TO: SURFACE WATER GROUP, REGIONAL WATER QUALITY MANAGERS

FROM: DON ESSIG, WATER QUALITY STANDARDS

SUBJECT: EVALUATION OF WATER COLUMN CHEMISTRY DATA FOR COMPLIANCE WITH HUMAN HEALTH CRITERIA

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APPLICATION OF HUMAN HEALTH CRITERIA

Surface water human health criteria are based on human exposure to water borne toxic substances through two primary routes: 1) drinking of surface water, and 2) consumption of aquatic organisms, principally fish, that may accumulate toxins in their flesh. Consequently there is typically a pair of criterion values for a contaminant, reflecting these two different routes of exposure. Which of these criteria applies depends on the use designation of the water.

If a waterbody is designated for recreational use (either primary or secondary contact), the opportunity to fish and possibly consume any fish caught is included. The applicable criteria for toxic substances for recreational use are the so-called "organism only" criteria, column C2 in the table of criteria in section 210 of Idaho's Water Quality Standards (WQS). If a waterbody is also designated as a domestic water supply then there is the possibility of added exposure due to drinking water from the same waterbody from which fish may be caught and eaten, and the criterion is thus lower. The applicable criteria for toxic substances for domestic water supply use are the so-called "water + organism" criteria, column C1 in section 210 of the WQS.

DURATION OF EXPOSURE

Both sets of criteria, those for organism only and water + organisms exposure, are set to protect people from adverse health effects over a lifetime of exposure. Thus these are chronic criteria, accounting for long-term, persistent even if irregular, exposure.

WHAT DOES THIS MEAN TO CRITERIA APPLICATION?

While it is conceivable that an individual will habitually drink water and eat fish from the same waterbody, it is far more likely the location, type and quality of fish consumed and water drank will vary over a lifetime. Since exposure to a pollutant varies and the criteria are chronic, a single measurement likely provides little information about lifelong exposure. Nonetheless a single value may be all we have and in that case we will need to use it as our best estimate of water quality and attendant exposure. If we are fortunate enough to have a longer dataset it will likely show ups and downs. In such a dataset an average value, somewhere between the highs and lows will best indicate long-term exposure of concern to health at a given location.

HARMONIC AND 30-DAY MEANS

The Idaho WQS don't directly address appropriate averaging periods for evaluation of human health criteria against variable exposure, as they do for aquatic life. There is however guidance in the specification of flows to be used in application of human health criteria to permitting provided in section 210.03.b of the WQS. A harmonic mean flow is specified for carcinogens and 30Q5 flow for non-carcinogens. Harmonic means are mathematically preferred when averaging a series of rates, in particular rates that represent unequal periods of time, but equal units of the numerator of the rate.

Given that chronic exposure is what the human health criteria address, and that exposure is the product of various rates of bioaccumulation that occur over time, it seems reasonable and appropriate to apply the flow averaging schemes to evaluating the compliance of ambient monitoring data with the criteria. What follows is an example application.

EXAMPLE: HARMONIC MEAN ARSENIC CONCENTRATIONS AT BLACKBIRD MINE SITE

A record of recent arsenic monitoring data from the Blackbird Mine site was examined as an example of evaluating compliance with human health criteria. Arsenic is a carcinogen so harmonic means are used. Furthermore the criteria are based on total arsenic[1]. Total arsenic concentrations are used because it is assumed particulate arsenic will become bio-available in the human gut when drinking unfiltered water, or similarly in the guts of aquatic organisms. While likely not all particulate arsenic or other metals are bioavailable this is a conservative assumption, one that errs on the side of public health and safety.

The raw data and resulting harmonic means are attached. As is often the case with ambient monitoring data at or near criteria levels, some of the arsenic measurements were flagged as U – below the reporting limit; or J+ – estimated value biased high. A decision had to be made on how to deal with these flagged values in calculation of means. The approach taken was very simple; the reported values were used in calculation as if not flagged. Thus for values reported below the reporting limit, the reporting limit was used. And for values reported as estimated, biased high, the reported value was also used. The consequence is that any mean based on one or more flagged values, either U or J+, can also be said to be possibly biased high. Therefore, any such mean was then flagged J+ to indicate this possible high bias.

In this example we can be confident that any mean, flagged or not, below the criterion for arsenic of 10 µg/L meets the criterion and would likely be farther below the criterion were we to know the true values for the measurements flagged U of J+. Flagged means above the criterion could be questioned as not truly exceeding the criterion, particularly if barely over the criterion, e.g. a mean of 11 µg/L. In the example data set all means above the criterion were un-flagged, so there is no question that they exceed the criterion. Two sites, BBSW-02 and BBSW-05, exceed the criterion.

The means for two of the sites were right at the criterion of 10 µg/L reported to the nearest 1 µg/L, the implied precision of the individual measurements. This indicates compliance with the standard.

[1] Arsenic is unusual in that both the "organism only" and "water + organism" criterion are the same. Both are based on the Safe Drinking Water Maximum Contaminant Level.

