, multiple tiered tests may be required before material could be considered suitable for open water disposal or in-water placement, and/or for passing antidegradation. Further evaluations may include development of site-specific screening values, modeling, elutriate tests, or bioassays. Note that if both WQ-based and benthic SLs are exceeded, applicants must perform tiered testing for both SLs for material to be considered suitable.

Tiered Testing for Exceedances of Water Quality-based Screening Values

Tiered testing procedures for WQ-based SL exceedances may use several approaches, depending on the concerns. These could include elutriate testing, development of site-specific water quality criteria or SLs, or site-specific modeling to determine if water quality would be met at the point of compliance.

If the concern is for placement of dredged material or material being suspended during dredging, then elutriate tests should be conducted, and unfiltered water should be analyzed and the results compared to the water quality criteria. If concentrations are above criteria, modeling should be conducted to determine if criteria will be met at the project's point of compliance. If they are unable to meet criteria, special project Best Management Practices (BMPs), such as silt curtains, may be required.

If the concern is material remaining in place after dredging, then alternative approaches should be considered as appropriate to the project and permitting requirements, such as modeling what would be expected in overlying water, analysis of overlying water, or modified elutriate testing.

If site-specific data are available, the proponent has the option to calculate site-specific screening levels or site-specific water quality criteria for the project. Site-specific SLs can be developed using the spreadsheet provided in Attachment 1, where site organic carbon and expected suspended sediments can be taken into account. The development of site-specific water quality criteria must take into account ambient water chemistry (water hardness and pH), and would require ambient water analysis. Development of site-specific SLs or water quality criteria are subject to approval by the DMMP agencies.

Tiered Testing for Benthic Screening Values

If benthic screening levels are exceeded, then applicants can conduct bioassays to gather additional information for decision-making. These results may over-ride the benthic SL exceedances. Details for conducting bioassays are provided in Chapter 7 of the SEF. Note that for consistency with the SMS (WAC 173-204-563(-3)) bioassays selected should include three endpoints using both *Hyalella* and *Chironomus*, at least one chronic endpoint (20-day *Chironomus* or 28-day *Hyalella*), and at least one sub-lethal endpoint (growth).

Antidegradation in Washington

The DMMP agencies follow a detailed approach for antidegradation that is consistent with the SMS. This approach is outlined in the DMMP 2008 clarification paper, "Quality of post-dredge sediment surfaces (updated)". The DMMP will use this approach, with the SL2 from the benthic standards representing the CSL (consistent with SMS (WAC 173-204-563(-3)). Consistent with the DMMP 2008 clarification paper, the benthic SL1 and WQ-based SLs would both be considered SLs during antidegradation evaluations. The DMMP 2008 clarification paper allows tiered bioassay testing for SL exceedances. If FW WQ SLs are exceeded in the surface exposed by dredging, appropriate WQ-based testing approaches would be used to augment information available for decision-making, possibly overriding WQ-based SL exceedances as delineated in the DMMP 2008 clarification paper.

IMPACT ANALYSIS

The DMMP agencies evaluated the potential impact of the proposed freshwater approach on projects. Data from DMMP freshwater projects over a five-year span (2009-2013) were compared to the new SLs, to determine if there would have been significant changes in the evaluation (suitable or non-suitable). There were 12 projects with 43 DMMUs, mostly in the Columbia River but also including Lake Union (one project, seven DMMUs) and Lake Washington (two projects, four DMMUs).

Of these 43 DMMUs, 25 DMMUs had no change in decisions (six passed both sets of SLs, 16 had detected exceedances of both sets of SLs, and three had non-detected exceedances of both sets of SLs) (Table 3).

Two DMMUs passed the 2006 SLs but had detected proposed SL exceedances for nickel. These DMMUs would now require bioassays or site-specific background evaluation for nickel. Both of these were in the same project (South Lake Union).

Twelve DMMUs passed the 2006 SLs but had non-detects above SL (five for silver, five for pentachlorophenol (PCP), two for PCB) that previously had no exceedances of the 2006 guidance. These non-detect exceedances could be avoided for silver and PCP- the proposed silver (0.57 ppm) and PCB SLs (33 ppb) and are at or above the Ecology median PQLs (0.5 ppm and 33 ppb respectively) (Ecology draft SCUM II, appendix F). If sediment concentrations were actually present above the SL, the PCB exceedances would have triggered further evaluation based on the WQ-based SL (elutriate testing, modeling) and the silver exceedance would have triggered bioassays. For PCP, the standard methodology (typically SW8270D) PQL (265 ppb) and MDL (48 ppb) are above the proposed WQ-based SL (39 ppb). Non-detects exceeding the proposed PCP SL would normally trigger further evaluation (elutriate testing, modeling). Although an alternative method (EPA 8270 LL) could reach PQLs and MDLs below the proposed SL, unless there is a reason to believe that PCP is an issue at the project site, the agencies will not require the alternative method and instead will require reporting of PCP down to the MDL. Only detected exceedances of the WQ-based SL will trigger further evaluations.

