# Comments on Proposed Amendments to the Standards of Quality for Waters of the State R317-2, Utah Administrative Code

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## *Main Points of Concern*

- Harvesting, marketing, and selling of brine shrimp cysts for use in the global aquaculture industry is an existing and important use of Great Salt Lake (GSL) resources that should be protected under water quality standards and guidelines.
- The EC10 value (12.5 mg/kg) for selenium in avian egg tissue alone is not sufficiently protective of the GSL brine shrimp resource without a brine shrimp monitoring program that includes actionable levels (triggers).
- Brine shrimp cysts and nauplii tissue concentrations should be maintained in the range of 3.1 to 7.9 mg/kg dry weight.
- Actionable levels of selenium in brine shrimp tissue are detailed and supported herein and should be included in the assessment methodology of the standard and the permitting rules for selenium discharge into the GSL.

## *Comments on Main Points of Concern*

The need for actionable levels of selenium in brine shrimp tissue has been well established by the formal, written comments of the GSL Selenium Science Panel to the GSL Selenium Steering Committee. The Science Panel recommended that the concentration of selenium in diet items of birds (i.e., brine shrimp and other macro-invertebrates) be maintained in the range of 3.6 to 5.7 mg/kg (Fact Sheet, 2008). In previous documents submitted by the Science Panel and by the Utah Artemia Association to the Water Quality Board, the justification for the use of brine shrimp as a monitoring species was also thoroughly established.

Maintaining the concentration of selenium in the range proposed by the Science Panel (3.6 to 5.7 mg/kg) for adult brine shrimp would protect brine shrimp and cysts as avian and aquatic diet items, and would be fully protective of brine shrimp cysts as a viable aquaculture product. This document suggests a less stringent, acceptable, alternative actionable threshold that is based upon selenium in cysts and nauplii tissue. Actionable levels in the brine shrimp cysts are defined on the basis of protective levels for fish. This approach is utilized because brine shrimp cysts are the life stage of brine shrimp that are sold to international markets throughout the world as an essential diet component for aquaculture production. It is the cyst fraction that will be tested and must meet international standards of acceptability for aquaculture products that are intended for human consumption. A water quality standard for selenium in the GSL that allows the concentration of selenium in brine shrimp cysts to exceed levels tolerated by aquaculture markets would be disastrous for the GSL brine shrimp industry and for the global aquaculture industry (Sorgeloos, pers.com., 2008).

Actionable levels proposed in this document are derived from exhaustive studies on the impact of selenium on fish. Fish toxicity studies are used to establish actionable levels because fish are sensitive and reliable indicators of impairment to aquatic biota from dietary exposure to selenium. These studies are also used because regulatory action and market perceptions of the suitability of GSL brine shrimp cysts for use in aquaculture production facilities will be a function of demonstrable toxic impacts on any finfish and crustaceans that result from consumption of dietary selenium. The current trend in regulatory standards is for lower tolerances of contaminants in aquaculture diets (GreenFacts, 2005; EU Regulation, 2003; Reilly & Kaferstein, 1997). Any perception among aquaculture producers that the management of the GSL is not adequately protecting the brine shrimp cysts from contamination by pollutants would be seriously damaging to the reputation of GSL cysts as being among the highest quality cysts produced anywhere in the world.

*Actionable Levels in Brine Shrimp Cysts and Nauplii*

The assessment methodology to be included in the rule establishing the water quality standard for selenium for the open waters of the Great Salt Lake should establish triggers for brine shrimp cysts/nauplii and adult brine shrimp *no less protective* than indicated in Table 1.0.

**Table 1.0. Proposed actionable levels of selenium in brine shrimp adults, nauplii, and cysts based upon extensive reviews of fish toxicity studies. Consistent with the assessment methodology proposed by the GSL Selenium Steering Committee a tiered approach is provided in which the actionable thresholds are based upon percentages of the 100% TMDL actionable level.**

| Percent of Standard | Adult Brine Shrimp (mg/kg) | Cysts/Nauplii (mg/kg) | Implementation |
|---|---|---|---|
| 40.0% | 5.6 | 3.1 | Level-II antidegradation |
| 60.0% | 8.5 | 4.7 | Selenium caps on all permits |
| 80.0% | 11.3 | 6.3 | Study load reductions |
| 100.0% | 14.1 | 7.9 | TMDL Requirement |

*Selenium Concentrations in GSL Brine Shrimp and the Ratio of Selenium in Adults to Cysts and Nauplii.*

The geometric mean value of selenium that currently exists in the adult brine shrimp in the Great Salt Lake is 3.9 mg/kg. Data from GSL Selenium Project 2b indicates that the concentration of selenium in the youngest instar stages (naupliar fraction of the brine shrimp) and cysts are approximately 56% of the adult value (2.2 mg/kg).