SUMMARY

In summary, in answering the question "How do we evaluate data for compliance with human health criteria" three principles emerge:

1) Total chemical concentrations are preferred over dissolved. While this likely only matters for metals, it acknowledges the potential bioavailability of particulate bound contaminants upon ingestion and consequent under estimation of exposure if dissolved concentrations are used.

2) Concentrations must be averaged over time. This is because human health criteria reflect long term exposure. When multiple data points are available averages better represent the exposure of concern. Appropriate periods for averaging are 30 days for non-carcinogens and lifetime for carcinogens. For non-carcinogens the highest 30-day mean will be the concentration of interest.

3) Arithmetic mean should be avoided unless the data is shown to be normally distributed and is equally spaced in time. For typical irregularly spaced and skewed data sets a harmonic mean, over the appropriate durations from above, is preferred. This is suggested by the flow averaging for application of human health criteria in section 210.03.b of Idaho's water quality standards.

ATTACHMENT

Station	Date and Time	Dissolved Arsenic	Total Arsenic
BBSW-01A	5/19/10 14:15		0.023
	5/24/11 13:30	0.007	0.138
	6/1/11 15:00	0.008	0.008
	7/1/11 11:30	0.005	0.007
	5/15/12 15:00		0.007
	10/19/12 16:00		0.007
	4/24/13 13:50		0.007
	5/8/13 14:30		0.013
	Harmonic mean		**0.010**
BBSW-02	5/19/10 13:45		0.022
	6/1/11 14:35	0.007	0.008
	5/15/12 13:00		0.007
	10/19/12 15:40		0.026
	5/8/13 13:40		0.009
	Harmonic mean		**0.011**
BBSW-03/03A	5/19/10 11:55		0.059
	6/1/11 12:50	0.008	0.009
	5/15/12 12:45		0.011
	10/19/12 13:30		0.006
	5/8/13 11:40		0.01
	Harmonic mean		**0.010**
BBSW-05	5/19/10 11:45		0.025
	6/1/11 12:30	0.005 U	0.013
	5/15/12 12:30		0.009
	10/19/12 13:05		0.015
	5/8/13 11:20		0.009
	Harmonic mean		**0.012**
BBSW-07	4/27/10 11:40	0.005 U	0.005 U
	5/19/10 11:30		0.005 U
	6/1/11 12:00	0.005 U	0.009
	5/8/12 13:50	0.002	0.005

Station	Date and Time	Dissolved Arsenic	Total Arsenic
	5/10/12 15:00	0.002	0.003
	5/10/12 16:00	0.002	0.003
	5/15/12 12:00		0.002
	10/19/12 12:35		0.004
	5/8/13 10:55		0.002
		Harmonic mean	**0.003** J+
BBSW-07.2	5/19/10 10:25		0.005 U
BBSW-07A	4/27/10 11:30	0.005 U	0.005 U
	5/19/10 10:40		0.006
	6/1/11 11:00	0.005 U	0.006
	5/15/12 11:40		0.002
	10/19/12 10:35		0.003
	5/8/13 10:00		0.002
		Harmonic mean	**0.003** J+
BBSW-08	5/19/10 9:40		0.005 U
	5/15/12 10:05		0.001
	10/19/12 10:05		0.001 J+
	5/8/13 9:40		0.001
		Harmonic mean	**0.001** J+
PASW-01	3/13/13 15:20	0.002	0.002
PASW-04X	5/19/10 16:10		0.009
	6/8/10 17:25		0.005 U
	6/15/10 16:50	0.005 U	0.005 U
	9/16/10 15:00	0.005 U	0.005 U
	5/4/11 15:50	0.005 U	0.005 U
	5/24/11 15:00	0.005 U	0.018
	6/1/11 17:40	0.005 U	0.005 U
	6/14/11 7:15	0.005 U	0.005 U
	6/14/11 18:20	0.005 U	0.005 U
	6/16/11 15:30	0.005 U	0.005 U
	9/23/11 17:25		0.005 U
	10/4/11 14:50	0.005 U	0.005 U
	5/1/12 15:15	0.005 U	0.005 U

Station	Date and Time	Dissolved Arsenic	Total Arsenic
	5/15/12 17:05	0.001	0.002
	5/23/12 19:30		0.002
	5/29/12 15:05	0.002	0.002
	9/20/12 19:00		0.003
	10/19/12 18:20		0.003
	3/12/13 14:30	0.002	0.002
	4/17/13 15:00		0.002
	4/24/13 15:40	0.002	0.001 J+
	5/1/13 16:50		0.003 J+
	5/8/13 16:45		0.004
	5/10/13 15:40	0.003	0.004
	5/13/13 17:45		0.003
	5/15/13 17:00		0.003 J+
	5/22/13 18:20		0.002
	5/23/13 7:15	0.002	0.002
	5/29/13 16:05		0.002
	6/12/13 13:35		0.002
	9/25/13 15:35	0.003	0.003
	10/9/13 18:20		0.003
		Harmonic mean	**0.003** J+
PASW-05	5/19/10 16:00		0.009
	6/8/10 17:15		0.005 U
	9/16/10 14:50	0.005 U	0.005 U
	5/4/11 15:40	0.005 U	0.005 U
	6/1/11 17:25	0.005 U	0.005 U
	6/14/11 7:00	0.005 U	0.005 U
	6/14/11 17:40	0.005 U	0.005 U
	6/16/11 15:20	0.005 U	0.005 U
	9/23/11 17:05		0.005 U
	10/4/11 14:40	0.005 U	0.005 U
	5/1/12 15:05	0.005 U	0.005 U
	5/15/12 16:55	0.002	0.002
	5/23/12 18:50		0.002
	5/29/12 14:50	0.002	0.003
	9/20/12 18:35		0.004