Three DMMUs that exceeded the 2006 SLs (Cd, Zn, and bis(ethylhexyl)phthalate) had no detected exceedances of the proposed SLs, but did have non-detected exceedances for PCP. Bioassays were not run on two of these DMMU, so it is not known whether the exceedances of the 2006 guidelines were associated with toxicity; however, bioassays were conducted and passed for the project with the Cd exceedance (Kitittas).

A single DMMU had a non-detect exceedance of the 2006 SLs (Hg) and a detected exceedance of the proposed nickel SL; either exceedance would have triggered bioassays.

Table 1. Proposed ECY Benthic SLs, WQC-based SLs, and Nickel Background for Washington

ANALYTE	ECY BENTHIC SLs		WQC-BASED SLs (EPA)		WA-specific metal background
	SQS/SL1	CSL/SL2	chronic	acute	
Metals (mg/kg)					
Arsenic	14	120	1900	3400	
Cadmium	2.1	5.4	3.9	20	
Chromium	72	88	2380	18330	
Copper	400	1200	110	140	
Lead	360	>1300	160	4030	
Mercury	0.66	0.8	150	280	
Nickel	26	110	510	4550	38 (*interim)*
Selenium	11	>20			
Silver	0.57	1.7		15	
Zinc	3200	>4200	3630	3600	
Organic contaminants (ug/kg)					
4-Methylphenol	260	2000			
Benzoic acid	2900	3800			
beta-Hexachlorocyclohexane	7.2	11			
bis(2)-Ethylhexyl)phthalate	500	22000			
Carbazole	900	1100			
Dibenzofuran	200	680			
Dibutyltin	910	130000			
Dieldrin	4.9	9.3	90	380	
Di-n-butyl-phthalate	380	1000			
Di-n-octyl-phthalate	39	>1100			
Endrin ketone	8.5	**			
Monobutyltin	540	>4800			
Pentachlorophenol	1200	>1200	39	50	
Phenol	120	210			
Tetrabutyltin	97	>97			
DDDs	310	860			
DDEs	21	33			
DDTs*	100	8100	7		
PAHs	17000	30000			
PCB Aroclors	110	2500	33	4720	
Tributyltin	47	320	18	110	
Bulk Petroleum Hydrocarbons (mg/kg) (NW-TPH method)					
TPH-Diesel	340	510			
TPH-Residual	3600	4400			

* Elutriate-based DDT value is based on the sum of sum of o,p'- and p,p'-DDXs
** no SL2 available

Ammonia and Sulfides, listed below, are used only to inform bioassay testing.

Conventionals (mg/kg)		
Ammonia	230	300
Total sulfides	39	61

Table 2. Tiered Testing Matrix

Comparison	CoCs	If the SL is exceeded, material is unsuitable for open water disposal/placement* unless the appropriate tiered testing listed below passes	Pass SL
Benthic SL	all compounds	Bioassay testing- must use both species (*Hyalella* and *Chironomus*), at least one chronic exposure, and at least one sub-lethal (growth) endpoint.	If a sample is at or below all SLs, then the material is suitable for dredging/disposal/in-water placement and meets the antidegradation standard. However, when ESA-listed species are present, the Federal action agency may need to contact NMFS and/or USFWS (as appropriate) to discern whether additional analyses are needed, and whether those analyses should be done as part of an ESA consultation.
WQC-based SL	metals, dieldrin, PCP, sum DDT, PCB Aroclors, TBT	WQC-based testing options- elutriate tests show WQC will be met; develop and pass site- specific WQC SL;, or model to show standards will be met at the point of compliance.	

*For antidegradation evaluation, see "antidegradation" section. Tiered testing may not be required in some cases, even with SL exceedances, for example, when the exposed surface would be lower than both the SL2 and the existing surface.

Table 3. Matrix Comparing DMMU Evaluations for Impact Analysis

	All COCs are less than or equal to proposed SLs	One or more detected exceedance of proposed SLs	One or more non-detects exceed proposed SLs
All COCs are less than or equal to 2006 SLs	6	2 (Ni)	12 (5 Ag, 5 PCP, 2 PCB)
One or more detected exceedance of 2006 SLs	0	16	3 (PCP)
One or more non-detects exceeded 2006 SLs	0	1 (2006 Hg, proposed Ni)	3

References

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Glossary of Terminology

Benthic Screening Levels (Benthic SLs): Sediment screening levels based on regional data and the Floating Percentile Model (Avocet, 2011).