*Justification for Actionable Levels for Selenium in Brine Shrimp*

It is not within the scope of this document to include an exhaustive list of all relevant toxicology studies on selenium and fish. Rather, this document includes seminal publications and review articles from acknowledged leading authorities in the scientific community on selenium and fish. In addition, this document includes information from United States government agencies that have conducted extensive scientific literature reviews regarding selenium and formulated position documents on selenium regulations. An upper limit of 7.9 mg/kg is proposed because it reflects the generally accepted upper dietary concentration for selenium (6.5 to 8.0 mg/kg) as well as the defined concentration of selenium in fish tissue that causes impairment. Table 2.0 summarizes these studies and the benchmark concentrations of selenium that result in adverse impacts on fish

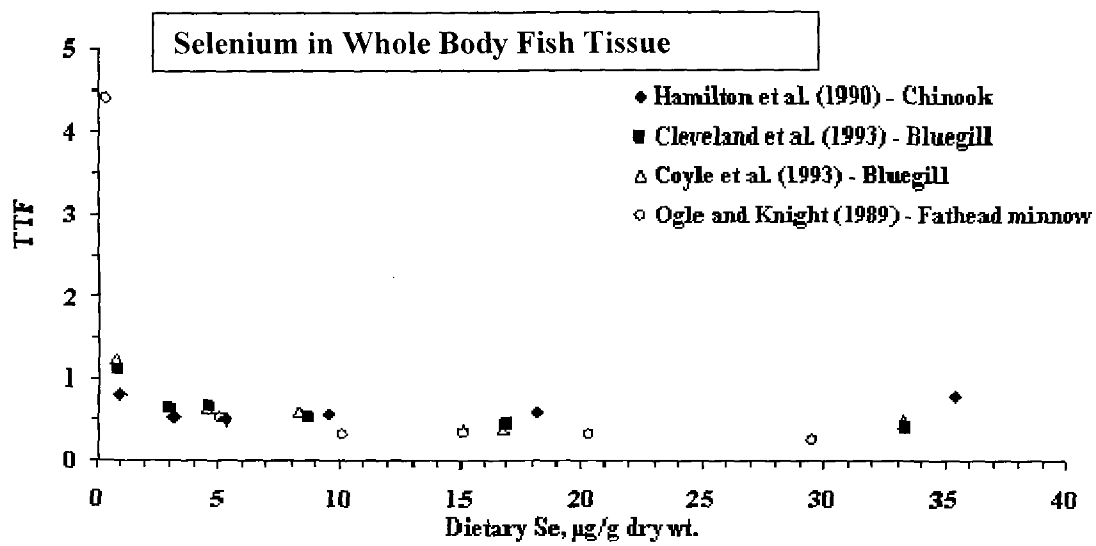
Fish toxicity research has shown reduced growth or survival for certain fish species once the dietary concentration exceeds 3.0 mg/kg (Hamilton, 2004). In his review article on selenium toxicity thresholds for freshwater fish Hamilton (2003) cites studies that found adverse impacts from dietary exposures of 2.4 to 6.5 mg/kg. There are, however, some researchers who have defined substantially higher selenium dietary values for the protection of fish. The publications by DeForest et al., (1999) and Brix et al., (2000) suggest dietary thresholds of 10 to 11 mg/kg as being more indicative of impairment threshold levels in fish. These values are well in excess of the other, more extensive and well substantiated reviews. Furthermore, it is noteworthy that Hamilton (2003) summarily dismisses the values defined by DeForest et al. (1999) and Brix et al. (2000) as being the result of biased research. Hamilton (2003) states: "DeForest et al. (1999) and Brix et al. (2000) have used selective data to present high toxicity threshold (sic) for selenium in the tissue and diet of fish." Hamilton continues to state that the proposed high-selenium thresholds defined by DeForest et al. (1999) and Brix et al. (2000) do "not stand on equal footing with reviews of more extensive datasets" by other authors.

