Arsenic Background Paper and Draft Options for Discussion

Introduction

DEQ has agreed to review the science behind the human health water quality criteria for arsenic due to the following concerns, which were expressed to the EQC at their meeting in October, 2008. First, arsenic is a naturally occurring earth metal found in Oregon waters at natural background levels greater than the human health criteria. Second, the ambient water quality criteria for arsenic are much lower than the Maximum Contaminant Level (MCL) developed under the Safe Drinking Water Act for drinking water delivered to people's homes.

DEQ plans to conduct this review and propose revised arsenic criteria simultaneously with the human health criteria revisions being made to incorporate an increased fish consumption rate of 175 grams/day.

Concerns about Oregon's Human Health Water Quality Criteria for Arsenic

Background levels. DEQ expects that natural background levels of arsenic in Oregon are in the range of 1 to 3 µg/l in many waters of the state. There is limited data available on arsenic concentrations in surface waters because until recently DEQ used 5.0 µg/l as a quantitation limit. Therefore, much of the data collected by DEQ or permittees report "non-detectable" levels of arsenic. In 2008, DEQ reduced the quantitation limit for arsenic to 0.5 µg/l.

DEQ data from approximately 1979-1981 indicate that much higher levels of arsenic may be present in some south central and southeastern Oregon basins.

Natural sources. There are natural geologic sources of arsenic in Oregon. The City of Portland has found arsenic levels in the Bull Run reservoir, a primary source of Portland's drinking water ranging from less than 1 µg/l (their minimum reporting level) up to 3 µg/l.

A USGS (1998) report on arsenic concentrations in ground water of the Willamette Basin found concentrations ranging from < 1 to 2,000 µg/l. The report concludes:

1. "Regional patterns of arsenic occurrence in the Willamette Basin indicate that the sources of arsenic in ground water are not human related. Arsenic-containing metal

oxides, volcanic glass in volcanic rocks of rhyolitic to intermediate composition, and clays are likely sources."

2. High arsenic concentrations (concentrations exceeding the current MCL established by EPA) appear to be associated with particular associations of rock in some areas and with alluvial deposits in others (i.e. the Tualatin basin). (paraphrased)
3. "For alluvial ground water of the Tualatin Basin, (1) presence of competing anions and (2) occurrence of reducing conditions may be important controlling factors in arsenic adsorption/desorption reactions. Dissolution of iron oxides, with subsequent release of adsorbed and (or) coprecipitated arsenic, also may play an important role in arsenic mobility in ground water of the Tualatin Basin."

A 1998 arsenic study by the Washington Department of Ecology (Ecology), that included data collection from the Columbia River, reported: *"the recent data suggest that total recoverable arsenic concentrations in local rivers and streams are typically in the range of 0.2 - 1.0 µg/L, while concentrations greater than 2 to 5 µg/L may indicate contamination from anthropogenic sources. Arsenic levels in most 303(d) listed waterbodies are not clearly different from waterbodies that have no apparent sources, and some are comparable to rainwater"* (Results and Recommendations from Monitoring Arsenic Levels in 303(d) Listed Rivers in Washington – DOE 2002).

Human sources. What are the anthropogenic sources or pathways? [To be added.]

Arsenic impaired waters. The streams shown in the table below are currently 303d listed for exceeding the arsenic criteria.

Basin	River	River Miles	Year listed
Multi	Columbia	0-142	1998
Willamette	Willamette	175 – 186	2002
Upper Willamette	A-3 drain	---	2002
Upper Willamette	Amazon Cr.	0-23	2002
Upper Willamette	Willow Cr.	0-3	2002
North Umpqua	N. Umpqua	35-52	2002
North Umpqua	Sutherlin Cr.	0-16	2002
North Umpqua	Unnamed Cr.	---	2002
South Umpqua	Middle Cr.	0-13	2004
South Umpqua	S. Umpqua R.	0-16	2002
Warner Lakes	Twentymile Cr.	0-29	2002
Owyhee	Owyhee River	71-200	2004
Jordan	Jordan Cr	0-95	2004
Mid Col-Hood	Lenz Cr	0-1.5	2004
Mid Col-Hood	Neal Cr.	0-6	2004
Molalla-Pudding	Zollner Cr	0-8	2004

Potential Health Impacts of Arsenic

Arsenic is a known carcinogen that may cause cancer in skin or internal organs such as the liver, kidneys, lungs and bladder. Other potential health impacts from arsenic include cardio vascular, kidney, central nervous system and hyper pigmentation/keratosis effects (USEPA, 2000). Factors for how to represent these effects in the criteria equations are included in EPA's Integrated Risk Information system (IRIS) database. The federal arsenic criteria are based on the cancer endpoint, as shown below.

