The Importance of Algal Polyunsaturated Fatty Acids (PUFA) and Carbon Flow Pathways in Mercury Transfer into the Lower Biota of Two California Lakes

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Executive Summary:
Statement of the Problem: The anthropogenic input of mercury into aquatic systems via mining, agricultural pesticides, and industrial pollution has made mercury contamination of fish a growing problem with important human health implications (Weiner et al., 1990; Linquivst et al., 1991). In California alone, mining is thought to have mobilized over 70,000 tons of mercury resulting in large deposits to San Francisco Bay and its upper watershed (Nriagu, 1979). Currently, major sources of mercury into streams come from the hundreds of abandoned mercury mines in the Coast range and gold mine sin the Sierra Nevada foothills (Abu-Saba, 1999). Many of these streams are impounded by reservoirs which block the export of methyl and sediment bound mercury (Slotton, 1997) which can result in the contamination of fish. These levels, through the processes of bioconcentration and biomagnification can exceed the recommended human health guidelines of 0.5ppm, in some cases dramatically (Slotton, 1995).

Mercury levels in fish have been correlated with a number of environmental and biological factors such as pH (Winfrey, et al. 1990), humic material (Meirle, 1990), temperature (Parks, et al., 1986), particulate matter (Hurley, et al. 1991), algal density (Jackson, 1986), and zooplankton composition (Mason, 1996). Dissolved oxygen and redox potential are two of the most important factors influencing both mercury speciation and microorganisms which methylate mercury (Regnell, 1990). Seasonality of lakes and organism behavior also plays an important role in the uptake of mercury in higher aquatic organisms (Slotton et al., 1995). However, these relationships do not identify the precise ecological mechanisms involved in the bioconcentration and biomagnification of mercury through the aquatic food web.

Many ecologist hypothesize that the tropic structure of a food web strongly influences the rate at which energy (Brett and Goldman, 1996, 1997; Air and Waste Management Association, 1999) and contaminants (Cabana 1994, 1996) move through aquatic systems. Energy in higher biota is thought to come through two pathways at the base of the food web, by way of phytoplankton or via the microbial loop. However the relative importance of these two pathways is still hotly debated (Lampert and Sommer, 1997; Reinman and Chriotfferson, 1993). Recent research suggests that the polyunsaturated fatty acid (PUFA) content of seton may determine the rate at which energy moves through the planktonic food web (Brett and Muller-Navarra, 1997), and thus the amount of mercury moving to higher trophic levels. PUFA are important in regulating cell membrane physiology and are only produced by plants. Thus, zooplankton and fish must obtain them through their diet. Laboratory and limited field studies have shown that algal seston vary in PUFA content, with higher concentrations in cryptophytes and diatoms, intermediate concentrations in green algae, and low concentrations in blue-green algae (Brett and Muller-Navarra, 1997; Ahlegen, 1990, 1992). There are strong positive relationships between algal PUFA content and zooplankton growth and reproduction (Muller-Navarra, 1995a, 1995b, 1996, Demott and Muller-Navarra, 1997). Also several studies have shown the biomagnification of these fatty acids into higher trophic level organisms including fish (Watanabe, 1982). However, no studies to date have been conducted to investigate the relationship between PUFA transfer, energy flow, and the transfer of contaminants form primary producers to higher order consumers.

Our preliminary research indicates that algal PUFA content is important in the flow of carbon into *Daphia*, a filter feeding zooplankton found in many temperate lakes. Furthermore, data collected during the summer of 1998 from two mercury contaminated lake systems, Clear Lake and Davis Creek Reservoir, suggest that PUFA levels in algae correlate well with the total mercury accumulation in *Daphnia*. These limited number of data points (n=10) however, include one outlier point. If removed this data suggests a significantly strong relationship between seston PUFA levels (based off of species composition) and *Daphnia* mercury uptake.

Summary of Research Approach: Given the potential implications that algae PUFA content may have on carbon flow up the food web and the potential for contaminant movement, this project aims to accomplish the following objectives:

1. Quantify the relationship between the seston PUFA and carbon flow into zooplankton in two representative lentic systems.
2. Quantify carbon flow pathways (algae vs. microbial loop) and rates of contribution to zooplankton in these two water bodies.
3. Quantify mercury uptake rates from different seston structure in these two systems.
4. Create a model predicting mercury movement into lower biota of aquatic food webs by including carbon flow pathway information based on seston biotic structure.

We will accomplish these objectives by monitoring and conducting semi-natural field experiments from two mercury contaminated lakes in Northern California, Clear Lake and Davis Creek Reservoir. These lakes differ in algal food web structure that allows for the contributions of differing PUFA concentrations on *Daphnia* carbon uptake and mercury assimilation to be measured. We will conduct monthly experiments by feeding cultured *Daphnia* with natural lake seston. Laboratory control over temperature and light will allow the controlled comparison of the experiments over seasons. In one part of the experiment, natural lake seston will be inoculated with stable isotopic ^{13}carbon of differing forms. These forms include sodium bicarbonate for measuring algal flow rates and contributions of energy into *Daphnia* and glucose for measuring microbial flow rate and energy flow into *Daphnia*. In the second part of the experiment, we will use these same feeding procedures to quantify mercury uptake rates into *Daphnia* based off of differing algal composition. This data will be analyzed to determine if there is a relationship with corresponding algal PUFA concentrations (collected in our monthly monitoring of seston, zooplankton, and fish of the two lakes).

Statement of Expected Results: This project provides critically needed information on the role lower biota play in the transfer of energy and contaminants up the food web. Until recently most ecotoxicological studies largely ignored the role of food webs in the transfer of contaminants up the food web. Recent research has suggested the importance of ecosystem structure and function in the movement of contaminants (Air and Waste Management Association Conference, 1999; Brett and Goldman, 1996, 1997; Cabanna and Rasmussen, 1996). However, the role of lower biota such as phytoplankton and microbes are often neglected due to the intensity of labor require din classification and analysis of these groups. This project will compliment the existing research on mercury pollution and fish contamination in aquatic systems and hopefully will add to the framework of factors to include when assessing contaminated systems. We will present our data both in publication and at the annual scientific conferences such as the American Society of Limnology and Oceanography and the Society of Environmental, Analytical and Toxicological Chemistry.