**Table 2.0. Review articles, seminal papers, and United States government documents pertaining to selenium impacts on fish.**

| Source | Biota | Statistic, Consequence or Purpose | Tissue Selenium mcg/g dry wt. (unless indicated otherwise) | Dietary Concentration mcg/g dry wt. (unless indicated otherwise) | Number of References Cited | Number of Pages |
|---|---|---|---|---|---|---|
| Ohlendorf (2003) | Fish | Whole body dry weight | (background) 1.6 to 2.0 | 4.0 to 9.0 | 228 | 34 |
| Ohlendorf (2003) | Invertebrates | Dry weight | (background) Usu. < 2.0 (0.4 to 4.5) | *Intentionally Blank* | 228 | 34 |
| EPA (2004) | Fish | Final Chronic Value (FCV) whole body | 7.9 | *Intentionally Blank* | 1274 (est.) | 331 |
| EPA (2004) | Fish | Critical monitoring trigger for fish | 5.8 | *Intentionally Blank* | 1274 (est.) | 331 |
| Lemly 2002 | Fish | Dietary threshold | *Intentionally Blank* | 3.0 | *Intentionally Blank* | 161 |
| USDI (1998) | Fish (perch, bluegill, salmon) | Reproductive impairment | 4.0 to 6.0 | *Intentionally Blank* | 227 | 45 |
| USDI (1998) | Fish (perch, bluegill, salmon) | LOAEL (reproductive impairment) | *Intentionally Blank* | 3.0 to 8.0 | 227 | 45 |
| USDI (1998) | Fish (perch, bluegill, salmon) | Threshold reproductive failure | *Intentionally Blank* | 10.0 | 227 | 45 |
| USDI (1998) | Fish | Human consumption health advisory | 2.0 (wet wt) 10 (dry wt est) | *Intentionally Blank* | 227 | 45 |
| USDI (1998) | Fish | Complete ban human consumption | 5.0 (wet wt.) 25 (dry wt est) | *Intentionally Blank* | 227 | 45 |
| Hamilton (2003) | Fish | Reduced growth and survival | 4.0 | 3.0 | 93 | 10 |
| Hamilton (2004) | Fish | Adverse impacts threshold | 4.0 | 3.0 | 234 | 31 |
| GSL Science Panel (2008) | Aquatic wildlife | Prevents impairment | *Intentionally Blank* | 3.6 to 5.7 | *Intentionally Blank* | *Intentionally Blank* |
| GSL Science Panel (2008) | Bird egg tissue | Prevents impairment | 6.4 to 16.0 | 3.6 to 5.7 | *Intentionally Blank* | *Intentionally Blank* |
| Brix et al., (2000) | Fish | Adverse impacts | 6.0 to 9.0 | 10.0 to 11.0 | 13 | 7 |

The U.S. Environmental Protection Agency (EPA) Draft 2004 Water Quality Criteria Guidelines provide a threshold for selenium concentrations in fish tissue of 7.91 mg/kg. Ohlendorf (2003) cites research that indicates adverse impacts on fish when the tissue selenium concentration exceeds 4 to 6 mg/kg. The relationship between dietary selenium and fish tissue selenium concentrations is a function of many factors, such as inorganic and organic solute composition in water, fish species, gender of fish, type of tissue evaluated, molecular form(s) of selenium, and the presence of other contaminants. Notwithstanding these influential factors, a variety of studies examining the bioaccumulation of selenium from diet to fish tissue have identified a reproducible pattern. The general pattern of selenium bioaccumulation from diet to fish tissue is an inverse relationship that is dependent upon the dietary concentration. At low concentrations of selenium the ratio of dietary selenium to fish tissue can be in the range of 1 to 5 (Lemly, pers. com. 2008). As the concentration of selenium in the diet increases the ratio shifts to less than 1.0 (Cleveland, Little, Buckler, & Wiedmeyer, 1993; Coyle, Buckler, Ingersoll, Fairchild, & May, 1993; Hamilton, Buhl, Faerber, Wiedmeyer, & Bullard, 1990: and Ogle & Knight, 1989). The results of these studies are summarized in Figure 1.0.