Current Arsenic Criteria: State and Federal

The current Oregon and EPA arsenic criteria are shown in the table below.

Arsenic Criteria		
	Water and Organism (µg/L)	Organism Only (µg/L)
Currently effective Oregon criteria (Table 20)	0.0022	0.0175
Criteria adopted by Oregon in 2004	0.018*	0.14*
Current EPA criteria	0.018*	0.14*

* Inorganic arsenic

Oregon's currently effective criteria (Table 20) are based on EPA's 1986 recommended criteria. These criteria were based on a fish consumption rate (FCR) of 6.5 g/d. Table 20 does not specify whether the human health criteria are for the inorganic arsenic or organic form arsenic. The toxicity data EPA used to calculate the 1986 recommended criteria was for inorganic arsenic.

EPA's current arsenic criteria and the criteria adopted by the EQC in 2004 are based on a fish consumption rate (FCR) of 6.5 g/d and a cancer slope factor of 1.75, and are specifically identified as criteria for inorganic arsenic. In 1992, EPA promulgated these arsenic criteria in the National Toxics Rule. Although EPA has since changed the cancer slope factor in IRIS to 1.5 (4/10/1998) and changed their recommended FCR to 17.5 (EPA, 2000), they have not revised their national recommended arsenic criteria since 1992.

Although DEQ adopted the current criteria in 2004 and submitted them to EPA on July 8 of that year, they are not yet effective in Oregon because they are less stringent than our prior criteria

and have not yet been approved by EPA. Therefore, the Table 20 criteria remain the effective criteria for Clean Water Act purposes in Oregon.

EPA did not promulgate human health criteria for arsenic in the California Toxics Rule (CTR) in 2000, stating that "a number of issues and uncertainties existed at the time of the CTR proposal concerning the health effects of arsenic." Neither did EPA include arsenic criteria in its promulgation of criteria for the Great Lakes States in 1995.

Most states have human health arsenic criteria ranging from a low of the current federal criteria to a high of 50 µg/l. Almost half of the states have criteria of 10 or 50 µg/l based on the current or previous Safe Drinking Water Act maximum contaminant level (MCL). A few states have recalculated their arsenic criteria using EPA equations but altering some of the variables in those equations, including the following: using a different bioconcentration factor (BCF), applying an inorganic proportion to the calculation, using the current IRIS cancer slope factor of 1.5, using an updated fish consumption rate, and/or using a risk level of 10^{-5} rather than 10^{-6}. One EPA Region (Region 6) has developed a methodology for developing alternate arsenic criteria. The factors and methods used in the Region 6 approach are discussed further below. About 10 states have no "water & organism" arsenic criterion and several have no "organism only" criterion.

How the Federal Arsenic Criteria Were Calculated

The following two equations and accompanying table describe the variables that were used to calculate EPA's current national human health criteria for arsenic, which Oregon adopted in 2004.

$$\text{Water + Organism Criterion (µg/L)} = 1000 \times \frac{RF \times BW}{q1^*[DW + (BCF \times FCR)]}$$

$$\text{Org Only Criterion (µg/L)} = 1000 \times \frac{RF \times BW}{q1^*[BCF \times FCR]}$$

where:

Symbol	Description	Value Used for Arsenic
RF =	risk factor (dimensionless)	$1x10^{-6}$
BW =	body weight (kg)	70
q1* =	cancer potency factor (mg/kg/day)-1	1.75
DW =	Drinking water consumption (L/day)	2
BCF =	bioconcentration factor (L/kg)	44

FCR =	fish consumption rate (**kg**/day)	0.0065

Options Discussion

DEQ is considering several options for deriving arsenic criteria as an alternative to EPA's current recommended criteria. Three primary alternative approaches are described in this paper:

1. Re-calculation of the federal criteria,
2. Use of the MCL value for drinking water in some manner, and a
3. Natural background based approach.

The table below shows estimated values under these three potential approaches as well as the value if the criteria are revised by changing only the FCR.