Station	Date and Time	Dissolved Arsenic	Total Arsenic
	10/19/12 18:00		0.004
	4/24/13 15:25	0.002	0.004 J+
	5/8/13 16:35		0.005
	5/10/13 15:20	0.003	0.004
	5/13/13 17:05		0.004
	5/23/13 6:50	0.002 J+	0.003
	9/25/13 15:20	0.003	0.004
	10/9/13 17:50		0.003
		Harmonic mean	**0.004** J+
PASW-09	5/19/10 15:10		0.009
	9/16/10 13:35	0.005 U	0.005 U
	5/4/11 15:05	0.005 U	0.005 U
	5/24/11 14:00	0.005 U	0.029
	6/1/11 16:20	0.005 U	0.005 U
	6/4/11 19:20	0.005 U	0.005 U
	6/5/11 20:00	0.005 U	0.006
	6/6/11 21:25	0.005 U	0.018
	6/7/11 21:40	0.005 U	0.016
	6/8/11 22:10	0.005 U	0.044
	6/9/11 18:00	0.005 U	0.038
	6/10/11 21:50	0.005 U	0.006
	6/14/11 6:20	0.005 U	0.005 U
	6/16/11 14:35	0.005 U	0.005 U
	6/20/11 16:25	0.005 U	0.005 U
	7/1/11 11:05	0.005 U	0.005 U
	10/4/11 13:35	0.005 U	0.005 U
	5/1/12 14:25	0.005 U	0.005 U
	5/8/12 16:25	0.002	0.003
	5/9/12 15:35	0.002	0.003
	5/10/12 18:45	0.002	0.003
	5/11/12 14:45	0.002	0.006
	5/15/12 16:00	0.001	0.002
	5/29/12 14:15	0.002	0.003
	9/15/12 16:00	0.002	0.002
	10/19/12 17:00		0.002

Station	Date and Time	Dissolved Arsenic	Total Arsenic
	3/12/13 13:15	0.001 U	0.002
	4/17/13 14:15		0.005
	4/24/13 14:45	0.001	0.002
	5/1/13 16:00		0.003 J+
	5/8/13 15:30		0.005
	5/10/13 14:40	0.002	0.004
	5/15/13 16:15		0.003 J+
	5/22/13 17:30		0.002
	5/23/13 6:20	0.001	0.002
	5/29/13 15:20		0.002
	6/12/13 13:00		0.001
	9/5/13 17:45	0.002	0.002
	9/5/13 19:45	0.002	0.002
	9/5/13 21:45	0.002	0.001
	9/5/13 23:45	0.002	0.002
	9/6/13 1:45	0.001	0.002
	9/6/13 3:45	0.002	0.002
	9/6/13 5:45	0.002	0.001
	9/6/13 7:45	0.001	0.002
	9/6/13 9:45	0.002	0.001
	9/6/13 11:45	0.001	0.001
	9/6/13 13:45	0.001	0.001
	9/6/13 15:45	0.001	0.001
	9/25/13 14:30	0.002	0.002
	Harmonic mean		**0.003** J+
PASW-11	5/19/10 14:30		0.005 U
	9/16/10 13:10	0.005 U	0.005 U
	5/4/11 14:50	0.005 U	0.005 U
	6/1/11 15:40	0.005 U	0.005 U
	6/14/11 6:05	0.005 U	0.005 U
	6/16/11 14:20	0.005 U	0.005 U
	10/4/11 12:50	0.005 U	0.005 U
	5/1/12 14:10	0.005 U	0.005 U
	5/15/12 15:30	0.001 U	0.001 U
	5/29/12 14:00	0.001 U	0.001 U

Station	Date and Time	Dissolved Arsenic	Total Arsenic
	10/19/12 16:25		0.001
	3/14/13 15:15	0.001 U	0.001 J+
	4/24/13 14:10	0.001 U	0.002 J+
	5/8/13 14:40		0.001
	5/10/13 14:15	0.001 U	0.001 U
	5/23/13 6:00	0.001 U	0.001 U
	9/25/13 14:10	0.001	0.001
		Harmonic mean	**0.002** J+

Notes: The following qualifiers are used in the table:

U - Concentration below reporting limits.

J+ - The result is an estimated quantity, but the result may be biased high.