**Figure 1. Summary of tissue transfer factors (TTF) from diet items to fish (whole body tissue). There is an inverse relationship of TTF with increasing concentration of selenium in fish diet items. At low concentrations of selenium the TTF is between 1.0 and 0.6. As selenium concentrations increase in fish diets the TTF generally remains below 1.0. Graph compiled and provided by Ohlendorf, 2008.**




In other studies Dobbs, Cherry, and Cairns (1996) observed that 2.5 ug/g of selenium in rotifers resulted in the same concentration in fathead minnow tissue concentration. Hamilton, Guhl, Faerber, Wiedermeyer and Bullard (1990) found that salmon fed dietary selenium of 3.2, 5.3, and 9.6 mg/kg demonstrated tissue concentrations of 3.3, 4.5, and 8.4 respectively. These and other studies (Coyle, Buckler, and Ingersoll, 1993) indicate a relationship of diet to fish tissue of 1:1 as being generally representative of the relationship between diet and whole body fish tissue selenium concentration for dietary selenium concentrations less than 5.0 mg/kg.

Dietary values from the scientific literature can be compared to selenium concentrations that are biologically incorporated into macro-invertebrate tissue. This is substantiated by the comments of Ohlendorf (2003) in which he states that "...once the selenium is biologically incorporated in the food organisms, the risk to fish is similar at equivalent dietary concentrations." Although it is an oversimplification of the extensive number of bioaccumulation studies on selenium uptake in fish, these studies do suggest that the selenium concentration in invertebrate prey species is a reasonable predictor of fish whole body tissue concentrations and therefore should be maintained below levels that would result in impairment to predatory species (i.e., aquaculture production).

It is evident from the extensive review papers published on selenium toxicity that adverse impacts on fish can be expected once the dietary level exceeds 3 mg/kg dry weight. In the multiple and thorough reviews by Hamilton (2003 & 2004), the selenium assessment book by Lemly (2002), extensive literature reviews and guidelines established by the United States Department of the Interior (1998), and the vast review and proposal by the United States Environmental Protection Agency (2004) that detrimental impacts on fish occurs from dietary exposure to selenium in the range of 3.0 to 8.0 mg/kg and that fish whole body tissue concentrations of 4.0 to 7.9 are indicative of impairment. There is a notable degree of consistency in the scientific literature in the dietary range of selenium that is protective of birds and fish.

### *Selenium Hazard Assessment for Aquatic Systems*

Dennis Lemly (1995), arguably one of the leading experts on selenium impacts on fish, compiled information for aquatic systems and selenium and distilled the information into a generalized hazard assessement for aquatic systems. Figure 2.0 shows this generalized relationship between dietary concentrations of selenium and associated hazards to aquatic dependent birds and fish. This graph provides a relevant perspective on the proposed actionable levels in Table 1.0 and actually implies that in order to reduce risk to fish the dietary concentration of selenium needs to maintained at or below 5.0 mg/kg. This 'high risk' threshold corresponds to the 63% of our proposed upper limit of 7.9 mg/kg in brine shrimp cyst or nauplius tissue and further substantiates the need for caution when regulating selenium discharge into the GSL.

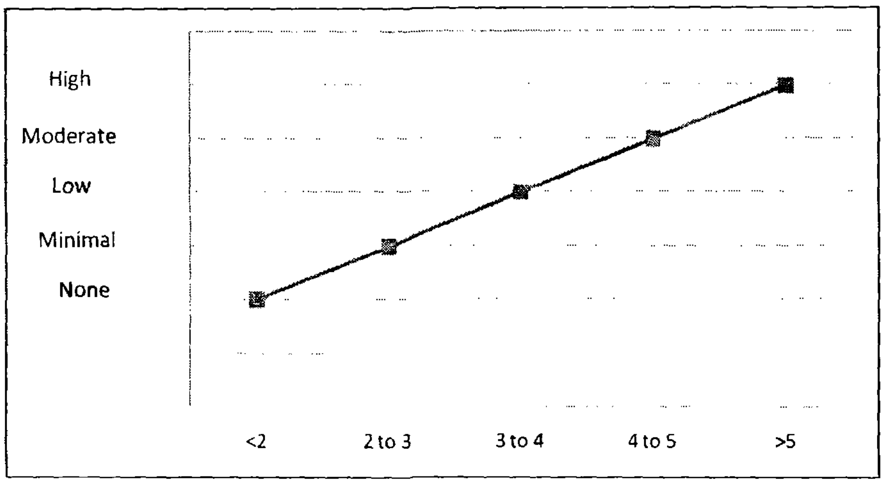



**Figure 2.0. Hazard profile for dietary toxicity and reproductive failure in fish and aquatic birds from ingestion of selenium-contaminated macro-invertebrates. Values are in mg/kg dry weight of macro-invertebrates (Lemly, 1995).**