Elutriate Test: A sediment test where water and sediment are shaken, allowed to settle for a pre-determined amount of time, and the overlaying water and suspended sediments analyzed for chemical concentrations.

Elutriate Trigger (ET): A sediment SL based on a targeted water allowable water concentration and equilibrium partitioning. These were originally developed in the SEF for acute WQC only. This paper expanded the use to include chronic WQC, and re-named the resulting sediment SLs as the WQC-based SLs.

Water Quality Criteria-based Screening Levels (WQC-based SLs): Sediment SLs based on water quality criteria and equilibrium partitioning.

Appendix A: Supplemental analysis of available sediment and soils data for Washington State.

Dredging projects need a way to determine when background concentrations of metals in freshwater sediments may be above the risk-based screening values (benthic SL or WQ-based SL). According to the SMS, when natural background concentrations are above risk-based values, background concentrations over-ride the screening values.

For freshwater, there are no established sediment natural background values. Data from both Washington state soil ("Natural background soil metals concentrations in Washington state", Ecology publication #94-115) and sediment data (Ecology's publication #09-03-032, "Baseline characterization of nine proposed freshwater sediment reference sites, 2008") were examined to determine which, if any, metals may require a default to natural background. Soil 90th percentile[1] and sediment 90/90 UTLs were compared to the sediment SLs (benthic, WQ-based) (Table 1). Only four metals had values higher than SL: Ni, As, Cu, and Hg, which could be the basis of an over-ride.

Because it is preferable to have a sediment background value for use in dredging rather than defaulting to soil values, the sediment data from publication #09-03-032 were examined more closely to determine whether that data could be used to generate Washington state freshwater background concentrations. The data were not normally distributed for any of the metals, and while outlier analysis indicated there may be some outliers, there is insufficient data for the non-normally distributed dataset to prove that the potential outliers were either in or out of the background distribution. For this analysis, outliers were removed from the data set, and the 90/90UTLs re-calculated and compared to their respective SLs. Only Ni remained higher than the risk-based SLs; no outliers had been identified for this metal.

In order to determine if sufficient nickel data were available, the approach used in the regional background studies was applied. The precision for the 95%UCL on the mean was higher than 25%, indicating more samples are needed to better characterize the upper part of the distribution that is used to set the background value.

The RSET FW technical group is proposing that the Willamette upstream natural background values calculated for the Portland Superfund area be used for metals natural background unless there are other data to support natural background for other regions. Based on data in Ecology's publication #09-03-032, many metals in Washington sediment had higher concentrations

[1] 90th percentile reported in the publication was used for soil since the publication did not have the individual data values available to calculate the 90/90UTL.

compared to the background values from the Willamette, thus Willamette background may not be appropriate for WA.

Using available sediment data for the state and biasing towards lower concentrations by using outlier analysis, only Nickel appears to clearly have sediment background higher than risk-based level. However, statistics indicate that more freshwater sediment data are needed for nickel to better define the upper tail, which is what defines the background concentration. Since it appears that the Willamette sediment background may not be appropriate for WA sediments, but sufficient WA sediment data is not available, the DMMP needs an approach for assessing nickel in the interim. Either the 90th percentile of WA soil data or the 90/90UTL of existing WA sediment reference (Ecology's publication #09-03-032) data can be used in the interim. Given the uncertainties around the sediment data, and the fact that the soil data are lower than the sediment, the DMMP proposes to continue to use the soil background data for nickel until sufficient sediment background concentrations can be established.

Table A-1. Metals concentrations (ppm dry wt) in selected sediments and soil. More Washington state freshwater sediment data are needed to determine usable background concentrations. Nickel is the only metal where Washington sediment and soil were above the SL after outliers were removed.

Metal (lowest risk-based SL in parentheses)	Willamette sed bkg (95th %ile)	WA sed (all data) (90/90UTL)	WA sed (outliers removed) (90/90UTL)	WA soil (90th %ile)
Arsenic (14)	3.8	17	6.5	7
Cadmium (2.1)	0.2	0.7	0.5	1
Chromium (72)	32.7	60	no outliers	42
Copper (110)	38.0	146	49	36
Lead (360)	14.3	53	12	17
Mercury (0.66)	0.1	0.22	0.14	0.04
Nickel (26)	**26.1**	**57**	**no outliers**	**38**
Selenium (11)	0.4	2	0.6	na
Silver (0.6)	0.7	0.19	0.13	na
Zinc (459)	105.0	110	no outliers	85