Approach	Estimated Water + Organism (µg/l)	Estimated Organism Only (µg/l)
OR re-calc: FCR=175	0.004	0.005
OR re-calc: FCR=175, BCF=1 and percent inorganic=10	0.21	2.7
MCL hybrid	1 to 8	1 to 8
Natural background (statewide)	1 to 3	1 to 3

Option 1: Re-Calculating the Criteria Using Oregon Appropriate Values

The first approach would be to recalculate the criteria using EPA equations, but using alternative values for some of the factors that we believe are more appropriate to Oregon. This approach has been used in other States and approved by EPA. It is described by the EPA Region 6 interim strategy for arsenic.

One locally driven factor is the fish consumption rate. DEQ expects to proposal revising the FCR used in our recalculation of the criteria to 175 g/d. The current federal criteria are based on a consumption rate of 6.5 g/d.

Other factors that could be revised to reflect Oregon conditions include the bioconcentration factor (BCF) and the proportion of total arsenic found in fish tissue that is in an inorganic form.

Bioconcentration factor (BCF). Bioconcentration refers to the uptake and retention of a chemical by an aquatic organism from water only. A bioconcentration factor (BCF) is the ratio (in L/kg-tissue) of the concentration of a substance in tissue of an aquatic organism to its concentration in the ambient water, in situations where the organism is exposed through the water only and the ratio does not change substantially over time. Past arsenic criteria recalculation efforts have explored several aspects relating to the selection and use of the BCF variable.

EPA's current BCF for arsenic is found in EPA's 1980 *Ambient Water Quality Criteria for Arsenic*. The BCF was calculated from the geometric mean (weighted with consumption rates) of two species. Data from the eastern oyster (BCF=350, 112 day test) and bluegill (BCF=4, 28 day test) resulted in a BCF for arsenic of 44. In addition, the data set for these numbers was relatively small.

One concern raised regarding the use of a BCF of 44 is that inclusion of the eastern oyster BCF may result in an overestimation of the health risks associated with freshwater finfish consumption. Other data reflecting lower BCFs for freshwater species is also cited as support for this concern. As a result, some states have selected a BCF that they believe is more representative of the aquatic life in their state. In particular, a BCF of 1, as provided in a draft version of the Great Lakes Initiative rule, has been used by some states (i.e. Idaho, Michigan, and Colorado) as a basis for revising the BCF used in the equation to derive human health criteria for arsenic. This value is also used by EPA Region 6 in their interim strategy for deriving arsenic criteria.
Use of a higher BCF value results in more stringent human health criteria for arsenic.

EPA (Stephan, 1993) used the following information to support a BCF of 1 for the draft proposed Great Lakes Initiative arsenic criterion. They noted that "Spehan et al. (1980) obtained BCFs of zero for various inorganic and organic forms of arsenic based on whole-body measurements on rainbow trout; Barrows et al. (1980) obtained a BCF of 4 using whole-body measurements on bluegills; and DeFoe (1982) found a BCF of 3 for whole-body measurements of fathead minnow. EPA states, "BCFs for muscle should not be higher than those for whole body; thus it seems reasonable to use a HHBAF of 1.0 for arsenic."

DEQ is considering using a BCF of 1, based on EPA proposals in the Great lakes and Region 6.

Percent Inorganic Considerations.

Arsenic is present in the environment and in fish tissue in organic and inorganic forms or "species." Inorganic arsenic is more toxic to humans and EPA's toxicity data for cancer and other end points are for inorganic arsenic. EPA's recommended human health criteria only apply to the inorganic form of arsenic; however, the BCF value (44 L/kg) that EPA used in deriving the human health criteria for arsenic are based on total arsenic, not inorganic arsenic. Therefore, some states have also elected to multiply the BCF value by what might be called a "% inorganic" variable. For example, the EPA Region 6 Interim Strategy and the State of Colorado use a 30% inorganic variable, and the Maryland recalculation used 4% inorganic.

An EPA study (2002) on fish contaminants in the Columbia River found the following:

Percent inorganic arsenic found in fish tissue: (p. 5-78)

- Overall arithmetic average for all composite samples 6.5%
- Average % inorganic by species ranged from 0.5% in carp to 9.2% in sturgeon.
- Anadromous species about 1.0% on average
- Resident species about 9% on average

The study said that these findings were consistent with the literature, which shows low percentages of inorganic arsenic levels for most saltwater fish species. A risk assessment performed as part of this EPA study assumed 10% of total arsenic was inorganic for all species.