### *Current Selenium Concentrations in GSL Brine Shrimp*

The geometric mean value of selenium that currently exists in the adult brine shrimp in the Great Salt Lake is 3.9 mg/kg. Data from Selenium Project 2b indicates that the concentration of selenium in the youngest instar stages (naupliar fraction of the brine shrimp) and cysts are approximately 56% of the adult value, or 2.18 mg/kg.

### *Monitoring Program Based on Brine Shrimp Selenium Tissue Concentrations*

Brine shrimp are ideally suited as a monitoring species:

- Brine shrimp adults, nauplii, and cysts are available for monitoring year round (unlike avian eggs which are only available in the spring).
- Brine shrimp are an accurate indicator of the presence and concentration of selenium in the ecosystem.
- Brine shrimp are a keystone aquatic species for the GSL ecosystem.
- Brine shrimp are a critical component of the aquaculture industry and therefore of global food security.

### *Conclusion*

The major concerns and objectives of the GSL brine shrimp industry are: 1) that the GSL brine shrimp population and its ecosystem functions are reasonably protected from avoidable injury, and 2) that the suitability of brine shrimp cysts for international aquaculture markets is not adversely impacted by injudicious discharge of selenium into the GSL.

Without a mandatory brine shrimp tissue based monitoring program with actionable triggers, there would be unacceptable/excessive risks to the GSL brine shrimp resource. Once the avian egg tissue levels reach, or exceed, the proposed 12.5 mg/kg avian egg tissue-based standard, much of the damage to the brine shrimp resource may already have been done.

The action of the Utah Water Quality Board at its June 20, 2008, meeting directed that the Division of Water Quality work with the brine shrimp industry to establish an adequate brine shrimp monitoring program and actionable brine shrimp triggers in the assessment valuation of the proposed standard.

The brine shrimp industry would prefer that the range of acceptable selenium concentrations in brine shrimp tissue (3.6 to 5.7 mg/kg) as proposed by the Science Panel should be enforced. Such a standard would be fully protective of the brine shrimp resource.

However, a higher range of actionable levels based on an upper limit of 7.9 mg/kg selenium in brine shrimp cysts and nauplii should be reasonably protective of the resource for aquaculture markets. The Utah Artemia Association strongly urges the Water Quality Board to adopt the actionable levels detailed in Table 1.0, and requests the State Department of Environmental Quality, Division of Water Quality, to ensure that the extremely important GSL brine shrimp population, and its many uses and ecosystem functions, are not harmed by selenium discharge into the open waters of the GSL.

### *Note on Utah Artemia Association and the Brine Shrimp Industry:*

*The Utah Artemia Association (UAA or Association) is a coalition of the nineteen (19) companies in Utah that have permits (CORs) to havest the excess brine shrimp eggs from the Great Salt Lake. The Association supports management and conservations efforts to protect the GSL and to maintain the sustainability of the Great Salt Lake ecosystem. Contact Don Leonard of the UAA at 801-560-1900.*

*The local GSL brine shrimp industry is the world leader in supplying on-demand, live feed to commercial shrimp and fish hatcheries. These brine shrimp eggs (artemia cysts) contain high protein and are an indispensable breeding feed in aquaculture. We harvest only the excess brine shrimp eggs from the Great Salt Lake. We process these eggs in a way that keeps them viable for the long trip to our overseas customers in more than 55 countries around the world. We employ more than 200 people in Utah and contribute significantly to our local economy and towards a positive trade balance for our state. For the brine shrimp resource to thrive and for our industry to survive, we must prevent the bioaccumulation of contaminants in brine shrimp eggs, nauplii and adults to levels that impair their growth, survival, reproductive capacity, or suitability for aquaculture markets.*

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