Use of a higher "% inorganic" value results in more stringent human health criteria for arsenic.

DEQ is considering using an inorganic arsenic fraction 10 percent based on the Columbia River fish contaminant and health risk assessment study (EPA, 2002).

Toxicity factors. DEQ is not going to review the toxicity data or re-evaluate the cancer slope factor used to derive human health criteria for arsenic. We rely on EPA research to provide this information. DEQ proposes to use the cancer slope factor in EPA's Integrated Risk Information System (IRIS) data base as of the date of this review, which is 1.5 mg/kg/day.

Option 2: Use the Maximum Contaminant Level from the Safe Drinking Water Act to Derive Oregon's Arsenic Criteria

One option for Oregon to consider is using some combination of the maximum contaminant level (MCL) for drinking water and the EPA criteria calculation method to represent exposure through fish tissue. Nearly half of the states have utilized the MCL value for arsenic in place of EPA's national criteria recommendations and additional states have used a combination of the MCL and EPA criteria. DEQ believes that using a fraction of the MCL (10) as the water quality criteria is a preferable option over adoption of the MCL due to the additional exposure to arsenic through consumption of fish tissue.

An MCL is the highest level of a contaminant that is allowed in drinking water delivered to the tap (post treatment). MCLs are enforceable standards developed by EPA under the Safe Drinking Water Act. MCLs are set as close to maximum contaminant level goals (MCLGs) as feasible using the best available treatment technology and taking cost into consideration. MCLGs are non-enforceable public health goals that describe the level of a contaminant in drinking water below which there is no known or expected risk to health and allow for a margin of safety. For carcinogens, MCLGs are set to zero.

On January 22, 2001, EPA revised its maximum contaminant level (MCL) for arsenic from 50 to 10µg/L, and established a date of January 23, 2006, for all public water supply systems to achieve compliance with the revised MCL.

Option 3: Natural Background plus a Minimal Increment for Assimilative Capacity if that Value Protects Human Health

Under this approach, DEQ would consider the current natural background levels of arsenic that occur on a widespread basis in the State and set the human health criteria for arsenic slightly above that level to allow for some assimilative capacity in localized areas to allow for mixing zones. The purpose of setting a criterion slightly above natural background would be to allow discharge of concentrations that have been increased due to evaporative cooling, for example, which can occur even if there has been no addition of mass, to be mixed the receiving water and meet the criteria at the edge of an assigned mixing zone. This concept is in the early stages of consideration and much more thought and discussion is needed. DEQ understands that in order for this approach to be viable, we must be able to demonstrate that the criteria will protect human health.

Additional Considerations:

The additional considerations listed here could be combined with the 3 primary options discussed above.

1. Apply the fish only criterion where drinking water (public domestic water supply is not a designated use and revise beneficial uses in a follow up rulemaking to more narrowly designate water bodies considered suitable for drinking water supply.
2. Adopt the alternate approaches on a site-specific basis by region or basin where natural background levels are above the criteria that would be set using the default calculations.

References

ODEQ, 2008. Molalla-Pudding TMDL. Chapter 6. Iron, Manganese and Arsenic. http://www.deq.state.or.us/wq/TMDLs/willamette.htm#mp

ODEQ, 2001. Tualatin Subbasin TMDL. Appendix G: Toxics Discussion.

USEPA Region 10, 2002. Columbia River Basin Fish Contaminant Survey, 1996-1998. Seattle, Washington. EPA 910-R-006.

EPA, 2000. Health Affects of Inorganic Arsenic. Integrated Risk Information System (IRIS); www.epa.gov/iris

"Issues Related to Health Risk of Arsenic," EPA. Contained in record for CTR, 2000. (Melinda is tracking this down for us)

FR Notices for NTR and CTR (have links)

National Research Council (National Academy of Sciences) report on health effects of arsenic. March, 1999. (Ask for this)

Comments and responses on proposed NTR arsenic criterion. (Melinda has sent this.)

USGS, 1998. Arsenic in Ground Water of the Willamette Basin, Oregon. *By* Stephen R. Hinkle *and* Danial J. Polette. USGS Water-Resources Investigations Report 98-4205, 28 pages, 6 figures, 4 tables, 1 appendix, 1 plate

Stephan, Charles E., 1993. Derivation of Proposed Human Health and Wildlife Bioaccumulation Factors for the Great Lakes initiative. EPA Environmental Research Laboratory, Duluth, MN. CAS # 7440-38-2.